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SPECIAL FEATURE: NOTE AND COMMENT

Promises of Bioeconomic Change as a Strategy for Avoiding Socio-ecological Transformation

Reflections on the popularity of the circular bioeconomy concept: the ontological crisis of sustainability science

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Abstract
I argue that the popularity of the circular bioeconomy concept in policy-making is symptomatic of a profound crisis in sustainability science, which is generated by the adoption of an obsolete scientific paradigm, i.e., obsolete ontologies used to describe our interaction with the external world. The result is a systemic lack of quality control on the science–policy interface. The growing awareness of a pending collapse of our life support systems and the rapidly changing world order would require society to rediscuss its identity. However, current mechanisms of control of the quality of the scientific input used for governance do not allow us to do so. The problem is how to detect and change obsolete scientific paradigms referring to sustainability science. I conclude that a swift move to a new scientific paradigm would require a more reflexive science and a more reflexive society.

Keywords Bio-based economy · Circular economy · Ontological crisis · Paradigm shift · Reflexivity · Post-normal science · Sustainability science · Science and society

Introduction

In the last decade, few concepts in scientific research and policy have been so appealing yet at the same time so controversial as that of the (circular) bioeconomy. In the European Union in particular, the bioeconomy is being sold as a key element of a package of solutions to the current economic and ecological crisis (European Commission 2018). The EU bioeconomy strategy invokes imaginaries of 'green growth' by claiming that biotechnological innovations and a shift to 'circular' biomass-based processes will tap vast economic potential and solve ecological problems (Vivien et al. 2019; Giampietro 2019; EEA & Eionet 2022). Even though these promises have been questioned by several scholars (Kleinschmit et al. 2017; Ramcilovic-Suominen and Pülzl 2018; Giampietro 2019; Kovacic et al. 2020; Giampietro and Funtowicz 2020; Töller et al. 2021), they remain politically and discursively persuasive (Petersen and Krisjansen 2015).

In this note, I claim that the circular bioeconomy concept epitomizes the ontological crisis currently experienced by sustainability science and I reflect on the difficulty of maintaining a fruitful relation between science, policy, and civil society during a radical process of transition. In the next two sections, I first explain my concerns about the official endorsement of the bioeconomy concept by decision-makers. In particular, in "Use and abuse of the concept of bioeconomy", I show that the term bioeconomy has never been properly defined nor agreed upon, neither in the sciences nor in the political realm. In "Nomological impossibility of a circular bio-based economy", I argue that a pro-growth circular bio-based economy—the dominant conception of the bioeconomy in the EU—is a plain nomological impossibility. I then move on, in "The ontological crisis in sustainability science", by explaining that this lack of quality control on knowledge claims used in policies in the sustainability domain is due to the obsolescence of the existing scientific paradigm adopted in scientific inquiry. In "Reflexivity and post-normal science", I reflect on the nature of the problems

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preventing scientific inquiry from becoming more reflexive, which is a necessary step toward solving the current impasse. The final section concludes.

Use and abuse of the concept of bioeconomy

The amount of literature published on the concept of bioeconomy in sustainability science is daunting. Yet there still is no unanimous agreement on the meaning of the term, not in the scientific community, nor in the political arena, nor among stakeholders. Vivien et al. (2019) distilled the following three broad interpretations of the term bioeconomy on the science–policy interface:

