Environmental Science and Policy 109 (2020) 64–72

Contents lists available at ScienceDirect

Environmental Science and Policy

journal homepage: www.elsevier.com/locate/envsci

From elite folk science to the policy legend of the circular economy

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ARTICLE INFO

Keywords:
Circular economy
Decoupling
Life-support system
Policy legend
Uncomfortable knowledge
Post-Normal science

ABSTRACT

This paper explores the implications of the widespread success of the term circular economy in the institutional and public debate. The concept of circular economy in itself implies a logical contradiction: on the one hand, the concept acknowledges the dependence of the economy on biophysical flows; on the other hand, the proposed solution—a business model guaranteeing a full decoupling of the economy from natural resources—seemingly ignores that biophysical processes are subject to thermodynamic constraints. A biophysical view of the sustainability predicament—the flows exchanged between the technosphere and the biosphere — is depicted to show that the idea of a full decoupling is simply due to ignorance of the knowledge generated in (inter)disciplinary scientific fields other than the dominant economic one. The success of economics as an 'elite folk science' is explained by the need of the establishment to ignore uncomfortable knowledge that would destabilize existing institutions. The success of the term circular economy can be seen as an example of socially constructed ignorance in which folk tales are used to depoliticize the sustainability debate and to colonize the future through the endorsement of implausible socio-technical imaginaries. A strategy that can lead to an irresponsible management of expectation: implausible master narratives are impossible to govern. Rather than continuing to impose technocratic plans, as if we knew the optimal thing to do, Post-Normal Science suggests that it is much more effective and responsible to adopt a flexible management approach, exploring the ability of self-organization of social-ecological systems.

1. Introduction

> "*I use the concept 'elite folk science' to explain how a discipline can have functions other than those of the increase of positive knowledge, or the improvement of practice. Such other functions can be in the ideological sphere, providing reassurance for a general world view*" (Ravetz, 1994).

The widespread success of the term 'circular economy' in the institutional and public debate over sustainability marks an important progress. For the first time in history, different and conflicting perspectives on sustainability seem to agree that the economy needs biophysical inputs (energy and material) for its operation and, therefore, generates outputs in the form of wastes and emissions. Indeed, the existence of biophysical inputs and outputs is implicitly acknowledged by the concept of circular economy as both these inputs and outputs are the flows to be circularized.

This positive development is coupled with a disturbing one implied by the adjective 'circular'. Circularity entails that the existence of natural processes—generating the inputs and absorbing the outputs in our interaction with nature and outside of human control—is seemingly seen as an inconvenience that must be corrected by technological innovations, human ingenuity and the invisible hand of the market. More explicitly, the uncontested adoption of the concept of the circular economy points at two worrying misconceptions in the 'official' narratives about sustainability: (1) interacting with (or worse—depending on) nature is an inconvenient feature of the economy that must be revised as soon as possible; and (2) the economy can operate independently of natural processes under the guidance of the market simply by using more and better technology.

According to the widely-used definition provided by the Ellen MacArthur Foundation (Ellen MacArthur Foundation (EMF, 2015): "A circular economy is one that is regenerative by design and aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles. This new economic model seeks to ultimately decouple global economic development from finite resource consumption". This definition is problematic because it is not simple to define what "products, components and materials" have to be preserved and kept at "their highest

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https://doi.org/10.1016/j.envsci.2020.04.012
Received 12 February 2020; Received in revised form 14 April 2020; Accepted 20 April 2020
Available online 06 May 2020
1462-9011/

utility and value" in order to "decouple global economic development from finite resource consumption".

Indeed, this definition raises a number of uncomfortable questions. Should we care only about the products, components and materials that 'circulate' within the economy? Are we (who is 'we'?) capable of identifying all the "products, components and materials" that must be kept at "their highest utility and value" (value for whom?) if we also consider natural processes (e.g., biological cycles) beyond human control? Who defines the utility and the value of natural processes? At which scale and how? Are the economic process and the resulting price signals capable of 'properly' (what is properly?) assessing nature's contribution to 'our' sustainability? These conceptual questions have been around in economics for a long time, and have not only been the focus of intense debate in the field of ecological economics (Giampietro, 2019; Martínez-Alier and Muradian, 2015; Plumecocq, 2014; Røpke, 2004; Spash, 1999), but also among those dealing with the protection of biodiversity (see Section 2).

In this paper, we reflect on the following questions: Can perpetual global economic growth be achieved by keeping products, components, and materials—operating in the *biosphere outside of human control*—at their highest utility and value? Are economic narratives capable of assessing the value of processes beyond human control that we do not even fully understand? Can technology replace these processes when they do not live up to the expected services? If the answer to these questions is no, why are we framing sustainability problems using economic narratives?

