Basics of Life – Stocks, Stores and Funds

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Abstract

Life and forms of living beings began around 4 billion years ago. However, the terms *stocks* and *stores* have only developed as scientific concepts over the course of the last two centuries, while the term *fund* came into use even more recently (Georgescu-Roegen 1971). A fund can be understood as a source of services for one or more species of living beings.

While Mainstream Economics does not focus on the origins of life, this is a basic concern of Ecological Economics. To understand life, we need concepts which focus on its temporal structure and are suitable to examine the interaction between the dynamics of coupled systems, made up of natural and economic components.

A central concept is that of a stock, hence this concept develops a general theory of stocks, applicable in ecology and economics. Some stocks are used as stores in ecosystems and economic systems. Crucial questions for sustainability are: When do stores become scarce? How can they be replenished or substituted by other stores? To answer these questions, we need a third concept, a fund. Essential for a fund is that it maintains itself, and that it gives services to other living beings. Take an apple tree, for example. Its services are material and immaterial, be they shelter or aesthetic services. Drawing on three other concepts a Teleological Concept of Nature, Thermodynamics and Irreversibility, enables us to operationalize the concept of life. This concept helps us grasp the intertemporal relationships between stocks, stores and living beings.

As a practical example we use the three concepts to examine the development of oxygen in the atmosphere and its consequences for life on earth.

Related concepts: TELEOLOGICAL CONCEPT OF NATURE; THERMODYNAMICS; IRREVERSIBILITY; EVOLUTION; BASICS OF TIME; ABSOLUTE & RELATIVE SCARCITY; INDIVIDUAL, COMMUNITY & ENTIRETY

1. History

The history of the concepts of stocks, stores and funds is very long, reaching back to the start of our cosmos i.e. about 14 billion years ago. Life and forms of funds began around 4 billion years ago. However, the terminology of stocks and stores have only developed as scientific concepts over the course of the last two centuries, while the term fund, the way we use it, came into use even more recently (Georgescu-Roegen 1971; Faber et al. 1995, 2002).

“The terms *stock* and *funds* as well as their *services* were introduced to the Ecological Economics debate by Georgescu-Roegen (1971); one of his purposes was to steer the debate among economists regarding the concept of capital in a new direction. His concern was to place greater emphasis on the real or material aspect of what was known as capital, such as machines, factories, ships railways, harbours etc., which seemed to him to be largely hidden by a value-based, technical concept of financial capital. Georgescu-Roegen contrasted *stock* with *flow* – a change in stock. The conceptual pairing of stock and flow was intended to address the structures of change over time independently of market value and exchange value.

During the 1980s and 1990s, both the concept of capital and – less conspicuously – the conceptual pairing of stock and flow, used as a means to study intertemporal decisions in economic systems, were introduced into the debate around sustainability (cf. e.g. Faber 1986: Chapter 3, Faber et al 1996; 1998). At certain points in this process, these concepts were interpreted in new ways. Materials flows were a significant element in this, particularly in the debate about the closed substance cycle economy and life cycle assessments (cf.eg. Bund and Misereor 1996). At the same time efforts were underway in ecology to understand ecosystems as networks of materials and energy flows, a subject taken up by Ecological Economists to generate information about their sustainability” (Klauer et al. 2018: 34; cf. e.g. Odum 1983: Chapter 4; Hannon 1973, 1995; see also concept SUSTAINABILITY & JUSTICE).

“Those readers familiar with Georgescu-Roegen’s (1971) pioneering work [Joint Production; Thermodynamics; Irreversibility] will recall that the concepts of funds and flows have been developed and analysed in detail in his chapter 9 (cf. Wodopia 1986). While Georgescu-Roegen uses these concepts within the context of economic production, we shall develop these concepts within the context of the natural world [Teleological Concept of Nature]” (Faber et al. 1998: 178-179).

2. The Concepts of Stocks, Stores and Funds

We start by introducing a fundamental concept of ecology, the notion of *biocoenosis*, as it will give us orientation for our main goal, namely to develop an encompassing and adequate concept of life (Section 2.1). Then we turn to the definitions of stores, stocks and funds (Section 2.2). This will allow us to deal with the basics of life by taking recourse to thermodynamics, self-organization, triple teleology, stocks, stores and funds (Section 2.3). This lays the groundwork for an encompassing conceptual model to integrate different areas of discourse, physical, biological, ecological and social (Section 2.4). – We note that this concept is mainly taken from the book Faber and Manstetten Philosophical Basics of Ecology and Economy (2010).

2.1 The economy of biocoenoses: an introduction to our line of questioning.

The three tele of living things as introduced in the concept TELEOLOGICAL CONCEPT OF NATURE were conceptualised from the viewpoint of the individual living thing. In contrast, with this concept we wish to start from the viewpoint of the biocoenosis; this word is a combination of two Greek words, *bios*, meaning life, and *coinos*, meaning Mingling, sharing. Common examples of a biocoenosis are a forest or a pond, each consisting of many species.