1. The bioeconomy seen as the advancement of biotechnology. This interpretation is essentially technology-based, and centers around new business models and innovations based on high-tech production processes involving "green chemistry", such as biorefineries.
2. The bioeconomy seen as a sustainable and circular bio-based economy. This essentially resource-based interpretation, dominant in the European Union, envisions a transition from a fossil-based to a bio-based economic system and "green" rather than fossil-based economic growth, through decoupling (e.g., see imaginary "the great decoupling" described by EEA & Eionet 2022). While this interpretation (in contrast to the first one) acknowledges the need for a change in the business as usual, the envisioned change is expected to reside mainly in the resource base exploited rather than in a redefinition of consumption patterns.
3. The original interpretation of the term bioeconomy, dating back to 1918 when it was coined by Baranoff (Gordon 1954). This conception was elaborated by Georgescu-Roegen (1971, 1977) in the mid-late 90s and is often referred to as Georgescu-Roegen's bioeconomy (Mayumi 2001). In Georgescu-Roegen's interpretation, the bioeconomy is an economy based on activities that respect the limits imposed by nature. In this interpretation, re-thinking the entire economic process is central, including the intensity of exploitation of natural resources (i.e., consumption side) (Giampietro 2019). In the current political climate, this original interpretation of the bioeconomy represents uncomfortable knowledge (as defined by Rayner 2012; Giampietro and Funtowicz 2020; Giampietro and Bukkens 2022), although it has found resonance in the "eco-retreat narrative" (Hausknost et al. 2017) advocated by some civil society movements, such as the degrowth movement (Latouche 2010; Schneider et al. 2010), and the 'Ecotopia' imaginary of a sustainable Europe described by EEA & Eionet (2022).

In this note, I focus on the second interpretation given by Vivien et al. (2019), that of the circular bio-based economy, which, I believe, is the more problematic one of these imaginaries, it being subtly packed and sold as a 'green solution' by decision-makers yet not envisioning any substantial change to current social practices and still supporting the (classic) mantra of economic growth. This interpretation coincides with the 'pro-economic growth' bioeconomy vision (as opposed to the 'pro-planetary limits' vision) recently proposed by Ramcilovic-Suominen et al. (2022).

Note that many other interpretations, imaginaries, narratives, and strategies related to the bioeconomy have been identified (see, for example, Staffas et al. 2013; Pfau et al. 2014; Bugge et al. 2016; Hausknost et al. 2017; Eckert 2021; Dieken et al. 2021; EEA & Eionet 2022).

Nomological impossibility of a circular bio-based economy

In an earlier paper (Giampietro 2019), I have shown that our contemporary economy (operating at high levels of labor productivity and density of material and energy throughput) cannot be circular given the basic principles of thermodynamics and knowledge from the field of non-equilibrium thermodynamics. In brief, all systems studied in sustainability science, including economies, are complex adaptive systems and hence dissipative in nature. In other words, they are systems that preserve their expected identity (and thereby distinguish themselves from their context) by continuously (i) gathering inputs from their environment; (ii) using these inputs to reproduce their structural elements and express expected functions; and (iii) discarding the resulting wastes into their environment. They are, therefore, necessarily *open* systems (Prigogine 1980), feeding on the negative entropy provided by their environment. Within this general conceptualization, the idea of closing the metabolic process of modern economies by recycling their output as inputs (the basic idea of the circular economy)—with the ultimate goal of preserving the current unnatural density and pace of flows—is simply inconsistent with basic thermodynamics principles.

How is it possible that this glaring violation of thermodynamic principles inherent in the idea of "green growth based on a circular bioeconomy" is completely ignored by decision-makers? Is not scientific inquiry expected to control the quality and the validity of the knowledge claims used to inform policy? In the next section, I will argue that science has failed to provide this control because of its reliance on an obsolete scientific paradigm.

The ontological crisis in sustainability science

The concept of ontology is key to my argument and hence I will start with defining it. I base my definition on the work of Winter (2001), who states (p. 587): "In the philosophical tradition, ontology is related to what exists a priori to perception, knowledge, or language. It is sometimes further divided in reality-based and epistemological ontology; the latter describes human conceptualizations of reality (Smith 1999). In knowledge engineering formal ontology copes with (language dependent) knowledge: it is used for 'an explicit specification of a conceptualization' (Gruber 1995) or a 'shared understanding of some domain of interest' (Uschold and Gruninger 1996)."

Winter's distinction between a reality-based ontology and epistemological ontology resonates with the Taoist distinction between, respectively, the *Tao*—the world to which we belong but that we cannot know in all its forms and meanings—and the *Named*—the universe of all the possible perceptions that we can share using representations based on a common language.

Another, similar, but perhaps more familiar definition of ontology—which better suits my argument—is: "A set of concepts and categories in a subject area or domain that shows their properties and the relations between them" (Oxford Dictionary 2022).

