Economic rationality and ecological functionalism: epistemological affinities and temptations

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Abstract: When applied to ecological objects, instrumental rationality naturally takes the form of functionalism: the question is then to know what is the ‘function’ of these objects (i. e. organisms, species, communities, etc.) in the system that contains them. Faced with a systemic issue like the ecological crisis, such an approach is particularly useful, as it allows to represent a complex or intertwined reality and solve it rationally, by assuming functional equivalences between the system’s elements. While functionalism has grown in popularity since the emergence of environmental issues in the 1970s, however, the concept has only a narrow range of scientific validity. This article reviews the epistemological status of functionalism in ecology and highlights some important implications for ecological economics. One of the most important aspects is that there is no such thing as "functioning" in nature: functionalism is a view of the mind, which depends directly on the field or the object studied. It follows that functionalism can never be separated from a specific ecological structure, and that it becomes inapplicable wherever singularity prevails. Since singularity is omnipresent in ecology, the application of a functionalist perspective appears particularly delicate. While instrumental rationality stays relevant and necessary, in our opinion, to respond to the ecological crisis, we contend that economists (as well as all theorists who opt for an instrumental perspective) risk conceptualizing the environment through purely abstract functionalism, i. e. of supposing functional equivalences that do not correspond to any ecological reality. Following Horkheimer and Adorno, we argue that such reasoning brings about the “fetishism of equivalence”, of which functionalist thinking could be a contemporary variation.

Keywords: instrumental rationality, functionalism, ecological functioning, ecological crisis

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> Earlier, fetishes had been subject to the law of equivalence. Now equivalence itself becomes a fetish.
> --- M. Horkheimer & T. W. Adorno, *Dialectic of Enlightenment*

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Introduction: Economic rationality and the ecological crisis

Economic intelligence or rationality consists, fundamentally, in rationally arranging means for a given end. It corresponds, in Aristotelian terminology, to instrumental rationality or *poeisis* and is in contrast with practical rationality, or *praxis*. Instrumental rationality relates to the realm of necessity (the realm of constraints) while practical rationality relates to the realm of freedom – as Arendt (1958) pointed out. The latter pertains to politics and the 'good life', while the former pertains to economics and the 'bare life'. Classically, the given end that orients economic rationality is production: production is the reflection of a still-unmet necessity, and increases in production are meant to fulfill it, thereby ensuring the greatest satisfaction of the agent or social group. The ecological crisis, however, poses formidable questions to the exercise of such a rationality. Indeed, with the ecological crisis, the economic agent suddenly finds himself immersed in a much broader and more complex environment than he imagined. He is placed in an environment made up of multiple interdependencies, a world that turns out to be moving and indeterminate (Mayr 1961), in which his action is diffused and eventually disintegrates into a multitude of unforeseen consequences. At a pinch, the ecological crisis can be interpreted as a saturation of what could be called the 'repercussion space': each action directly or indirectly affects all biophysical cycles across the whole of planet Earth. The risk, then, is to block any process of rational action: because of the globalization of consequences, it becomes nearly impossible to identify beneficial actions, as repercussions multiply infinitely. In each case, associated benefits appear to be too weak in the face of the multiple ecological aftereffects. Such a situation risks permitting a culture of catastrophism: if the consequences of our actions propagate *ad infinitum*, no end is ultimately legitimate, and the possibility of action is annihilated.

To remedy such a situation, economic rationality is forced to abandon individual utility in favor of a more holistic approach. It means extending the scope of analysis beyond the direct environment of the agent, to include ecological interdependencies. In doing so, theorists build a rational cartography of the entire socio-ecosystem, in order to prevent after-effects from escaping their attention. For this purpose, the concept of function is paramount: functionalism is based on the idea that the contribution of every ecological item to the general system's functioning can be evaluated. By incorporating this concept, theorists can begin to outline a complete socio-ecological metabolism.

One can easily see that functionalism is a natural extension of instrumental rationality: while instrumental rationality links an agent to some corresponding good (i. e. an end to some corresponding means), functionalism links a multiplicity of agents (ends) and goods (means) all together. In other words, functionalism is the language for describing situations of multiple interdependencies. The functionalist approach was introduced early in environmental studies (De Groot 1987; Ehrlich and Mooney 1983; Westman 1977) and has gained increasing popularity, especially since the *Ecosystem Millennium Assessment* (MEA 2005) and the TEEB (2008). Ecosystem services, whose success among environmental practitioners and in the scientific literature is well known, typically fall under the 'function' category[1]. Functionalism has also gained prominence in ecology, as we will see later.