We shall now "examine the foundations which make the life of a biocoenosis possible. Within the sphere of humanity, questions pertaining to the foundations of life belong to the economy: How do we find or produce what we need to live, how is it resources distributed, in which ways is it consumed and what happens with the waste? How is life in the future safeguarded the future? For human beings, questions of the foundations of their life thus entails the problems of their way of life, in particular their view of justice [Sustainability & Justice], i.e. the partitioning and allotment within the framework of their living space. The shaping this way of life represents an ever – new challenge to human reason, to our ability to think and to plan ahead. Our foundations of life are not simply 'there' by themselves, but require shrewd and farsighted management: what we need and what we enjoy must be produced in the right amounts for our use and consumption, and it must be distributed in such a manner that all can partake of it and, if possible, be satisfied. In addition, all of this must occur in such a manner that the production and consumption of today do not exhaust the foundations of life for tomorrow and the day after" (Faber/Manstetten 2010: 97)

The concept of a biocoenosis applies to all kinds of living beings. Although they all have to be taken into consideration when studying environmental economic interaction, the focus is often on the biocoenosis of human beings. The prototype of community, which gives the economy its Greek name, is the house (Greek: *oikos*). “Oikos not only mean the building itself, it also refers to everything that can be better summarised under the term household. The household of a farm – at least as it was understood in Ancient Greece – included, apart from the inhabited buildings, all the stalls, pastures and fields, as well as the people, slaves and animals living therein. The economy extends to the area dedicated to the acquisition and application of the means of life. Its corresponding context is the household. The household of a farm – at least – as it was understood in ancient Greece – incorporated apart from the inhabited buildings all the stalls, pastures and fields, including the people and animals living therein” (Faber/Manstetten 2010: 16).

“What, however, happens with the foundations of life in a biocoenosis of nonhuman beings? How are they foundations produced, distributed and consumed, and what happens with the waste? How is the long-term survival of the biocoenosis safeguarded? If we regard the entire Earth as a biocoenosis, we are confronted with the miracle that – despite the extinction of countless species, despite the emergence and disappearance of biocoenoses over the course of time – the foundations for the continual development of life on Earth have until now always been given. How has this been possible? How do living things divide their foundations of life among each other? How do they preserve their life? How do they preserve themselves as species? And how does a natural biocoenosis preserve and develop itself lastingly?

These questions lead also to the economy of human life. Since the emergence of life some billion years ago, human beings as living things have necessarily participated in the economy of life as human beings have been developing without any recognisable planning. But human beings – as rationally planning creatures with an abundance of needs that hugely change nature – subject all life to a form of an economy that nonhuman nature does not know” (Faber and Manstetten 2010: 97f).

2.2 Stocks and stores: definitions

“How is the economy of life to be conceived? In the following sections we introduce a terminology that allows us to grasp the structure of economic relationships within biocoenoses.

Starting from the fact that, since its emergence, life on Earth has not been interrupted for even a moment, we refer in the following to biocoenoses as ‘immortal’. With this we do not imply that such entireties cannot terminate or be destroyed – they remain transitory. But their transience is of a principally different kind than the mortality of individual living things. An individual possesses a certain ‘natural lifespan’, one which is derived from its inner constitution and can be fallen short of, but not randomly exceeded. Thus, it is possible to predict with near certainty a boundary which the individual life of an organism cannot exceed. In contrast, the demise of a biocoenosis cannot be predicted. In general, we know of no ‘natural’ lifespan, one which corresponds to their inner structure and sets a temporal boundary.

Using the characteristic of ‘immortality’, we wish to draw attention to the following difference between living things and biocoenoses: Living things *must* die, biocoenoses need not expire (even though they *can* expire). The entire biocoenosis of the Earth, however, has already lasted some billion years. What holds for biocoenoses also holds in principle for species. They are not mortal, they cannot die, but they can, in the event of all their individual members dying, ‘die out’. The immortality of a biocoenosis or a species is, however, an abstraction because the concrete biocoenosis with its species exists only through the life and death of its individual living things.

The foundations of the life of a biocoenosis are the embodiment of the foundations of life of all living creatures belonging to it: How then are these to be described? In the following we operate with three essential terminological pairs. First, we will define the pairs: *stock* and *flow* as well as *store* and *extraction*. In a further step we will introduce the particularly important pair *funds* and *service*. (Goergescu-Roegen 1971: Chapter 9)

Stocks and flows

A *stock* is an accumulation of a finite amount of ‘homogeneous’ material (Faber et al. 2005). The definition of homogeneity is derived from a particular view of the object under examination. Thus, in regard to biological activity, the atmosphere is, for example, generally regarded in the long-term view as homogeneous. When, on the other hand, short-term weather patterns are being examined, these are generally viewed as heterogeneous. A *flow* is the continuous or discontinuous change of a stock. Or, to formulate it as Georgescu-Raegan did: a ‘flow’ is a continuous or discontinuous change of a stock and thus in the words of Georgescu-Roegen (1971: 233) a stock spread over a time interval. The unit of measurement of a flow is described in quantity units of the stock in question per unit of time.

Every useful stock can be used according to the view of whoever it affords utility to. In this case it is practical to speak of stores instead of stocks. Stores are therefore the subset of stocks that can be viewed under the perspective of positive utility. As a store consists of a finite amount of homogeneous material, it can be (and tends to be) depleted.

Stores and extraction

A store is generally recognisable as such in that someone can extract something useful from it. In this case we speak of extraction. If we view a store as a stock, we can say that the extraction is that part of the flow which is extracted by users in a controlled fashion, and then employed according to its utility. An extraction can only be carried out as long as the store lasts. This entails that the upper limit for the measure of possible extraction is set by the size of the store.