Whatever the definition we want to use, it is obvious that before carrying out any scientific analysis, we must have a shared agreement on what type of entities, attributes, or modes we ought to use for obtaining a useful perception and representation of the external world. Note that this choice of ontologies takes place in a pre-analytical step before the scientific inquiry even starts. Obviously, a poor choice will affect the quality of the entire investigation.

In my view, the problem currently experienced by sustainability science lies exactly here. Being essentially a trans-disciplinary endeavor, sustainability science must handle the co-existence of multiple levels and dimensions of analysis, all of which can in principle be used to perceive and represent relevant events in the external world. Hence, sustainability science must simultaneously use different ontologies (Giampietro et al. 2006). The co-existence of different ontologies thus translates into the need to handle non-equivalent descriptive domains, irreducible scientific models, and incommensurable quantitative representations.

To make things even more challenging, the validity of an ontology is extremely difficult to verify when the object of investigation is a complex adaptive system, as is the case in sustainability science. These systems are "becoming systems" (Prigogine 1980), i.e., in constant evolution, and hence require a continuous update of the ontologies used for studying them. Indeed, the validity of any one ontology adopted in scientific research sooner or later expires. An interesting example is the definition of what should be considered "green energy" in Europe (Reuters 2022). More in general, the validity of a scientific inquiry depends on an agreement about the validity of the ontology used to study a given subject area.

In relation to this point, Kuhn (1962) defines a scientific paradigm as generated by "universally recognized scientific achievements that for a time provide model problems and solutions to a community of practitioners" (p. viii, emphasis added). Hence, the pre-analytical choice of an ontology that led to a scientific inquiry that "delivered", should be considered as valid.

Note that the pre-analytical choice of ontologies not only regards scientific inquiry, but also the formation of the identity of modern society. The latter depends on the existence of shared mental configurations, moral principles, ethical rules, and expectations, which are held up by social institutions. As pointed out by Carril (2021), this dual definition of ontologies (one for scientific inquiry and one for the definition of societal identity) can become problematic in the face of a rapid transition; "We live in a globalised consumer culture with an ontology installed and established under the assumption of stability, prosperity and uniformity of nature. It is from these foundational assumptions that we have built the mental order in which we position ourselves in front of reality, in front of the universe, in front of nature, and we build society as perceptions, guides and systems of meaning-making. From these foundational assumptions stem not only attitudes, but the very configuration of the world, its modern institutions and political and economic systems. It is from environmental stability and prosperity that the illusion of progress, of technological mastery, of manifest destiny emerge. The world-system of the culture forged in Western modernity as a whole presupposes such stability, uniformity and prosperity, and from its hegemonic dominance has extended its foundational assumptions to permeate over other cultures and ontologies."

As pointed out by Ramcilovic-Suominen et al. (2022), in all prevailing visions of the bioeconomy these narratives of Western modernity dominate, leaving little space for addressing "multidimensional and intertwined existential and civilizational challenges, including overconsumption, extractivism, and global socioecological inequalities and injustices". This raises the question whether there exists an impredicative relation between the choice of the ontology associated with social identity and the choice of the ontology adopted by scientific inquiry. This fundamental question has been addressed by post-normal science.

Reflexivity and post-normal science

How can we check the validity of the ontologies used by scientific inquiry for informing sustainability policy and who should decide when and how to update them when they are considered obsolete? In answering this question, one should be aware that the validity of the ontologies used in scientific inquiries cannot be scientifically proven. In fact, scientific peer review only deals with the scientific rigor of the analysis and cannot judge the quality of the pre-analytical choices of ontologies. According to the definition given by Kuhn, the "scientific achievements" that led to the acceptance of scientific paradigms refer to solutions given to scientific problems (what he called "puzzle solving") and not sustainability/political problems (Kuhn 1962). The field of biosemiotics is useful to explain this difference.

In biosemiotics, the criterion of "truth" for information is based on its usefulness for guiding action, i.e., an information applied to a system of control is valid only if it can achieve the goal for which it was selected (Pattee 1995). For social–ecological systems, this means that policy action has the goal of preserving and adapting the identity of the self-organizing system. Hence, in science for governance, the quality of the information provided by the scientific community is linked to its fitness for political purposes. But since the definition of the identity and purpose of the society cannot be given by science, a quality check on scientific information necessarily must come from outside the scientific process that generated it, i.e., from those using the scientific information for guiding action.