From an epistemological point of view, however, such a perspective is not trivial. Functionalism has some prerequisites. Notably, it requires a system of functional equivalences, i. e. equivalences in the effects produced by the components of the 'system' (e. g. species A and species A' produce the same effect inside the 'system', and thereby belong to the same functional group). It also requires an objective function (or meaning) for the 'system' as a whole: the 'system' must be a 'functioning' system (e. g. species A and species B, through their specific strategies, contribute together to the system's coherence). Before laying claim to some unified economic-ecological knowledge, it is therefore necessary to verify whether these prerequisites are valid for ecological entities. As we will see in the following sections, functionalism appears to be admissible in biology only in certain specific cases, according to precise definitions. The question of equivalence, in particular, is delicate, because it is the singularity of situations that predominates in the 'ecological theater', to use G. E. Hutchinson's expression. One cannot simply assume the existence of functional equivalences between items in ecological systems, as when observing some mechanical system, like a watch or an engine. In the living world, equivalences must be actively *conquered* by instrumental rationality, and not simply assumed. Or to put it another way, ecological singularity is not easily *reduced* by economic rationality: one can expect ecological entities to resist to their functionalization, despite theorists' taste for coherent functionalist diagrams. In that respect, the question arises as to whether the tendency to assume equivalences in environmental sciences[2] would not constitute a form of what Horkheimer and Adorno (2002, 12). referred to 'equivalence fetishism'. The two critical theorists had underlined a great risk ensuing the deployment of instrumental or economic rationality in late modernity: the risk that, as economic reasoning saturates cultural imagination, we end up believing that equivalence is the rule, while it is the exception. The risk, then, is of not being aware of the specificity of the ecological problem, and of underestimating what is at stake.

In the following sections, this specificity is explored, based on an analysis of the epistemology of biology and contemporary ecology. Such an exploration is consistent, in our opinion, with what Melgar-Melgar and Hall (2020) have referred to as the original goal of ecological economics: to aim for full coherence between the two disciplines. Section 1 reminds of the persistent plurality of ecology, which entails that different epistemological postulates coexist, in which functionalism receives more or less attention. On a more fundamental level, section 2 highlights that the concept of function is relatively ambiguous, and that it can potentially pose problems with respect to scientific rigor. Section 3 reviews the two theories of function that are admissible in biology, which defines the permitted uses of the concept. Moving on to ecology, section 4 examines the paradoxical situation of post-odumian ecology, which still largely mobilizes a functionalist framework, despite

1 The "environmental functions" of de Groot (1987) and the "ecosystem functions" of de Groot, Wilson and Boumans (2002) can be seen as forerunners of the "ecosystem services" concept.

2 A trend that is particularly noticeable as more pragmatic approaches, coming from economics and ecosystem management, gain importance in the field.

the revision of odumian principles and the ambiguity of this type of approach. Section 5 returns to ecological economics, pointing out the crucial condition for a valid use of functionalism: always relating any functionalist framework to an observed, updated and well-defined structure. Finally, section 6 discusses what is probably the main obstacle to the application of instrumental rationality to ecological entities: the singularity of situations. There is a profound antagonism between economic equivalence and ecological singularity that should not be underestimated, as we highlight in the conclusion.

Section 1: Facing economic rationality, a plural ecological science

What is the status of functionalism in ecology? The interest (and the difficulty) of this question is that ecology is not, in fact, a unified science: although there have been significant convergences for the previous decades, different approaches and different visions coexist to this day, which prevent an unequivocal economic integration. Ecology is a polyphyletic science which, towards the end of the 19th century, brought together several previously existing sub-disciplines (McIntosh 1985). From the beginning, the community of botanists, zoologists, geographers and soil scientists that were brought together under this name remained divided into subgroups, and Van der Valk (2011) points out that the discipline remains plural. Causes of the persistent disunity may lie in the difference in the objects of study: indeed, drawing up scientific laws that would be common to plant and animal communities, for example, is not obvious. More fundamentally, conflicting epistemological principles are also a cause for confrontation. Some of the main still-existing divisions are as follows:

- division, first, according to the environments examined: terrestrial or aquatic, forest or open, tropical or temperate, deep water or surface water, aerial or underground, etc.;
- division, then, according to the hierarchical level, from autecology (one individual of one species) to "global" ecology (all individuals of all species), including the ecology of populations, communities, ecosystems, landscapes (Wiegleb 2011);
- division, on the epistemological level, between holism and reductionism – of which the oppositions organicism/individualism and “emergentism”/“anti-emergentism” are avatars – and which founds the recurrent debate about the fundamental unity in ecology (Jax 2006);
- another dichotomy, which follows from the previous one, opposes the "population-oriented" approach of population ecology (populations are considered the highest level of living organization and therefore the most robust unit) to the “process-oriented” approach of systems ecology (which supposes a supra-populational organization called ‘ecosystem’);
- the latter is similar to the dichotomy of Callicott et al. (1999) between a "compositionalist" approach, centered on the interactions of individuals assembled in populations – a perspective that the authors qualify as "entity-oriented" and which comes from the evolutionary tradition – and a "functionalist" approach, centered on processes in which individuals are only ‘performers’ – a perspective described as "process-oriented" and which belongs to the systemic tradition;
- finally, the ‘equilibrium’ dividing line is worth mentioning. The notion of equilibrium has been debated for decades since the origins of the discipline. Clementsian’ conceptions[3] (= ecological associations form a ‘system’ that balances itself and reaches an optimum) were opposed to ‘Gleasonian’ conceptions (= ecological associations are always fortuitous and never form a ‘system’ in the strong sense), until the nearly complete victory of the latter in the 1980s (Simberloff 2014).

3 Named after Frederic E. Clements, the late 19th century botanist who favored organicism in ecology. Henry A. Gleason (see further) was his individualist opponent.

It is immediately clear that the persistence of such theoretical divisions considerably complicates the treatment of ecological knowledge by economic rationality. On the other hand, it must be seen that from the point of view of this type of rationality, not all theoretical positions are equal: in particular, functionalist approaches will receive a clear preference, since their conclusions can be directly translated into an economic language that requires equivalences for the purposes of aggregation and exchange. Two points of discussion in ecological debates will now catch our attention: the role of function and the question of singularity. Functionalism is interesting because it is the link between ecology and utilitarian reasoning; singularity, because it is its stumbling block.

Section 2: The role of function in ecology

In its quest for rational coherence, economic reasoning naturally relies on the concept of 'function', which is how we can estimate the contribution of a part to the whole. Discerning the functional statements that underlie an ecological complex means, for the economist, highlighting the 'grammar' that should allow him to compose a general performance scheme (i. e. a matrix of respective contributions). The concept of function appears to be very much present in biology: the French philosopher and epistemologist Jean Gayon (2006, 480) had emphasized its "omnipresence". Ernst Mayr (1961), the renowned biologist, proposed the famous general distinction between a functional biology, related to the "proximate causes", and an evolutionary biology, related to the "ultimate causes". The "proximate causes" correspond to the short time of present biological patterns (where synchronic causality applies) while the "ultimate causes" refer to the long-term of natural selection (where diachronic causality applies). As Gayon (2006, 486) pointed out, these two approaches do not exclude each other but correspond to two distinct "regimes of scientificity", both necessary for the explanation, as the author says, "of any organic phenomenon*[4]". Short term versus long term, physiology versus phylogeny, functioning versus history: two regimes that must be dialectically combined. Functionalism therefore appears as one of the two fundamental aspects of the living world[5].

The concept of function is also very present in ecology, in a variety of meanings mapped by Jax (2005):

- function as a synonym for "process" or "interaction" between two objects, in a purely descriptive meaning of cause and effect;
- function as a process related to a coherent whole (e.g. an ecosystem), which itself is assumed to "work";
- function as the role attributed to certain entities within the system, which makes it possible to distinguish the function (e. g. primary productivity) from the entities that provide it (e. g. plant species), and to define "functional groups" or "types" (e.g. primary producers, primary consumers, decomposers, etc.)[6]; and finally
- function in the sense of an ecosystem service, following an expressly anthropocentric conception, which we also find, as Jax notes (p. 646), in the ecosystem health research program.

4 Citations with an asterisk have been translated from French to English.

5 Although Mayr spoke of "functional biology", according to Gayon the term "functioning" ("fonctionnement" in French) should be preferred, since functional biology ("biologie fonctionnelle") can refer to the biology of adaptation.

6 This meaning heads to Woodward (1994)'s "universal functions" that describe some general processes, such as the circulation of carbon, energy, minerals, water, etc.

As one may see, these four meanings draw the implicit path of a progressive 'mobilization' of ecological items, going from the simple statement of existing causal relationships to an examination vis-à-vis a general functioning, then an attribution of 'roles' (several items can perform the same role) to a normative selection of convenient processes. What such a progression suggests is the possibility of an assimilation of functional statements by economic rationality, i. e. the possibility of designing an overall performance scheme that would include all ecological items. It should be noted, however, that the historical dimension is excluded here, although it is decisive for the understanding of the dynamics of life.