Apart from the controlled flows from a stock, which we understand as extractions from a store, uncontrolled flows from the same stock can exist. An example for this would be a water reservoir that diminishes through both the controlled extraction of drinking water and uncontrolled evaporation and seepage into the ground water.

One could attempt to describe all foundations of life in regard to living things as stores. A living thing lives by extracting from its stores and using or using up (consuming) whatever is extracted. This would also hold for hunter/prey relationships in nature: A population of rabbits that foxes' prey upon is (however involuntarily) a store from the viewpoint of the foxes, even if the extraction may not always be easy. Therefore, it would seem appropriate to view the foundations of life of biocoenoses from the perspective of which living things extract which amounts out of which stores for their self-preservation.

Where do the stocks come from and how do they change?

Such a view is, however, incomplete. In order to understand the relationship of a living thing to its resources, one must also ask the following, more complex questions:

- Where do the stores come from?
- How do extractions alter the stores?
- What happens to the extracted quantity after the point in time of extraction?

Using these three questions, our examination is enhanced by the aspect of time [BASICS OF TIME; THERMODYNAMICS; IRREVERSIBILITY; cf. also: Faber, Proops, Speck 1999; Klauer et al. 2016]. If, in contrast, we speak only of stores and extractions, we are performing a purely static examination. Initially we can say: the extracted quantity directly or indirectly serves the consumption of a living thing that consumes for its self-preservation or self-development [which is the 1. Telos as defined in TELEOLOGICAL CONCEPT OF NATURE]. In nonhuman biocoenoses the quantity is generally directly consumed, or at the most stored for a limited amounts of time, as we experience bees and hamsters.

Two things must be noted here in the case of direct or indirect consumption:

1. Every store is diminished by every extraction (as well as by uncontrolled flows). If stores are not replenished or supplemented from somewhere, in borderline cases they are entirely depleted.

2. The quantity extracted from stores cannot be destroyed by the user. The consumption or the production leading to consumption may physically or chemically change the extracted quantity, but it is subject to the laws of energy conservation and entropy [THERMODYNAMICS]. Consequently, the quantity does not disappear; it is only altered. Thus, every extraction is supplemented by the dimension of waste in the broadest sense. Direct consumption produces unconsumed leftovers – e.g. the remains of plants or animal carrion – as well as faeces, gases (such as the methane produced in keeping cattle), sewage, etc. Even the carcasses of living creatures ultimately belong to such waste. Every extraction within a biocoenosis leads to a decrease in the store in question and an increase in waste. Why then have the stores of the biocoenosis Earth not been continuously decreasing over the billions of years since the emergence of life, and the waste not continually increasing?

Viewing life solely from the viewpoint of stores, extraction and consumption

“So, if one views a living creature as an element of a biocoenosis solely from the viewpoint of store-extraction-consumption, two of the questions posed above are disregarded (Where do the stores come from? How do the extracted quantities develop after consumption?)

Most living things do not concern themselves with how their stores are replenished. This fact is addressed in the Sermon on the Mount (Matthew 6, 26): ‘Look at the birds of the air; they do not sow or reap or store away in barns, and yet your heavenly Father feeds them.’ Bees collect nectar every year to produce their store of honey, but, as far as we can tell, they do not concern themselves with cultivating the plants from which they draw the nectar.

For nonhuman living things, it appears neither possible nor necessary to ask where their stores come from or what happens with the waste they produce. The life of the living creature ‘human being’, however, is characterised by the fact that almost from the beginning we are faced with the question of the origin of our stores – on the other hand, what happens with the consequences of our consumption is a comparatively new problem" (Faber and Manstetten 2010: 98-100).

2.3 The terms fund and service – definition and explanation

"Stores are not simply 'there'; they are formed in one way or another, and are in many cases continually formed anew. In nature, this occurs without human input. In the sphere of human affairs, however, the employment of labour and capital is required. On the one hand, agricultural raw materials, which grow and are replenished every year, are the result of capital and human labour; on the other hand, they are the product of nonhuman nature. Climate, soil and weather conditions, etc. play an essential role for agricultural production.

Those contributions of living things that directly or indirectly serve other living things we wish to call 'services'. Thus, the development and replenishment of stores in nature are services for the living things that are dependent on them. A source of services that can lead to the formation of stores, but can also represent other useful contributions, we call a *fund*" (Faber and Manstetten 2010: 100).

The characteristics of living funds

"Going back to the history of the notion of funds in economics, we may understand funds in a rather narrow sense and may say: The fund renders *services* to man. We not that the services may be either material or immaterial. Up to now we have confined ourselves to funds which are living beings; now we wish to apply the concept of a fund also to nonhuman organisms.

First, we make some introductory remarks. Consideration of our three tele – (1) self-preservation, (2) self-reproduction and (3) necessarily rendering services to other organisms [TELEOLOGICAL CONCEPT OF NATURE] – indicates that all organisms are funds, necessarily rendering services to other organisms, i.e. provide services. On the other hand, from the first and second tele we know that there is self-maintenance and reproduction, implying the organism/species maintains itself so that each organism/species also needs services. If a species is able to maintain itself, it implies that the basis for its necessary services is not depleted. Thus organisms/species can also be viewed as users of funds, in addition to acting as funds themselves.