For this reason, Post-Normal Science (PNS) proposed the idea of "reflexivity" to carry out a quality check on scientific inquiry (in particular, the pre-analytical selection of ontologies) coming from the outside (Funtowicz and Ravetz 1990, 1993, 1994; Funtowicz et al. 1998). Habermas, on the other hand, specifically proposed the idea of reflexivity (in a similar sense to that of PNS) in relation to the validation of the process determining social identity, i.e., the need for a quality control from the outside on the action of political/administrative systems (Habermas 1996). According to Habermas, in modern states, the confrontation between the political power (expressed by institutions) and the moral power (expressed by the civil society) is organized by the democratic process. This process represents a moment of reflexivity in which the society can provide a critical appraisal of the validity of its own master storytelling (ideologies), forms of organization (institutions), and systems of controls (knowledge claims and consequent rules)—used to preserve and update its identity—that are embodied in the operations of the political power. This quality check does not consider each of the individual policies and practices that together make up governance, but rather the overall feelings of the civil society about how these different factors combined (the choices made so far by the political power) have served the common good.

However, applying the process of reflexivity suggested by Habermas to science is not so straightforward:

1. In modern society, science plays two key roles: (i) keeping together the social fabric by legitimating the institutions (i.e., reassuring the members of the society that governments know what they are doing); and (ii) identifying serious concerns requiring a change in ideologies and institutions (i.e., "this is wrong, and it should be changed"). Scientific inquiry can therefore help correct specific choices made by the government but cannot challenge the ontology associated with social identity.
2. Citizens cannot vote on the credibility or the rigor of scientific inquiry nor on the usefulness of its basic ontologies. Particularly in sustainability science, which typically deals with rapidly changing complex systems, it is unavoidable to find large doses of uncertainty and a variety of legitimate but contrasting views about what should be considered as our common good (the desired states associated with societal identity). But even assuming a revolution of the civil society against governments that are not delivering on what is expected (e.g., radical environmentalists demanding more action on climate change), would they have an alternative ontology and alternative anticipatory models for dealing effectively with the problem?

Thus, on the one hand, scientific inquiry should be protected from interferences from the political power and lobbies to preserve its legitimacy, but on the other hand, the civil society can only obtain information about the quality of scientific inputs from the academic community. It is precisely for this reason that the legitimization of the scientific process is based on the acceptance of "scientific paradigms" (Kuhn 1962), i.e., tacit agreements about not questioning the validity of the choices of ontologies used in the various scientific disciplines. This situation has been labeled by Kuhn as a period of "normal science".

We should expect that the reciprocal legitimization between scientific inquiry and political power will fail in periods of rapid transition, as is currently the case, when radical changes of narratives are required, because the gross shortcomings of the scientific paradigm will eventually become evident inside and outside the academic community. But what if the society does not *want* to change its "identity paradigm" (the choice of ontology describing its expected state)? What if the society does not like the results of the policies currently enforced by the government, but at the same time does not want to change its own definition of "common good" (consumer society)? For instance, the

"Ecotopia" imaginary of a sustainable Europe 2050 (EEA & Eionet 2022, see Sect. 2) may not be appealing to all citizens. In this situation, obsolete ontologies in science will remain in place (i.e., neoclassical economics) and systemically generate unreliable scientific advice (i.e., economic growth based on a circular bio-economy) as the political power cannot (or does not want to) detect the flaws in the scientific inputs it is receiving. Such an ontological crisis of sustainability science results into national governments and international organizations trying to save the world using solutions that violate thermodynamic laws, as we are witnessing now.

Conclusion

The popularity of the circular bioeconomy concept in policy-making is symptomatic of a profound ontological crisis in sustainability science, resulting in a systemic lack of quality control on the science–policy interface. Rapid evolutionary changes in our life support systems and current world order imply that we must not only learn how to change as soon as possible existing social practices, but first and foremost, how to change the mechanisms used to control the quality of the production and use of scientific information for governance. The concept of reflexivity is essential in this endeavor.

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Declaration

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