Nevertheless, the term of function has been the subject of considerable epistemological debates in biology for several decades. The reason is that functionalist statements bypass conventional causal schemes by explaining causes with effects. Instead of sticking to strictly causal statements (like "the heart circulates the blood in the organism", or "the iceberg provides drinking water to the valley"), these statements provide so-called "total" explanations ("the purpose of the heart is to circulate blood in the body", or "the purpose of the glacier is to supply drinking water to the valley"). By doing so, functionalist statements reintroduce a teleological way of thinking[7]. A function is a sort of *expected effect*; but saying that an item "has a function" is not only supposing some effect regularity of the item, but it is also saying that the *raison d'etre* of this item is to produce the effect. This is a typical finalist/teleological statement, which is hard to assert scientifically. De Ricqlès and Gayon (2011, 143) also underline a paradoxical aspect of the concept of function: it is an abstract notion, but in fact it is inseparable from a concrete structure, which gives it its full meaning. Function is not a substance but "an interaction, a process of action", as the authors say, which cannot be considered apart from the structure that produces it. De Ricqlès and Gayon evoke some "indissociable structural-functional couple*": if the function is abstract, there can only be a function in relation to a fully described system (or situation), whose function is an emergent property. Yet as highlighted by Devictor (2018, 150), this comes with some risk: if the functions are described independently of any precise ecological context, they lose their meaning and become "phantom functions*"[8].

Section 3: The two theories of function

Two distinct theories of function have remained to this day, which attempt to ensure the scientific validity of the term: the so-called "etiological" (or evolutionary) theory of function, pioneered by Larry Wright (1973), and the "systemic" (or 'dispositional') theory of function, initiated by Robert Cummins (1975). The etiological theory of function relates the 'traits' of an organism to natural selection; in this case, function is akin to a "selected effect" (Gayon 2006, 483). The etiological theory is therefore inseparable from the theory of natural selection: function is relative to a trait such that it has conferred a selective advantage on the 'typical' individual who bears it. It follows that function in the etiological sense only has meaning for a single organism, since it is at this level that selection takes place. This conception of function is related to the works on 'functional traits' (Díaz et al. 2013), which attempt to evaluate the 'performance' of certain biological properties with regard to natural selection. A 'trait' in functional ecology means a defined and measurable individual property, which may be morphological, physiological or phenological (like beak size, body mass, metabolic rate, freezing tolerance, etc.). A 'functional trait' refers to any property that influences the performance (the fitness) of the organism, i. e. which allows it to survive, grow and

7 Functionalist language, says Gayon (2006, 481), "is a spectacular example of a teleological way of thinking in modern science*". The examples of the heart and the glacier are taken from Gayon and De Ricqlès (2010, 3).

8 With regard to the epistemology of sciences, this logical combination between 'structure' and 'function' reveals couples of functional and structural disciplines, like physiology and anatomy, or, as De Ricqlès and Gayon (2011, 144) suggest, ecology and demography. The authors describe ecology as a "meta-physiology of supra-specific interactions*".

reproduce in a defined environment. Work on functional traits therefore consists of examining the ‘success’ of different traits against gradients or environmental variations; in other words, to quantitatively identify the best performing traits.

The other view of function, the "systemic" theory, differs from the first as it ignores history and considers only structure as it can be described. Function, in this case, is an effect or ‘capability’ inferred from more basic capabilities. Gayon (2006, 485) calls this conception "overtly mechanistic and analytical*". It consists, according to a method comparable to physico-chemical sciences, in breaking down the system into parts, and in identifying within the ‘game’ of these parts some phenomenal regularities. It is therefore no longer a question here of finding explanations for the origin of a particular trait, but looking for laws that can be replicated on the scale of the system. History does not matter: one can say that the systemic conception of function is a matter of ‘homoplasies’ (i.e. fortuitous functional identities: species A and species B produce a similar effect, although they are not related) and not ‘homologies’ (i. e. functional identities arising from phylogenetic proximity: species A and species B produce a similar effect because they are related).