There exist inherent difficulties generally in defining individual organisms as funds, although this may be possible in some cases, instead it is convenient to employ the corresponding species as the elementary unit of a fund. This is so because a fund continues over time, which does not hold for an organism, but only for a species, which can maintain itself over very long-time scales. In principle, the continuity of a species is indefinite, though, of course, species can, and do, become extinct. Therefore, it is convenient to employ the corresponding species as the elementary unit of a fund.

The fundamental characteristics of a living fund may be summarised as follows:

(i) A fund has relationships with species, because it gives services to one or several other organisms.

(ii) A fund reproduces itself.

(iii) A fund is indefinite nature with regard to its time scale.

Concerning the first characteristic, we note the following. An organism which uses the services of a second organism treats this second organism as a fund, and through its use of the service of that fund is acting towards its first telos (i.e. self-maintenance). On the other hand, the organism giving the service is acting towards its third telos (i.e. service to other species). So, the relationship between organisms as funds need not be symmetrical.

On the occasion when the relationship between organisms is symmetric, we speak of *symbiosis*. The fact that the fund reproduces itself reflects the second telos (i.e. self-reproduction) [TELEOLOGICAL CONCEPT OF NATURE].

The last characteristic makes sure that the services, which are essential resources for the existence of organisms, continue to be available. Thus, this trait of a fund contributes in an essential way to the continuing existence of a basis for living.

Renewable and non-renewable resources

From the "discussion of stores and funds above, we can see a relationship to the well-known concepts of nonrenewable and renewable resources. A store need not be self-reproducing, so withdrawal from a store may be possible only for a finite period. This limitation will certainly apply to non-organic stores, which we can speak of as non-renewable resources. On the other hand, a fund can reproduce itself, as it is organic, and we speak of these as renewable resources. Of course, funds may be treated unsustainably and be depleted by overuse" (Faber/Proops 1998: 179-180).

A question concerning the foundations of life

"A living *fund* therefore is, in our terminology, understood as a source of services for one or more species of living things. These living things are to be regarded as the recipients of services. The terminological pair *fund/service* can be used to reformulate the question concerning the foundations of life of living things, species and biocoenoses as follows: What funds and what services are required for the conservation and development of a biocoenosis, a species or an individual living thing. To answer this question we now apply the concept of a fund to non-living things.

Sun, air, water and soil as funds

On its own, nothing can be called a fund, for something is only a fund insofar as it is useful for something or someone else. Calling something a fund means being able to name for what or for whom it acts as a fund. Something can only be regarded as a source of services if it belongs to the foundations of life of one or more recipient of said services. A stock of fish can only be called a fund if other living things extract utility from it in one way or another.

Certain funds are necessary foundations of life for all species. Thus, the sun provides services in the form of energy (warmth and light), which is absorbed by the most diverse living things in the most diverse ways but is indispensable for all. Other requisite funds can be addressed by the generic term 'water'. The water circulation of the Earth includes seas, humidity, clouds, glaciers, watercourses, lakes, ground water and vapour or evaporation from soils and plants, etc. Further funds of significance for living creatures can be summarized under the terms 'soil' and 'air'.

Duration of funds

Such funds share the traits that their duration (by biological measurement) is never terminated. In the same way that we defined biocoenoses and species as immortal, we wish to define such funds as non-transient in the sense that they – from a human perspective – need not end. The importance of these funds differs, however, from one recipient to another. For some living things, these funds or a number of them are sufficient, for others only necessary conditions, for existence. Thus, rural plants nourish themselves on 'light, CO_2 and water' as well as 'mineral resources […], macronutrients […] and a series of trace elements'; (e.g. nitrogen, phosphorus, sulphur, potassium, calcium, magnesium and iron. See Begon, Harper and Townsend 1990: 95). 'Many of these chemicals are also essential to animals, although it is more common for animals to obtain them in organic form in their food than as inorganic chemicals.' (Begon, Harper, Townsend 1990:95) Accordingly, most animals require other living things as part of their nutrition. From the perspective of funds, we can say that species that are dependent on living things require *living funds*.

The difference between the funds we have mentioned thus far and those we define here as 'living' cannot be precisely delineated. Farmlands, as well as river waters, are full of life, and for this reason alone provide services on which many living things depend. However, in our following considerations of living funds, we do not implicitly regard farmlands and river waters as such, but rather as spaces for a multitude of living funds as we will define in the next paragraph.

Duration of living funds

Living funds are by no means non-transitory in the sense of those mentioned so far. What they must possess, however, is the characteristic of immortality in the sense portrayed above. For insofar as they are necessary for the survival and development of one or more species, they must possess the same trait of permanence as the species themselves.

The result of this is that living funds are themselves species. Put more precisely, living funds are species insofar as they are to be viewed as service providers for other species. Such services can consist of specific contributions by the living things involved (such as the shade provided by trees), by parts of these living things (such as the blossoms, leaves and fruits of a plant), or by the whole of the living things if these serve the sustenance of other living things.

The difference between living and non-living funds

Living funds differ in several essential aspects from non-living funds. Unlike non-living funds such as the sun, living funds have no permanent substratum. Their non-transience derives from a continual renewal of their elements. Thus, a precondition of living funds is set by the first and second telos of living things, those tele through which a species preserves and renews itself [TELEOLOGICAL CONCEPT OF NATURE]. The first telos is linked to a constant cycle of material and energy, whereas the second telos is linked to a cycle of death and birth: the disappearance of individuals that are replaced by new ones.