The rest of the paper is organized as follows: Section 2 reflects on the reasons of the failure of the various strategies aimed at preserving biodiversity and the limitations of the economic narrative used in the problem framing. It is shown that the approach of ecosystem services is inadequate to describe processes that we do not fully understand. Section 3 provides examples of quantitative storytelling about the interaction of the economic process with its biophysical context to show the 'hypocognition' (Lakoff, 2010) implied in the use of economic narratives. It is shown that the activity of the life support provided by nature (determined by processes beyond human control) cannot be replaced by economic activities because it is by far too large. Section 4 provides a brief overview of the unknown-knowns in economic narratives: the scientific advances that can help explain the challenge of sustainability and the impossibility of a circular economy. Section 5 deals with the momentous challenges facing humankind and the planet and the resulting difficulties for the governance of the transition: the reasons, the mechanisms and the dangers of socially constructed ignorance. Section 6 concludes and reflects on the need to transcend folk science and policy legends by acknowledging the ideological and political nature of the sustainability challenge, and the relevance of scientific advances in the fields of non-equilibrium thermodynamics, evolution and complexity.

2. Reflecting on biodiversity protection

The recent report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, 2019) clearly states that global biodiversity is declining rapidly, and that this should be a major concern to scientists, policy makers and society. In relation to this failure, Díaz et al. (2018) have provided a critical appraisal of the concept of ecosystem services, commonly used to inform policy in this domain, that has sparked a heated debate (e.g., Kadykalo et al., 2019). Although the concept of ecosystem services has yet only occasionally surfaced in the policy domain of the circular economy (Kapsalis et al., 2019; Liu and Côté, 2017; Masi et al., 2018), it is relevant for the framing of our discussion. In fact, Díaz and her colleagues (active in the IPBES) have proposed to replace the concept of ecosystem services—popularized by the Millennium Ecosystem Assessment (Finlayson et al., 2005)—with that of Nature Contribution to People (NCP) in the framing of policymaking to promote sustainability (see also Pascual et al., 2017). In their view, the narrow perspective of the concept of ecosystem services echoes the current economic framing of the sustainability debate and carries the risk of generating hypocognition. Indeed, focusing only on a limited set of services identified by economic analysis—ignoring the diversity of existing knowledge systems and legitimate concerns of other stakeholders—entails the risk of missing other (non-economic) dimensions that are important for sustainability both in the ecological and social domain (Norgaard, 2009).

The biodiversity example is relevant because it deals exactly with the need to identify the 'services' that would have to be replaced by technology in the new circular business model. Is biodiversity included in the set of "products, components and materials" that have to be preserved and kept at "their highest utility and value"? Can the evaluation of biodiversity be carried out using monetary indicators (e.g., virtual prices?). If not, how should we frame its evaluation?

The concept of ecosystem services tends to an epistemic bounding of the perception and representation of biodiversity in predetermined categories: provisioning services, regulating services, cultural services, and support services (Díaz et al., 2015; Norgaard, 2009; Turnhout et al., 2012, 2013). These categories are closely related to the 'useful' environmental functions found in mainstream economic narratives: (1) resource availability for production; (2) assimilative capacity to absorb waste and pollution; (3) direct utility related to the enjoyment of nature (amenity value) (Gómez-Baggethun et al., 2010). Instead, the concept of Nature's Contribution to People proposes a more elaborate and broader framing: first the contribution for humans can be either positive or negative and second, the approach recognizes the need of considering different worldviews, legitimate context-specific perspectives, and relational values (Kadykalo et al., 2019). This necessarily implies a fuzzier and more fluid choice of accounting categories requiring the involvement of local stakeholders to handle the perception and representation of functions that cannot be fully evaluated in monetary terms. For example, it is impossible to quantify the ecological service of 'regulation' with monetary accounting in relation to extreme events and even more so in relation to the 'ordinary' functioning of the life support system, which is obviously priceless. Categories of nature's contribution, such as preservation and adaptation of the life support system escape quantification by default. They are about adding new meanings, purposes and codes to the web of interactions taking place in nature.

Thus, when considering the functioning of an economy embedded in nature, we find a complex network of processes that can be categorized as contributions: (1) of people to people; (2) of nature to people; and (3) of nature to nature (which indirectly contribute to people). The functioning of this complex network is impossible to quantify in general, let alone using monetary valuations. Particularly relevant is the category of contribution of nature to nature that completely escapes the mechanism used to perceive and represent economic transactions. Indeed, this is why human societies developed cultural values defining a 'sacred value' of nature associated with ethical values (Spash, 1999).

3. The hypocognition of economic narratives: the relative size of the economy and its life support system

3.1. Spaceship earth

In 1966, Boulding (1966) used the spaceship Earth metaphor to explain the sustainability predicament. The purpose of the metaphor was to propose a transition from the 'cowboy economy', unconcerned by biophysical limits, to a 'spaceman economy' based on an informed management of limited resources. Boulding's metaphor is a good starting point for the analysis of human dependence (the economy) on Nature's contribution.