Ultimately, these two theories imply two distinct forms of causality (and two evidentiary regimes):

> in the etiological conception, it is about historical causation: one is interested in the singular chain of events that can explain the presence of an item. In the systemic conception, it is about nomological causation: one is interested in the generic properties or laws on which the capabilities of a system are based, *which one supposes to be reproducible at will*[9]. The etiological concept emphasizes the evolutionarily contingent character of living systems. The systemic concept emphasizes the general physical properties that explain the capabilities of these systems*. (Gayon 2006, 485)

Similarly, De Ricqlès and Gayon (2011, 154) indicate that the first conception sees in functional statements some “condensations of historical explanations*”, and the second some “condensations of analytical and mechanistic explanations*”. One will recognize here the two regimes of knowledge formulated by Mayr (1961) a few decades before: the etiological conception relates to evolutionary biology, while the systemic conception relates to functioning biology. It follows that the use of the term ‘function’ remains polysemic in biology (De Ricqlès and Gayon 2011, 155). In some cases it refers to Darwinian adaptation, while in other cases it refers to "causal roles" within given structures. The two meanings occur at different moments in the explanatory process. The systemic function is used each time phenomenal regularities appear to the observer, while the etiological function applies each time a singularity appears to be irreducible, which obliges the observer to tease out the historical explanation. De Ricqlès and Gayon (2011, 153) note, in this regard, the decisive role of the observer in the case of the systemic conception:

> It can be pointed out that the systemic conception is less "realistic" than the etiological conception in the sense that there are no real systems in nature independent of our choice to distinguish them according to our explanatory perspectives, whereas there are objective causal histories[10].

Functionalism (i. e. nomological causation) and historicism (historical causation) can therefore be associated, on the express condition, however, that the functionalist proposition is purely factual: i. e. on the condition that it is derived from a temporary observation of the situation, without

9 We emphasize this part, which is of direct interest to the economist.

10 Jax (2005, 644) : “Ecosystems cannot be identified or found in nature. Instead, they must be delimited by an observer.”

involving some transcendental finalism. In De Ricqlès and Gayon (2011, 141–42)'s words, a valid functionalist description must be derived from the mere observation "of the non-trivial adequacy of the biological structure to the function*", and thus remain open to modification by natural selection.

Section 4: Functionalism and post-Odumian ecology

Functionalism has long found fertile ground within systems ecology, which is clearly organicist. Odumian ecology tended to detach itself from evolutionary considerations, to offer a clearly systemic perspective, "as much (if not more) physico-chemical as biological*", as Corriveau-Dussault (2016, 90) says. It aimed to provide an explanation of ecosystems as stratified, functionally differentiated structures. Inspired by cybernetics and thermodynamics, the Odumian model was made of feedback loops, where individuals were only 'performers', their role in the web of interactions being more important than their phylogeny. What matters to the systems ecologist is the ecological metabolism, the "meta-physiology". This results in less attention being paid to taxonomic variation: some generalization is required, which tends to summarize individuals into 'types'. Many of the propositions of systems ecology have a strong teleological emphasis: homeostasis, which is elevated to the status of a general biological principle; the principle of maximum power (H. T. Odum and Pinkerton 1955); stability as a criterion for natural selection; ecological wholes considered as the object of this selection, instead of individual differentiated reproduction. Towards the end of the 20th century, Odumian ecology was subject to increasing criticism (Mansson and McGlade 1993): contemporary ecology, described as 'post-Odumian' by Worster (1994), left behind earlier conceptions of the ecological realm "with neither location nor history*", to use Blandin and Lamotte (1987)'s pithy expression[11].

Paradoxically, however, the declining relevance of Odumian propositions did not mean the end of functionalism in ecology. Devictor (2018, 105) has shown that the functionalist framework largely re-appeared in the 1990s in ecology, what the author calls the "functionalist turn", which brought the idea of ecological functioning back into the spotlight, even though Odumian holism had been rejected. Different meanings of function have remained, noted by Jax (2005). A pivotal moment of this 'turn' was the Biodiversity and Ecosystem Functioning research program (BEF): the program took precedence over the 'diversity-stability' debate of the 1960s and 1970s (McCann 2000) by attempting to assess, in the context of the biodiversity crisis, the role played by species diversity in ecological functioning[12]. The BEF sought to prioritize which species to protect, in order to minimize the continued decline in biodiversity (Walker 1992). This is what Devictor (2018, 96) calls the "*prise de fonction*" of biodiversity[13]: the aim was a sort of "reconciliation" between biodiversity and functioning (p. 121), by demonstrating the existence of a positive relationship between the two terms[14]. Devictor however underlines (p. 124) the low generality of the statements that are formulated in the program (due to the high specificity of the models and experimental devices involved) as well as a certain intrinsic "circularity". Indeed, it appeared in the course of the program that both diversity and redundancy were necessary to the functioning: it followed that, whatever the situation, the 'role' of biodiversity was demonstrated. Moreover, according to Devictor (p. 136) the

11 Admittedly, Odumian ecologists did show open-mindedness to contingency and system non-enclosure, as non-equilibrium ecology was emerging. This is noticeable in Odum and Barrett (2004), for example.