Species as funds and as recipients of services

From our terminology it follows that species can be regarded both as funds and as the recipients of the services of funds. When regarded as the recipients of services, they are related to the first and second tele of the living things concerned. If, on the other hand, they are regarded as funds, then the third telos of living things shifts to the centre of attention, while the first and second tele are merely prerequisites.

The services of some species are, however, not as directly recognisable as those of others. The services of the species ‘antelope’ for the species ‘lion’ is evident, not so however the services of the lions for the antelopes. However, predators often prevent the uncontrolled spread of the species they prey upon, something that could have an extremely damaging effect on both the species itself – whose intraspecific pressure of competition would increase enormously – as well as on the biocoenosis as a whole. From the viewpoint of a biocoenosis (for example a steppe), it is not easy to say which services are more important and which ones less. It is precisely the interplay of all species in a network of services that leads to a balance in a biocoenosis. If one were to remove certain services from such a community, the result could be an explosive growth in other parts, or species could die out; both can also occur at the same time.

The services of living funds

The services of living funds can extend much further than initially seems. The leaves and the bark of trees, as well as the shade they provide, are services for a multitude of living things. Particular emphasis is to be laid on the services of funds that reintegrate all those things that would seem to be waste from a human viewpoint back into the cycles of nature. One need but think of the many forms of micro-organisms involved in the decomposition processes of organic materials, or think of ants, carrion-eaters, etc. These funds represent the practical answer of nature to the question posed above: What occurs with that which is consumed after consumption? The leaves and branches dropped from trees, the excrements of animals and carrion, are the basis of life for a multitude of living things which in turn serve as food for other living things. A particularly important role in this natural disposal is played by a large number of different bacteria and fungi. The term ‘disposal’, however, is not wholly suitable in this context, as what one is dealing with here is actually more a form of recycling in the sense of a perfect cycle of substances.

Recycling

The importance of the role ‘recycling’ plays in nature is made evident by the fact that the amount of biomass produced in a period of time (that is, the mass that enters the body of a living creature) must correspond to an approximately equal amount of ‘mass to be disposed of’ (see: Zwilling, Fritsche 1993). The leaves of a tree fall, the living things belonging to a species of plant or animal die, and they remain as carcasses or organic material in nature insofar as they are not consumed by other living things. Thus, the impression can be evoked that nature chiefly produces overabundance. But such an impression is based on too narrow a perspective: Everything that nature produces ultimately enters a cycle in which it is taken up as a service. All processes of decay or decomposition are the life-processes of living things. These are in turn the precondition for life of higher living things. When focusing on an entire community [INDIVIDUAL, COMMUNITY

& ENTIRETY], rather than on individual living things, one can hardly separate production, consumption and disposal.

Cyclic systems

As a true cyclic system, every process of production, consumption and disposal in nature can be regarded as necessary elements of one another: Production implies consumption and disposal, consumption implies disposal and production, disposal implies consumption and production. In a biocoenosis, any differentiation of these terms is purely analytical. The distinction of production, consumption and disposal only gains any authenticity in a human economy. One further – from a human viewpoint very important – distinction cannot even be made analytically from the perspective of a bioncoenosis: the distinction between positive and negative services – between services and disservices, so to speak. Such a distinction exists for an individual living thing from the perspective of its first telos [TELEOLOGICAL CONCEPT OF NATURE], but not for an entirety that, in the long-term [BASICS OF TIME], can make everything occurring within it to a moment of its own evolution [EVOLUTION].

Joint production

A further characteristic of funds in nature, both living and non-living, is so-called 'joint production' [JOINT PRODUCTION and Faber, Proops, Baumgärtner 1998a, Baumgärtner et al 2006]. As a rule, funds produce more than one service. We have already offered the example of a tree which, while realising its first two tele, necessarily produces leaves and fruit, bark and shade as services for other living things. An extremely important service provided as a joint product by the respiration of all green plants is the oxygen other higher living things require to breath. Some biocoenoses (for example the rain forests) even 'produce' their own climate in an interaction of their funds. Consequently, the climate of a tropical region is greatly changed if the predominant rain forests are destroyed" (Faber and Manstetten 2010: 97-103).

Funds in the economy

Besides labour and resources, capital goods are employed for production. While labour and resources are consumed by a production process, capital goods do not flow into it "as a substance, but render services. Therefore, they are called funds of services. A typical example is a machine. Of course, economic funds are also subject to qualitative change by wear and tear. The value of the latter is measured by its yearly depreciation. The function of a fund is not to be consumed, but to transform inputs. The counterpart to the flows of stock variables is their service flow" (Wodopia 1986: 189).

"Since the life time of economic funds is neither infinitesimally small nor infinitely long, funds render services over some finite-span. "The time which elapses in this process gives reason to distinguish economic funds and stocks clearly because in contrast to funds it is possible to accumulate and decumulate stocks nearly at any velocity" (Wodopia 1986: 190).