The International Space Station, hosting on average between three and six astronauts, illustrates the state of the art in life support technologies. It is a joint program of the space agencies of the USA, Russia, Europe, Japan, and Canada. Normally, every 3 months the International

Space Station receives a cargo of supply (mainly food, material products and special fuels) (Dempsey, 2018). The rocket that brings the supplies is subsequently used to dump the station's waste into space. Note that the station's dependence on the context is not due to a lack of interest in creating a self-sufficient living space capable of recirculating metabolized flows, i.e., a circular space station. On the contrary, in the 1960s, the 'space race' between the USA and the Soviet Union triggered a tremendous research effort in this area. The idea of colonizing other celestial bodies (e.g., the Moon and Mars) and, hence, long interspatial trips posed the challenge of realizing Controlled Ecological Life Support Systems. The Russian BIOS-3 lab, completed in 1972, and the NASA BIOHOME completed at the end of the 1980s, are examples of such research efforts. Many other experiments—the most famous being the Biosphere 2—have been carried out to test the possibility of closing the loop of the materials that have to be metabolized to sustain human activities. None of these efforts has even come close to succeeding, and this deserves a reflection (Battistoni, 2019).

Some important lessons have been learned from these decades of research:

1 Humans are unable to generate a controlled ecological life support system for themselves.
2 A plant-based life support system is problematic for two reasons:
  a An enormous amount of water is required to generate biomass in terrestrial plants (this would be the direct material and the regulation contribution for the life of the astronauts);
  b Maintaining the required level of biodiversity to guarantee a stable biological community is extremely difficult (this would be the non-material contribution to the stability of the life support system).
3 The higher the level of recycling striven for, the higher the energy inputs required from the outside.

What does this mean for spaceship Earth, in terms of the magnitude of nature's contribution to the economy? To get an idea of the dependency of the human food supply on the stability of existing biogeochemical cycles on this planet, a few figures may be helpful. The total amount of exosomatic or non-food energy controlled by humankind in 1999, for all its activities (agriculture, industry, transportation, military activities, services and residential), roughly amounted to 11 TW (1 TW = 10^{12} J/s), equivalent to about 350 × 10^{18} J/year. For maintaining the water cycle only, the natural processes of Earth use 44,000 TW of solar energy (about 1,400,000 × 10^{18} J/year), that is 4000 times the energy under human control (Giampietro, 2003).

The vast proportion of the water going through the water cycle is not directly consumed by the economy, but by the biosphere. This water provides the 'air conditioning of Gaia' (hosting us as guests in her house) and relates to two important 'ecosystem services': climate regulation and water purification. The amount of water required to produce biomass with terrestrial plants is simply gigantic. In terrestrial ecosystems, on average, 570 tonnes of water must be evapotranspirated per tonne of net primary productivity of global terrestrial ecosystems (Xia et al., 2015). Even more demanding is the requirement of water to produce crops (for the material contribution). Water footprint benchmarks for crop production are in the range of 600 − 1,700 tonnes of water per tonne of biomass (Mekonnen and Hoekstra, 2014). Thus, putting things in perspective, human technology is completely irrelevant in the control of the water cycle. The same is true for other biogeochemical cycles, such as nitrogen and carbon.

As for the preservation of biodiversity, the identity of ecosystems—where the niches of species are defined—establishes a link between the requirement of water for biomass, food production and the required external sources of energy needed to power all these processes (Lomas and Giampietro, 2017). Indeed, the processes generating food and energy carriers in the technosphere and the processes recycling water and preserving biodiversity in the biosphere are intricately entangled in what has been termed the resource nexus (Giampietro, 2018). The elements of the resource nexus cannot be studied or tinkered with independently. This means that products, components, and materials operating in the biosphere outside of human control cannot be kept at their highest utility and value for two reasons: (i) humans do not know the entire set of relevant elements, how they work, what should be done for reproducing and helping their adaptation; and (ii) considering the huge differences between the energy involved in stabilizing bio-geochemical cycles and that controlled in the technosphere, humans are completely inept to carry out such a task.

Considering the need for a *life support system,* we find the first elephant in the room missed by the idea that the circular economy can decouple economic growth from the depletion of natural resources: The concept of circularity should include the complex network of primary flows required to sustain the functionality of the biosphere within which the economy is operating (Giampietro, 2019).

3.2. Checking the size of material throughputs: how circular is our economy?

Haas et al. (2015), in a widely-quoted paper entitled "How circular is the global economy", show that neither the global economy nor the economies of developed countries are circular. Their assessment for the EU is based on the following data:

1. More than half of the total solid material throughput, 52 % or 3.5 GT/year, is composed of either food or energy inputs;

2. Only a small share of the material flow, 3 % or 0.7 GT/year, is associated with consumable and durable products;

3. The remaining 45 % of the material input entering the economy is composed of construction materials that become part of the structural components of society.

The authors state that 13 % of the material throughput consumed by the European Union (EU) in 2005—6.7 GT/year—is recycled. According to their analysis, this number refers mainly to the amount of recycled construction materials. However, in their conclusions, the authors report an overall level of recirculation in the EU economy of 37 %. The authors explain that this estimate is obtained by including biomass among the recycled solid flows. This choice is potentially misleading. First, what is recycled in the production of biomass are the nutrients (i.e., nitrogen, carbon, phosphorous) and not the water contained in the biomass (which constitutes a large part). Second, this recycling does not take place within the technosphere but in the biosphere, and therefore it is completely dependent on natural processes providing primary flows outside of human control (the pace and density of which cannot be altered at a large scale). Third, the biomass produced in modern agriculture can hardly be considered a renewable resource resulting from the natural recycling of nutrients. Technical inputs (fertilizers, pesticides, machinery, irrigations) produced with fossil energy (a non-renewable resource) are used to boost the density of nutrients in crop production far beyond their natural values.