12 Among the BEF flagship publications: Hooper and Vitousek (1997), Hector et al. (1999), Tilman et al. (1997), Loreau et al. (2001).

13 We could say the "functionalization" of biodiversity.

14 To this day, two explanations have been accepted that may account for such a positive relationship: the "selection" or "sampling" effect, whereby a more diverse community has a greater likelihood of including a "performing" species; and the "complementarity" effect, whereby the variety of species increases the variety of resource use strategies, and thereby increases (through competition or facilitation) the overall performance (Flombaum, Sala, and Rastetter 2014).

BEF bypasses the crucial issue of the interdependence between structure and function evoked above. Structures tends to be overlooked in favor of a decontextualized biodiversity. As the ecologist says, "functioning is no longer the result of a structure [...] but the result of the biodiversity itself*”. This issue will become even clearer with the emergence of ecosystem services, which the BEF had announced: these services remain, unless referred to specific contexts, notoriously separated from any fully described context.

Function finally became topical with the biodiversity crisis, reinterpreted in terms of “biotic homogenization” (caused by the "anthropogenic blender", as Olden (2006) put it), which operates genetically, taxonomically as well as functionally (McKinney and Lockwood 1999; Olden 2006). Functional homogenization means an increase over time of functional similarity within a community, either due to the arrival of species with similar traits or due to the loss of species with unique traits. Concretely, this homogenization corresponds to the replacement of ‘specialist’ species, whose abundance varies according to environmental gradients, by ‘generalist’ species, whose abundance varies little, and which therefore show a higher tolerance. In a situation of global changes, species specialization may become a weakness, since specialization is an evolutionary response to stable environmental conditions. Such a replacement is observed on a global scale: it may be due to the alteration of specialist species habitats, or, more indirectly, to competition between specialist and generalist species. This may occur, typically, during the colonization of new niches opened up by global changes (Clavel, Julliard, and Devictor 2011). Functional homogenization raises questions, in that the final effects are unknown. For example, one may fear that functional homogenization would lead to a reduction in species complementarity within a community, which could alter its functioning and viability. We know that ecosystem resilience depends on the diversity of responses of functional groups, which, by reacting differently to disturbances, provide a ‘buffering effect’. However, functional homogenization could also have some beneficial effects. As Clavel, Julliard and Devictor point out, it could be that the installation of generalist species would promote the transition to new perennial communities.

Section 5: The risk of assuming functions without considering structures

What use could economists ultimately make of ecological functioning? A ‘factual functionalism’ could allow them to come up with an ecological functioning scheme, where phenomenal regularities would be drawn from the analytical decomposition of ecological wholes. These ecological regularities could be put in relation to economic regularities, with a view to an integrated economic-ecological performance scheme (i. e. a scheme in which all requirements of all items, both economic and ecological, would be optimized). Economists must, however, keep in mind that the “systemic” approach does not show an objective ecological ‘reality’, but depends entirely on the observer and his point of view. It is therefore up to them to keep an eye on the system evolution, i. e. to always check the validity of the assumptions and categories and verify, in particular, the identity of functional units (i. e. the ‘modules’ that are distinguished to build the functionalist scheme). The danger of a functional interpretation would be to stop at an abstract idea of the function. As said above, if functions (or ‘services’) are detached from structures, they retain only a rhetorical meaning. Functional and structural perspectives must remain linked.

On the evolutionary level, the study of functional traits presents an undeniable economic interest in a context of biodiversity loss: Wood et al. (2015, 1) point out that “functional trait diversity, rather than the diversity of species *per se*, is the dimension of biodiversity most directly related to ecosystem functioning”. One can hope that these works will help to anticipate any biotic depletion and take preventive measures. By identifying the most vulnerable traits and adjusting actions accordingly, it would be possible to either curb biodiversity change or, on the contrary, to favor it in a preferential (more resilient) direction. The general challenge for economists is, however, to not underestimate singularities, which are omnipresent in the living world. The functional substitutability of biotic items, which directly ensues from a functionalist approach, must be more the goal than the means. This point is crucial, especially in the debates about ecological equivalence and ecological compensation. Singularity should never be eluded, but skillfully and patiently reduced through competent ecological engineering. Any economic approach that would attempt to wrestle ecological complexity within the confines of its inherent logic of equivalence risks promoting a dangerously abstract vision of ecological entities. Economic rationality must recognize the specificities of the ecological realm; it must get inside ecological complexity and operate within it.