2.4 Basics of life: thermodynamics, self-organization, triple teleology

The Laws of Thermodynamics, the relationships developed in THERMODYNAMICS and IRREVERSIBILITY as well as the triple teleology [TELEOLOGICAL CONCEPT OF NATURE] and our concepts to grasp the phenomena of evolution [EVOLUTION] can be combined with the concepts of stocks, stores and funds, elaborated in the present concept. Combining all these results has prepared the ground for an encompassing conceptual model to integrate different areas of discourse.

As stated in the summary "part of the endeavour of Ecological Economics is to construct a language and set of concepts with which this endeavour can be fruitfully pursued. One set of concepts that has been advocated revolves around Prigogine's work on self-organising systems (Prigogine 1962, Prigogine and Stengers 1984; Jantsch 1980; IRREVERSIBILITY). Another very influential author has been Georgescu-Roegen, who has not only illuminated the role of the Entropy Law in economics, but has also stressed the distinction between stocks and funds (Gerorgescu-Roegen 1971).

The theory of self-organising systems allows us to encompass biological and non-biological structures in the same conceptual model. On the other hand, the notion of funds, as discussed thus far in the literature, is explicitly concerned with human action. It seems to us that these two seemingly disparate areas of discourse offer great promise to Ecological Economics, if they can be subsumed within a broader conceptualisation of nature. How can we bridge the gap between Prigogine and Georgescu-Roegen? The approach we take looks back to Aristotle and his teleological characterisation of processes [TELEOLOGICAL CONCEPT OF NATURE]. We shall argue that a teleological approach can be justified even for non-reasoning systems. This range of applicability of teleological arguments allows a breadth of argumentation appropriate to the endeavour of Ecological Economics. Our methodological approach will be an evolutionary one. In particular we shall use the notions of genotype (potentialities) and phenotype (realisation), as discussed in EVOLUTION.

Thus, our aim is to find a language and a set of concepts to allow us to formulate the problem of economy-environment interactions [cf. JOINT PRODUCTION and Norton 1992]. In general, one is used to analysing nature and the economy with different kinds of concepts. In contrast to this approach, we wish to develop new concepts of nature and the economy, such that they enable us to use elements of each concept to discussing the other area. Our conceptual and methodological approach will be at the borderline between science and philosophy.

Regarding economics, we find we need a language to formulate economic problems in such a way that we can use the same concepts and language as for discourse on nature. In particular, as economics concerns choice (i.e. teleology) it is fortunate that we also find it convenient and useful to express behaviour in nature in a teleological way.

All these concepts will allow us to go directly from the ecological sphere to the economic one, and vice versa. If we succeed in this endeavour, this will enable us to use one language to speak on problems of both economy and ecology" (Faber et al. 1998: 168-169).

Since space does not allow us to present the program outlined above in detail, we refer to the publication on this topic (Faber et al. 1995) and give here summary of it: first "a brief characterisation of biological evolution [EVOLUTION] in terms of Prigogine's 'Far from Equilibrium Self-Organising Dissipative Structures' (FFESODS) [IRREVERSIBILITY]. The teleology introduced in TELEOLOGICAL CONCEPT OF NATURE can be employed to unify natural and social phenomena, for the triple teleology can be used to characterise organisms, including human beings. The final building block is the distinction between stocks and funds, which we discuss to indicate how the most general notion of funds is applicable to organisms. We also note that economic capital has some aspects of a fund. We then indicate how the history of human economic development can be characterised in terms of the three tele and the development of funds. The major conclusion of that publication is that using this newly developed language, it becomes evident that there is a great dichotomy between the way nature develops and the way modern economies evolve. In particular, it follows from the analysis that the way the modern economy works is inherently unsustainable [SUSTAINABILITY & JUSTICE*; Becker et al. 2015*] We apply our language to the problem of sustainability" (Faber et al. 1998: 169).

3. Practice

In this chapter we deal with the theoretical and practical dimension of stocks and stores and show the relationship between biocoenosis and moderation, a notion which is crucial for sustainability [SUSTAINABILITY & JUSTICE] (Section 3.1). Finally, we turn to case studies, two will be mentioned briefly and one at length (Section 3.2).

3.1 Theoretical and practical dimension of the concept of stocks

"The concept of stock, the stocks perspective and the stocks framework play a dual role in sustainability policy [SUSTAINABILITY & JUSTICE], namely,

1. as a kind of instrument and

2. as an internal *principle*, a *bridging principle* for purposes of judgement [POWER OF JUDGEMENT; ENVIRONMENTAL POLITICS] in relation to time.

In its theoretical dimension, the stocks framework is an instrument of judgement. In this regard judgement considers which aspects of a given situation are the ones to which the concept of stock can be applied. These might be pollutants, resources, goods or possibly institutions and patterns of behaviour. Equally, judgement must determine which of these aspects-as-stocks are relevant to the actions required to achieve a given purpose – in other words, which of them are conductive (or not conductive) to this purpose. The theoretical – one might say scientific – stocks framework is then applied to these stocks. Judgement draws on scientific analyses of stocks in order to determine the temporal dynamics involved as precisely as possible and then to make the right decisions; judgement itself does not play a part in these analyses, however.