Note also that the recycling rates of consumable and durable products, whose estimates differ substantially among materials and countries (Smil, 2013), is generally low, i.e., well below 50 % (Cullen, 2017).

As for construction materials, note that these are integrated into fund elements, such as buildings and infrastructures, for an extended period. Depending on the turnover of buildings and infrastructures, a part of this material flow is eventually recycled, but at different scales and paces. This makes it difficult to assess the recycling rate of this fraction of the material flow in an uncontested way. The issue of the different time scales at which the various material flows are actually recycled is not addressed by Haas et al. (2015) and this generates confusion in the analysis.

However, the most problematic aspect of the assessment of Haas et al. (2015) is represented by the fact that it does *not* consider the flow of water (a different type of material flow) nor the flow of gases. As

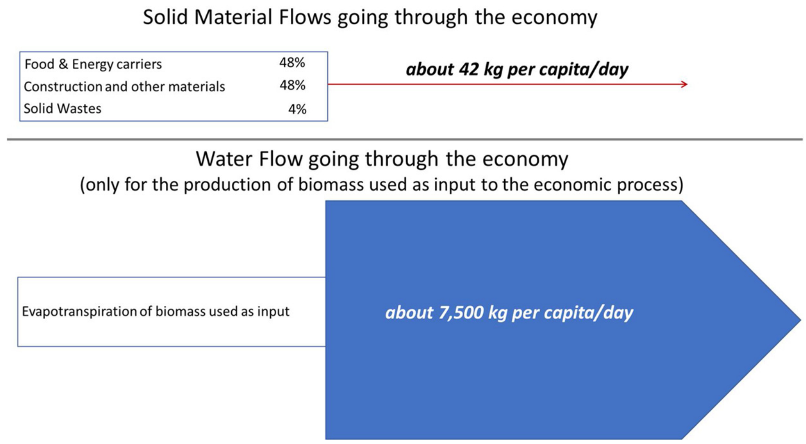

Fig. 1. Putting things in perspective: Material flows in the economy (EU27) without water (on the top) and including water (on the bottom). Gaseous flows are not included.

observed earlier, water plays a key role in stabilizing the functioning of social-ecological systems and the renewable production of biomass both in terrestrial and aquatic ecosystems (Lomas and Giampietro, 2017).

A coarse assessment of the order of magnitude of the material throughput associated with the operation of the EU economy (in 2005) is shown in Fig. 1. The assessment is based on the data on flows provided by (Haas et al., 2015) but also includes an estimate of the flows of water needed to produce the biomass used by society in the material throughput. The assessment of water consumption is based on two types of biomass produced and consumed by society: (i) crops (including food and feed); and (ii) other biomass not used as food (wood, fibers and energy feedstocks). Combining the two earlier assessments of the water requirement per tonne of biomass used by society (see Section 3.1), and adopting a conservative value of 600 tonnes of water transpirated per tonne of biomass consumed (for crops and generic biomass) we arrive at the picture illustrated in Fig. 1. In this representation, only the water used by plants to supply the biomass exploited by humans is included, that is green (natural occurring) and blue (abstracted from aquifers and controlled by humans) water. Other important uses of water, such as urban, industrial and energy use (e.g. hydropower and the cooling of power plants) are not considered. Thus, this assessment is an underestimate of the total water used by the economy.

The top arrow in the figure (in red) visualizes the assessment provided by Haas et al. (2015) for solid material (including the internal recycling) without considering the throughput of water. The lower arrow (in blue), shows that the level of re-circulation in the EU economy becomes negligible (0.005 of the total throughput) when we include the water throughput. The picture shows that the concept of circular economy does not bear any relation to the actual directions and the dimensions of the material flows (including water) going through the economy. A detailed discussion of the divide between the policies and imaginaries used in the EU to discuss of circular economy and thermodynamic knowledge has been provided by (Kovacic et al., 2020).

Note that the critical appraisal of the concept of the circular economy provided here by no means questions the need for recycling. On the contrary, it seeks to guide a more effective approach to recycling through an improved understanding of our interaction with nature and in particular of the closure of material cycles.

4. The unknown knowns in economics: scientific knowledge explaining the biophysical underpinning of the economy

Unknown knowns refer to knowledge claims that are publicly available—e.g., economies are complex adaptive systems that according to thermodynamic laws must be open systems—but omitted in the official storytelling. Indeed, the laws of thermodynamics predict an unavoidable decay for complex systems, and more in general, for the existence of gradients in the material world. The living world, however, seems to defy these laws by providing a variety of entities with a given identity expressing agency—these entities are distinguishable from the environment because they preserve differences with their context.