Section 6: The question of singularity

Georg Picht, the 20th century German philosopher, defined ecology as "the science of the singularity of situations, founded on the generality of natural laws"[15]. Singularity has an important place in ecological thought: if the search for laws constitutes (like any science) the final ambition of the discipline, ecologists are generally aware of the great complexity of their object, which encourages caution in the elaboration of definitive statements. The French ecologist Blandin (2009, 87), for example, is reticent about the idea of 'law'. According to him, ecology only offers falsifiable models for interpreting data. In ecology, each field of study, each experimental isolate is caught up in a complex that goes well beyond it, and with which it interacts. The fundamentally hierarchical structure of the living world creates a multiplicity of 'openings', of connections between levels, which prohibits any definitive theoretical closure. Even in rudimentary ecosystems, the number of species and the complexity of their interactions strongly limit the possibilities of mathematical modelling. Species richness is often such that a substantial part of the taxa remains unknown. For example, a single gram of soil can contain tens of thousands of prokaryotic species. From a biogeochemical point of view, different cycles (energy, carbon, nitrogen, phosphorus, etc.) intersect and influence each other, while they evolve irreversibly at the same time (erosion of the bedrock, soil formation, atmospheric deposits, etc.). A field study, even over an extended period of time, corresponds to a more or less instantaneous image of a dynamic process made up of different rhythms, different impulses – some of which going back several centuries or millennia. In that sense, Blandin (1992, 274) pointed out that "any fragment of the biosphere, as we can observe it today, is the local product of a singular history: it is definitely unique*". It is this complexity that made the systems ecologist Ulanowicz (2004, 349) say that the world of the ecologist is "granular" rather than universal: the singularity of each situation becomes a methodological prerequisite. At the same time, it increases the difficulty of a peer-to-peer agreement. Similarly, ecology can be said, like Allen and Hoekstra (1992), to be a "science of middle numbers": ecology is *more* than a science of small numbers, where the system can be described by differential equations, and *less* than a science of large numbers, where the system can be summarized by statistical averages (Sutherland et al. 2013).

Singularity, which constitutes a challenge for the mind, is not admissible by economic rationality, which requires clear functional statements (what is this or that for?), both generalizable and persistent. The challenge, therefore, is to establish a system of equivalences (i. e. this item is equivalent to this item within the performance scheme) that could reduce complexity and bypass singularity. In the same way that the ecological crisis requires mapping all biomes without leaving a blank spot on the map, it requires identifying the role played by each item within biological cycles, without leaving uncertainty about the respective contributions of this or that item. Economically, the aim is to find practicable (functional) statements at some reasonable cost that would be both

15 In "Ist Humanökologie möglich? (1979), quoted by Haber (2011, 225).

strategically sensible and sufficiently in accordance with the ecological reality. With regard to industrial development, we probably stand at the beginning of this process. Only a limited number of attempts have been sketched out, of which the most emblematic example is undoubtedly carbon engineering. Although it is a remarkable example of large-scale theoretical construction, one can wonder about the relevance of some categories that have been defined in carbon accounting. Characterizing the extremely varied ecological realms under gross headings such as 'forests' or 'grasslands' are poor approximations that can result in problematic oversimplification. If the climate system, by its relative simplicity, allows the translation in carbon terms of a large variety of biotic phenomena, it is to be feared that the conversions into CO_2 equivalents could elude other aspects of ecological dynamics that are of comparable importance but less 'maneuverable'.

Horkheimer and Adorno (1947) had shown that the stakes for the instrumental reason, which was personified by Ulysses in their famous book, consisted of three things. First, to recognize the superiority of antagonistic forces (Ulysses, in front of the odyssey's various monsters, is never the strongest); second, to cede to them in proportion to their superiority; and third, to bypass them by a lateral, indirect way. Monsters may have strength, but they are without flexibility: this is Ulysses' wisdom. Instrumental reason therefore faces two limits: the first is the obstacle itself, to which one must grant some inessential part (each monster has its own requirements, but these are always secondary to Ulysses' goal). This limit is eventually the easier one, the limit that Ulysses knows how to bypass. The second limit is more insidious, since it relates to the limits of our knowledge and understanding of the situation. We have to make an effective recognition, a fair assessment of the antagonistic forces at play. In other words, this second limit raises the question of the *acuity* of the instrumental reason, i. e. its force of penetration. This limit springs from the limits of the mind itself, and may prevent Ulysses from fully seeing what kind of force he is dealing with. Regarding the environmental issue, one could say that the limit is constituted as much by the ecological 'rigidities' to which one must agree to cede temporarily (to cede a part of one's well-being, economically speaking) as by the impossibility of recognizing the obstacles – due, in particular, to the singularity or complexity of ecological situations. This impossibility of recognition is revealed, in practice, by the appearance of unforeseen ecological behaviors, which are identified by ecologists as 'surprises' (Lindenmayer et al. 2010). Ecological surprises are the clue, for the economic agent, of an inadequate cartography of the ecological realm, or an overly naive tactic. As long as functional equivalences prove to be too simplified, the agent is forced to narrow his field of action, to concentrate his attention on a more restricted perimeter. Eventually, he could have to come back to the 'closed' world of the ancient peasant (whose domain is entirely singular and does not rely on abstract equivalences) with this difference that global changes no longer allow the 'rest of the world' (as we say in macroeconomic accounting) to be neglected[16]. Instrumental reason no longer has the luxury of relying on the 'ceteris paribus' hypothesis. It must exercise itself locally, while watching for the effects of global upheavals, and as far as possible, anticipate them with prophylactic adaptation measures.