3. The situation is different with regard to the practical dimension of the stocks framework. Here, as we have seen, the stocks framework explicates the sense of time. Using this sense, we can select an appropriate temporal horizon within which we can relate our own goals of action to objective temporal processes and developments in a meaningful way. For example, the temporal horizon of German water pollution control policy with regard to establishing the waste water charge was based notion years but on decades; it was this that enabled the policy to be successful. By contrast, the US environmental policy that produced the 1972 Clean Water Act and was based on much shorter timescales encountered severe setbacks.

Thus, the stocks perspective is capable of developing and schooling a sense of time [for more details see ENVIRONMENTAL POLITICS]. In doing so it clearly leads to better decision making” (Klauer et al. 2017: 133-134).

Biocoenoses and moderation

“An important ‘rule’ in biocoenoses is that species use their funds in moderation. In a manner of speaking, such use is an expression of the nomos (Greek: law, regulation of allotment) of a biocoenosis. The boundaries of such moderation are, however, not set by any inhibitions of certain species in the realisation of their first two tele [TELEOLOGICAL CONCEPT OF NATURE], but rather by technical limitations of the exploitation of the funds.

However, such moderation is not always easy to recognise: In the short-term, living things frequently use their funds in a way one could interpret as overuse. In light of the activities of the temporarily arising swarms of locusts in West Africa, for example, it would be difficult not to get such an impression. In reality, however, even this is an expression of the dynamic development of moderation in biocoenoses. Two examples:

Illustration of spatial structure

Remmert describes the breeding behaviour of the sandwich tern:

‘Terns breed only in small primary dunes which sometimes form after high tides, sometimes after island formation. Such primary dunes develop on sand slabs, and are destroyed by the next tide or, over the course of several years, become secondary dunes, those which island visitors generally know as dunes – the large dunes. Only in the narrow and brief period of transition between primary and secondary dunes can sandwich terns proceed to breed. The effect is an extremely erratic behaviour of the colonies. Very large colonies can suddenly emerge somewhere, and equally suddenly completely disappear. Small colonies can also appear here and there according to the size of the primary dune area. The number of all breeding birds in the coastal region of the North Sea is relatively constant. […] For science, an abundance of questions arises from this discovery. How do the terns learn of newly arisen primary dunes, and how is their communication accomplished? Why are they bound in such a characteristic way to a specific habitat? What is their effect on this habitat? It is likely that their close-quarter breeding, together with a great deal of excrement transport, results in a rapid growth of the primary dunes, and thus the self-destruction of their habitat’ (Remmert 1988: 95f).

For the sandwich terns this is not a great problem as long as they find new breeding areas. The habitat ‘North Sea’ is for them a fund which continually provides sufficient primary dunes. Temporarily, the habitat seems overused. Understanding the species in such a habitat, however, means viewing it in its immensity, not only momentarily.

Illustration of temporal structure

What this example demonstrates for spatial structures holds analogously for temporal ones: Understanding cannot be limited to a specific point in time, but must take long-term timelines into consideration [BASICS OF TIME]. In fact, Biocoenoses create internal time measures as, our second example shows:

'Larches and Arven in Engadin (Switzerland) are above a certain altitude completely stripped of their needles by the caterpillars of a butterfly; the damage is considerable. Before introducing a large-scale insecticide program, however, studies were permitted, the result of which was that, after such a stripping of needles, the needles formed in the following year possessed a harder surface which could not be penetrated by the young caterpillars. Thus, the butterfly population collapsed. In the course of the following years the original needle form gradually developed until the butterflies could once more attack. This occurred about once every ten years. If one were to combat the pest with insecticide – which could be easily accomplished – one would make the needles more vulnerable to the butterfly caterpillars from year to year. Thus, one would be forced to carry out insect control year for year until the end of time' (Remmert 1988: 100f).

Shock-like changes in living systems (biocoenosis)

However, the moderate interplay of different species does not imply that a biocoenosis remains constant over time,6 or periodically passes through certain states again and again. On the one hand, certain developments on the side of non-living funds, which caused considerable, sometimes shock-like climate changes, have over geological time periods led to radical changes in many biocoenoses, if not destroying them altogether. If, however, we viewed the entire Earth as a biocoenosis, we see that it has thus far been so stabile as to survive even enormous shocks in the form of meteorite strikes. Each time, such strikes appear to have caused a massive extinction of species, but they were simultaneously the cause of new and more complex forms of life developing. In the long-term, life has thus far proven itself capable of integrating such shocks into its evolution" (Faber and Manstetten 2010: 103f).

3.2 Case studies

Inland shipping

An illustration for the use of the stock concept to examine economic environmental interactions is given in chapter 12 of Klauer et al. (2017). The authors "examine how political decision makers in Germany in a sustainable way – or at least in a way that is more sustainable than at present.

The main focus at this point, however, is on method. Using this example, they demonstrate that their heuristic developed on the basis of the theory of stocks [ENVIRONMENTAL POLITICS] can be put to practical use to generate a rough overall picture of a given problem using relatively simple means, to outline the need for action and, where necessary, to gain pointers toward options for action and windows of opportunity [*Basics of Time*] for implementing them. The example is also provided by way of illustration in order to make the abstract and rather general description given easier to understand. There are two things the authors wish to highlight in particular in this regard:

- They deliberately do not describe the process of their heuristic in relation to a real-life situation involving policy advice or decision making.
- Given that their main interest lies with the method, they give only a cursory account of inland shipping rather than a detailed one. They attempt to show, in 'short sharp' fashion, how readily accessible items of information can be pieced together to generate a preliminary but fairly robust picture of inland shipping in Germany.