In his seminal book “What is life?”, (Schrödinger, 1967) provided an explanation for this apparent contradiction, by introducing the concept of negative entropy—something previously considered impossible in classic thermodynamics. The development of the new field of non-equilibrium thermodynamics then introduced the class of dissipative systems: self-organizing systems capable of maintaining identity and distinguishing themselves from their environment (Glansdorff and Prigogine, 1971; Nicolis and Prigogine, 1977). These systems are characterized by a peculiar existential predicament: they can express an identity that distinguishes them from their context, but at the same time they depend on (and alter) the characteristics of their context to express this identity.

A dissipative system is necessarily an open system. Its metabolic process translates into a continuous consumption of useful inputs (and production of useless wastes) for reproducing its structural elements and performing the required functions. In this process, the very activities that sustain the existence of the metabolic system destroy the favorable environment on which it depends. This predicament is more pronounced for metabolic systems that grow in size as well as rate of activity per unit of size (e.g., contemporary economies). A simple dissipative system, on the other hand, such as a tornado or a whirlpool, has a local and ephemeral identity that fully depends on the boundary conditions (Giampietro, 2018).

Thus, when operating at a large space-time scale, complex dissipative systems, such as human societies, must be fast in learning and adapting to changes in boundary conditions to preserve their identity. They must be *becoming* (Prigogine, 1980) and *anticipatory* systems (Rosen, 1985) and be prepared for the *tragedy of change* (Funtowicz and Ravetz, 1994). The rationale of non-equilibrium thermodynamics can be applied to the study of the evolution and sustainability of complex adaptive systems (Prigogine and Stengers, 1981). Since then it has been applied to biological systems, cities and modern societies (Allen, 1997; Broto et al., 2012; Daniels, 2002; Dyke, 1988b, 1988a;Giampietro et al., 2012; Odum, 1971a,1971b; Swyngedouw, 2006; Weber et al., 1988; Wolman, 1965).

Apart from non-equilibrium thermodynamics, which provides a solid theoretical explanation for the impossibility of a circular economy, there are several other scientific insights to improve the quality of the narrative about the functioning of the economy. For instance, the field of energetics, introduced in 1907 by Nobel Prize winner Wilhelm Ostwald, intuited the importance of energy in shaping human society (Ostwald, 1907, 1911). The mechanisms of self-organization, in terms of flows of energy and matter, have been systematically studied by biologists, ecologists (Brooks et al., 1989; Lotka, 1956; Margalef, 1968; Odum, 1971a,1971b; Weber et al., 1988), sociologists (Cottrell, 1955; White, 1943; Zipf, 1941) and anthropologists (Tainter, 1988), to explain the functioning of human societies. A further, remarkable deployment of thermodynamics in economics is represented by the bioeconomics of Georgescu-Roegen, (1971,1975,1977) (Martínez Alier and Schlüpmann, 1987; Mayumi, 2001).

In the 1970s up through the end of the 1980s, following the first oil crisis and the publication of "The limits to growth" (Meadows et al., 1972), the field of energetics gained a certain popularity with the development of accounting protocols of material and energy flows. This period saw an intense exploration of the concepts of energy and food security and, more generally, the relation between energy, society and natural resources (Debeir et al., 1991; Gever et al., 1991; Giampietro et al., 2013; Hall et al., 1986; Hall and Klitgaard, 2012; Leach, 1976; Odum, 1971a,1971b; Pimentel and Pimentel, 2008; Slesser, 1978; Smil, 2003, 2013, 2015,2017, 1991). The ideas generated forged the basis for the concept of *social-ecological systems* that was explicitly coined for the analysis of sustainability (Berkes et al., 1998, 2003; Folke et al., 2010; Gunderson and Holling, 2002; Holling, 2001; Ostrom, 2009).

The 'novelty' associated with the concept of circular economy in orthodox economics—i.e. that the economy is an open dissipative system that requires biophysical inputs and outputs— represents a tall order in relation to the goal of developing a business model supported by a set of technical innovations capable of defying the standard mechanism of self-organization. This challenge could represent an opportunity for economists to discover, explore and integrate the many relevant and useful scientific advances in other fields of knowledge. Among them, the insight that the processes of self-organization and evolution of complex adaptive systems, to which economies belong, can also be studied using narratives and metrics different from those adopted by economics. The vast body of scientific knowledge about the biophysical roots of the economic process could be used to complement economic analysis.

5. Policy legends: protecting the establishment from uncomfortable knowledge

In this section we use the following definitions for the terms folklore, legend and policy legend:

- Folklore: a body of truth verified by repetition and sanctified by faith (Ayres, 1927, p.30);
- Legend: a reflection of folk belief: commonly held values and beliefs in the community in which a given legend exists (Tangherlini, 1990, p.379);
- Policy legend: a historical narrative specific to a time and a place, delivered in a conversational mode, representing folk beliefs or collective experience, and reaffirming the group's common values (Tangherlini, 1990, p.385).

5.1. The mechanism generating the attractor of the ancien régime syndrome

Consider the following set of politically uncomfortable questions: What would have to change in our society if we were to admit that perpetual economic growth is impossible? How should we change the institutions currently controlling the functioning of society if we were to admit that the existing pattern of economic growth is not sustainable? Should we start checking systematically and rigorously the validity of the narratives used to justify and to provide legitimacy to existing power structures?