One can wonder if the proposals of carbon engineering, such as carbon storage or afforestation, do not deviate from Ulysses' rule, as they constitute an attempt to adapt biological cycles to human rhythms rather than an adaptation of human rhythms to biological cycles. One can fear that these attempts poorly recognize the ecological forces and cede too little. Certainly, ecological engineering will be able, in the coming decades, to refine its action and increase socio-ecological coherence. However, one could also see behind the mix of insufficient measures and political stalemate the effects of a weakened reason, confronted with a Cyclops that is too big for it to handle.

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16 It should be noted that past arrangements were based less on the replication of abstract functions than on the slow compromise of the forces involved – a compromise that has been obtained after hard struggle, and not without costs.

Conclusion

Despite its numerous criticisms, instrumental rationality should remain necessary in the future, at least as long as modern societies keep some purposes (that one of *perpetuating*, in particular). There is no end without a means to reach it, and navigating our way through the ominous future of global upheaval will require the ability to identify what in the living world can help us contain catastrophic biotic shifts and keep modern societies afloat. It seems unlikely, to say the least, that a complete renunciation of control (which underlies instrumental rationality) will guarantee the human species not to appear in the list of extinct species. Faced with the ecological crisis, applying instrumental rationality still seems legitimate, which means (if we consider this type of rationality as characteristic of an economic reasoning) that economics has a role to play in the search for socio-ecological adequacy.

In a context of high interdependence like an ecological situation, instrumental rationality naturally takes the form of functionalism. Functionalism aims to study the coherence of a system: it was logical that, with the ecological crisis – which can be seen as a mismatch between economic and ecological dynamics – this type of approach emerged, both in environmental economics (with the rise of the 'ecosystem service' concept) and ecology (with the 'functionalist turn' in the 1990s). However, epistemologically speaking, functionalism is not trivial: a functionalist approach does not reflect the entire ecological reality, given that associations between species are continuously modified by natural selection. Functionalism is only partial, and must be combined with a historical viewpoint. Moreover, the singularity of ecological situations is such that a functional scheme must imperatively be associated with its precise context. In biology, there are no functions *per se*, but only concrete relations deduced from a given structure. This means that the range of validity of a functionalist approach is limited, and that one cannot resort to some abstract, decontextualized functionalism: on the contrary, close attention must be paid to each situation. As a result, assuming functional equivalences between ecological entities may be problematic: indeed, equivalences are far from obvious in the living world. This is where a challenge for instrumental rationality appears: while it requires equivalences to operate, the ecological world does not easily provide them. This implies that instrumental rationality must search for equivalences carefully, without assuming them too quickly.

Now, assuming the equivalence of things might precisely be a characteristic flaw of the modern mind, if we believe the warning of Adorno and Horkheimer. As the two theorists show in *Dialectic of Enlightenment*, modernity has seen such an extension of instrumental rationality into social life, i. e. such an extension of the equivalence logic, that equivalences had become a general presupposition (which implies that reason can self-destruct as a result). Faced with an ecological problem of immense complexity, the question then arises as to whether such a danger is now our primary threat: whether we might be bewitched by the law of equivalence in spite of ourselves, when we spontaneously resort to instrumental language without recognizing its limited validity. In a recent paper, Rockström et al. (2017) rightfully point out that resolving the ecological crisis will require "Herculean efforts". We could also say that it will require sustained *cunning* with regard to nature, and that the appropriate model is Ulysses as well. And just as one might ask whether modern societies still have the strength to undertake the immense work of structural transformation that the ecological problem requires, one might ask whether these societies still possess a spirit tenacious enough to embark on such a journey.

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