It is in the nature of a heuristic that the information it helps to generate is neither inevitable nor incontrovertible. Additionally, of course, it is always possible to arrive at the same information by another route, that is, without the heuristic. The heuristic, then, is merely a device designed to help the enquirer move systematically along a path toward sustainable solutions. It cannot, however, be applied in a purely schematic or automatic way but rather requires expert understanding and the faculty of judgement." (Klauer et al 2017: 201; see for detailed information on this example Chapter 12) [POWER OF JUDGEMENT; ENVIRONMENTAL POLITICS].

The development of oxygen in the atmosphere as a paradigm of the development of a new service and its consequences

"The following example is to demonstrate how the development of the foundations of life of the biocoenosis Earth can be described in the terminology of 'funds' and 'services':

One of the conditions for life we take for granted the most would seem to be the availability of oxygen. At first glance we would hardly identify the air we breathe as a service based on the activities of any living funds. This is, however, the case: The oxygen in the air is the product of an evolutionary development of certain species which, by means of their production of oxygen, have acted as a fund for other species and still do.

Until approximately 3.2 billion years ago, there was as good as no oxygen in the atmosphere. The first forms of life that developed at that time on Earth could not possibly have developed in an oxygen-rich atmosphere. Conversely, the early atmosphere before the development of oxygen would have been harmful for most of the organisms today. It contained, among other things, hydrogen sulphide, carbon monoxide and hydrocyanic acid.

‘All three compounds are poisonous gases one would not think of as precursors of biochemicals of primeval times: They are, however, only poisonous for aerobic organisms [organisms which are dependent on oxygen, the authors]. For many anaerobes [organisms that require no oxygen, the authors], hydrogen sulphide is an important metabolite substance.’ (Schopf 1988: 897; our translation).

How is one to picture the transition from this oxygen-free atmosphere to today’s oxygen-rich atmosphere? In other words, how was it possible that not only bacteria and blue-green algae but also fungi, single-celled organisms, animals and plants could develop on Earth? (For a more detailed description see Faber and Manstetten 2010: 106-107)

The terminology of funds and services allows the processes leading to the development of the oxygen atmosphere and the related evolutionary changes [EVOLUTION] to be described as follows. The oxygen atmosphere (the following adheres closely to Schopf 1988) which provides most of today’s living things with the necessary air to breath, has not always been available. It is much rather a service that can be traced back to the interaction of several funds. The fund that set the development of an oxygen atmosphere in motion, originally (that is two billion years ago) consisted of cyanobacteria (blue-green algae) that performed aerobic photosynthesis. The oxygen accumulating through these processes was initially not a service, being neither useful nor harmful. The more abundant it grew; however, the more it became harmful for anaerobic forms of life.

The cyanobacteria were capable of adapting to the environment they had changed. The next stage consisted of them ‘discovering’ oxygen as a service by integrating it into their metabolism. The oxygen proved, however, to be a service which was by no means reserved for them. After the ‘discovery’ of the service oxygen, a sheer incalculable abundance of species developed, along with the organisms capable of making use of it.

Today, oxygen is produced and consumed in a kind of cycle: ‘currently the photosynthesis of green plants, cyanobacteria and certain single-celled organisms, together with the joint product oxygen, forms the basis for the synthesis of most substances produced on Earth.’

(Schopf 1988: 96; our translation). Accordingly, the green plants, cyanobacteria and the single-celled organisms mentioned are today funds providing services for most living things. The structure of funds emitting oxygen has qualitatively changed greatly over the course of the last two billion years. In the beginning it consisted entirely of cyanobacteria. Then a structural change occurred, and it was supplemented and expanded by single-celled organisms and green plants.

The fact that oxygen was initially not used as a service led to an accumulation of an ever larger store of oxygen. Only after had reached a critical level of enrichment with oxygen of the the atmosphere had been reached was sufficient oxygen available for the emergence of aerobic organisms that possessed a considerably more efficient metabolism. Thus, we recognise that such a development could only occur after a sufficiently large supply of oxygen was available. Had the supply not been available in the necessary amount, the diverse living things dependent on it (the plants and animals as consumers) could hardly have developed. The length of time between the formation of a supply and the corresponding demand, which identifies it as a service, is hereby of great importance. What is unique to this type of service is that it has a determining effect on the development of the consumers themselves" (Faber and Manstetten 2010: 105-107).

4. Literature

The content of MINE originates from scientific work published in books and peer-reviewed journals. Quotes are indicated by a special typographic style.

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The main sources of this concept are the following publications:

Faber, M. and R. Manstetten (2010) Philosophical Basics of Ecology and Economy. Routledge, London and New York. All rights reserved. No part of this publication may be

Faber, M., Manstetten, R., Proops, J.L.R. (1998), Ecological Economics. Concepts and Methods. Edward Elgar, Cheltenham.

Klauer, Bernd, Reiner Manstetten, Thomas Petersen and Johannes Schiller (2017) Sustainability and the Art of Long-Term Thinking, Routledge, Abington, Oxon and New York, NY. We want to express our gratitude to Bernd Klauer, Reiner Manstetten, Thomas Petersen and Johannes Schiller for supporting the MINE Project and granting the permission to use parts of the content of their book.

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