Questioning the storytelling about perpetual economic growth is not something new. Earlier confrontations took place during the 1970s and 1980s, mainly within the discipline of economics itself. In that confrontation, the majority of economists endorsed the cornucopian view—e.g., "the world can go along without natural resources" (Solow, 1974); while only a small minority of heterodox economists (referred to as Neo-Malthusians) opposed the idea of perpetual economic growth—e.g., Kenneth Boulding's famous quote: "anyone who believes exponential growth can go on forever in a finite world is either a madman or an economist" (United States-Congress- House, 1973). Note that at that time, the divide over the plausibility of a perpetual economic growth was limited to the field of economics; in other scientific fields (representing the unknown-knowns for economists) it was evident that perpetual growth within a finite biophysical world is implausible.

The story is repeating itself today, and we argue that the almost unanimous call by various international bodies (IMF, WB, UN, EU, OECD, FAO) and national governments for "green growth" —whether smart, inclusive or responsible— through strategies of circular economy, bioeconomy, and digitalization, has shaky scientific foundations. In biophysical terms the various strategies are in conflict and compete for the same resources - land, energy, water, minerals (Giampietro, 2018). The belief in the decoupling of economic growth from the use of natural resources through the unlimited power of the invisible hand of the market and human ingenuity—defying thermodynamic laws—should be considered a legend.

Today's legends incorporate beliefs about the supernatural that are consistent with a contemporary world view (Dégh, 1996). Ravetz's (1994) description of the political and social function of an elite folk science can be complemented with Fine and O'Neill's (2010) depiction of policy legends as true and accepted pictures of the world, expressing the values of the tellers and the group. Policy legends are explicitly political and are spread, and socially validated; they must survive in a harsh environment of skeptical questioning and disconfirming information (Fine and O'Neill, 2010, p. 151). This is particularly relevant for the credibility of the circular economy. The legends tend to persist because of their "ability to organize a complex set of environmental factors, which appear to be contributing anxiety and tension to the lives of the individuals concerned" (Crane, 1977, p. 147). That is, a "legend addresses real psychological problems associated with the geographic and social environments, acting as a reflection of commonly felt pressures. However, it is not only fears which are addressed by legends but also desires. They are a symbolic representation of collective experiences and beliefs, expressing fears and desires associated with shared environmental and social factors affecting both, the active and passive tradition bearers" (Tangherlini, 1990, p. 381).

As discussed by Saltelli and Giampietro (2017); Rayner (2012) refers to the exclusion and neglect of readily available knowledge in established scientific disciplines as the generation of *unknown knowns*. The systemic accumulation of unknown-knowns in the master narratives about the sustainability of the economy has led to a situation akin to the ancien régime syndrome: "a state of affairs in which the ruling elites become unable to cope with stressors and adopt instead a strategy of denial, refusing to process either internal or external signals, including those of danger" (Funtowicz and Ravetz, 1994). In this situation, societal deliberations over sustainability are unable to properly discuss the priorities and concerns felt by large sections of society. In such a situation, folklore and legends are deployed in an attempt to keep together the social and political fabric. Elite folk science is used to filter out uncomfortable knowledge so as to cope with the challenges of sustainability. An economics of promises and policy legends are used to promote technological silver bullet solutions attempting to remove messy and conflicting political issues from sustainability debates. The resulting sustainability strategies do not even consider the idea that sustainability entails the tragedy of change, i.e., difficult choices and painful adjustments. Thus, the economics of technological promises requires a massive adoption of folktales providing the justification to impose normative narratives.

5.2. Dealing with socially constructed ignorance

5.2.1. The societal need of filtering uncomfortable knowledge

Uncomfortable knowledge is described by Rayner (2012) as "knowledge which is in tension or outright contradiction with the simplified, self-consistent official storytelling about the world", and therefore, it "must be expunged". Knowledge about the lack of sustainability of the current pattern of economic development is kept out of the discussions over sustainability because it represents a threat to the stability of existing institutions, and the reassurance function of economics as an elite folk science. In fact for a young scientist it is not advisable and even shocking to say in policy circles that: (i) reaching zero emissions for metabolic systems is impossible (open/living systems must breath), (ii) the economic process is entropic and therefore a circular economy enabling perpetual economic growth is impossible (it is the biosphere and not the technosphere that recycles matter, while energy cannot be recycled), and (iii) the existing technosphere has been built on and relied on fossil fuels for over 200 years, and it cannot be completely replaced in 30 years reaching zero emissions while fulfilling all the sustainable development goals (including rapid economic growth in the developing world).

Socially constructed ignorance is not the result of a conspiracy, but rather of the sense-making processes employed by individuals and institutions: "To make sense of the complexity of the world so that they can act, individuals and institutions need to develop simplified, self-consistent versions of that world. The process of doing so means that much of what is known about the world needs to be excluded from those versions, and in particular that knowledge which is in tension or outright contradiction with those versions must be expunged. […] But how do we deal with […] dysfunctional cases of uncomfortable knowledge […]?" (Rayner, 2012; see also Ravetz, 1987 on useful knowledge and useful ignorance). A systematic elimination of uncomfortable knowledge (explanations that would make governance problematic), generalized and institutionalized in time, can eventually produce the ancien régime syndrome.

The concept of socially constructed ignorance (Rayner, 2012) provides an explanation for the poor quality control of the narratives used in the science-policy interface: the folk science associated with knowledge claims, and the policy legends used to frame the discussion over sustainability. Indeed, the narrative that perpetual growth is possible is essential for the stabilization of the social fabric of developed societies (e.g., the lifestyle of urban elites is an unspeakable taboo). Researchers are thus caught in a vicious circle: in order to secure their research funds, they must contribute to the generation of socially constructed ignorance by legitimizing the claims of the circular business model. The high level of demands and expectations placed by urban citizens (the vast majority of the population of developed countries) represents a further serious problem in relation to the goal of establishing an informed discussion over the sustainability of world economy. The combination of abundant fossil energy, a globalized market and acceptance of Ponzi scheme economics (the massive creation of debts in the world economy) has generated a situation in which urban citizens have come to perceive their high level of welfare as a human right. This combination of converging interests has been discussed by Jasanoff and Kim (2015).

5.2.2. Folktales and the depoliticization of sustainability

Daly (2017) eloquently exposed the ideological reasons of the systematic avoidance of biophysical analysis in sustainability research: the generation of uncomfortable knowledge in policy debates related to the following three taboos:

1. *Discussing about redistribution of wealth.* If one admits that there are biophysical limits to the expansion of the economy and that therefore perpetual growth is impossible, then in a globalized world we are dealing with a zero-sum game in terms of the use of available primary sources and primary sinks. This acknowledgement should be followed by a discussion on the re-distribution of wealth within developed countries and between developed and developing countries.

2. *Discussing about population growth and ageing.* If one admits that we moved from an empty world to a full world—as suggested by Daly (1990)—it is extremely important to develop narrative about sustainability in which the implications of the population are considered, both in relation to its size and demographic structure. This is an issue that is extremely complex in practical, political and ethical terms as it involves highly sensitive issues such as immigration and the progressive ageing of the population in developed countries. However, simply ignoring this issue will not improve our ability to handle it.

3. *Questioning the level of welfare of the urban elite in developed countries.* If one admits that there are biophysical limits, that the material standard of living promised by consumerism is not achievable by the entire human population on this planet and that it cannot even be maintained in the future in developed countries due to peak everything and equity issues (we arrived to what Daly calls a full world), we should start re-discussing our definitions and policies about what should be considered as a feasible, viable and desirable welfare.

To Daly's taboos, we can add a fourth:

4. *Questioning the Cartesian dream of quantification, prediction and control.* Guimarães Pereira and Funtowicz (2015) argue that in the current institutional settings, it is simply impossible to admit that we do not know and that, perhaps, it is impossible to know. Historical, ideological and political reasons sustain the belief and the promise of a pure technoscientific solution to the social and environmental challenges facing humanity. Sustainability solutions, thus, 'do not exist'; they must be continuously created in a political process (Funtowicz et al., 1998).

Note that the folktales of the circular economy (zero emissions, and the quick decarbonization in 30 years of the whole world economy while keeping a continuous economic growth) are not sufficient to keep the discussion over sustainability totally depoliticized; we have to add two other folktales: (1) the trickle-down theory – i.e. "a rising tide lifts all the boats" – claiming that as long as you have economic growth, everyone in society will be better off, an argument that has always been controversial (see, for instance, Piketty, 2014), and (2) the assumption of a positive effect of free-trade on the economy of developing countries, another argument that has been openly contested (Reinert, 2007).

Moreover, when considering the nexus between energy, food, water, land uses, ecological services, across different scales and dimensions, the legitimate aspirations of individual countries, the whole planet, present and future generations, can we even dream of *optimal solutions*? Optimal for whom? There is no *transition* from a known state towards another sustainable known state (Benessia and Funtowicz, 2015).

As illustrated by the iconic Post-Normal Science diagram (Fig. 2) we neither have a knowledge based on validated types, nor the possibility of observed established instances. When looking at the future, we can only deal with guessed propensities. If the blueprint age is finished, then we will have to experiment – learning by doing – how to move to

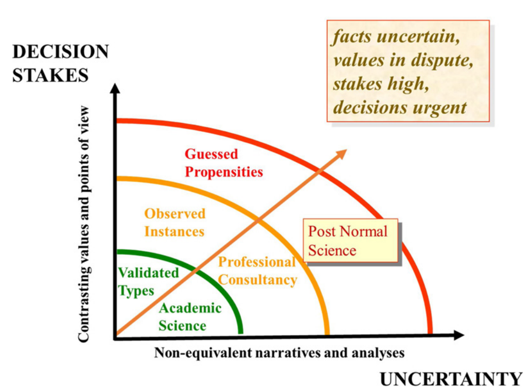

Fig. 2. Post-Normal Science: the need to face the end of the Cartesian dream—as proposed by Funtowicz and Ravetz (1993).

something completely different and new that we cannot even imagine now.

This acknowledgment has important policy implications. Rather than continuing to impose technocratic top-down plans, as if we knew what is the optimal thing to do, it would be much more effective and responsible to adopt a flexible management approach, exploring the bottom-up ability of self-organization of social-ecological systems, through a continuous deliberation over the role of institutional constraints (Benessia et al., 2016).

5.2.3. Are we witnessing an irresponsible management of expectations?

Expectations do play a key role in technological innovations and in sustainability transitions (Lazarevic and Valve, 2017), as “future expectations and promises are crucial to providing the dynamism and momentum upon which so many ventures in science and technology depend” (Brown and Michael, 2003). However, we must consider the dangers of an irresponsible management of expectations:

(i) An aggressive mobilization of expectations about sustainability translates into an endorsement of ideological justification narratives. As noted by (Brown and Michael, 2003) expectations bring futures into being while presenting pathways through which change is to be achieved. Therefore, expectations do political work by mobilizing resources and scripting actions into the present. Expectations can be seen as a strategy to colonize the future. This silver bullet narrative where society is ‘saved’ by smart technologies is reassuring, familiar and wrong. However, in this heroic story “the founding principles of Western patterns of consumption and production remain non-negotiable” and “ecological sustainability … remains firmly subordinated to economic growth” (Fournier, 2008) (p. 530).

(ii) An aggressive mobilization of expectations about sustainability translates into a suppression of criticism and the avoidance of considering alternative narratives, locking-in chosen normative narratives. Once they have attained normative status, assumptions are taken for granted, they neither must be justified nor reflected upon (Bakker and Budde, 2012; Konrad, 2006). The danger here is that the myths underpinning the reference points become naturalized, the result being that space for critical and hesitative reflection diminishes and it is socially discouraged (Buclet and Lazarevic, 2014). The all-encompassing expectations the concept brings together carry persuasive and performative power (Brown and Michael, 2003; Lazarevic and Valve, 2017). For these reasons those proposals perceived as implausible should be deemed irresponsible (Strand, 2012).

(iii) The creation of inflated and unfulfilled expectations about sustainability will generate new governance conflicts. In his book “Cat’s Cradle”, Vonnegut (1963) introduced the term Granfalloon to describe “a proud and meaningless association of human beings” who imagine (or are manipulated to believe) that they are involved in an important mission. The Granfalloon neatly characterizes this situation were inflated expectations are unfulfilled.

The circular economy promises radical technological transformations in a couple of decades, “nothing less than to open up new and immense horizons for industry”, “provide multiple value creation mechanisms”, produce “better welfare, GDP, and employment outcomes” (Ellen MacArthur Foundation (EMF, 2015). Looking at these claims, one wonders whether policymakers really believe that in 30 years EU citizens will live in an inclusive economy with zero waste, zero emissions, with a perpetual economic growth, continuously absorbing massive flows of immigrants while protecting and enhancing the ecological processes and environmental biodiversity.

6. Conclusion

Greek scholars not only described the Earth as a globe but also calculated its circumference from empirical data. In the sixth century A.D., however, many centuries after, the book *Topographia Christiana* proposed a flat Earth supporting the heavens with high walls. This illustrates how, even when better explanations/representations of an external world are available, social systems in their institutions may decide to socially construct ignorance, by adopting a set of simple, manageable and controllable descriptions.

This co-existence of contrasting narratives about the shape of the Earth in the middle ages is a nice metaphor to describe the co-existence of contrasting narratives about the nature of the economy: (i) the narrative of perpetual growth based on a continuous flow of new business models and technical innovations; and (ii) the entropic narrative of the biophysical limits to a perpetual expansion of the economy in a finite planet. At the beginning of the third millennium, an official narrative, ideologically motivated, is endorsed assuming that “a circular bio-economy that will boost economic growth forever” is possible, against the accepted knowledge of non-equilibrium thermodynamics.

Since 1960 both the world population and the consumption of energy and food per capita have more than doubled. A significant part of society has interpreted this as a sign that the Cornucopians were right: if it worked so far and so much, then the strategy of *doing more of the same* is a wise one to get out of the crisis. This belief is reflected in the family of optimistic narratives belonging to the 'yes we can’ class: we should implement an *economics of technological promises* (Levidow et al., 2019) aimed at boosting a green economic growth by establishing a circular bio-economy.

However, if we accept that social-ecological systems are becoming systems that need to continuously adjust to changing boundary conditions, then we must also recognize that an important contribution of science to the process of governance is anticipation. Scientific analyses should focus on holistic explanations of what is not working, what can go wrong, and what can be done to keep the definition of purposes of society aligned with the aspirations of its citizens.

Mainstream economics assumes that there is no need to anticipate problems as they will eventually be solved by ‘invisible hands’ and ‘human ingenuity’. Thus it can only offer a set of normative narratives for sustainability policies based on doing more of the same, such as more globalization and a quicker pace of innovations will maximize the competitiveness of our production processes and achieve a full decoupling of economic growth from resource consumption. These narratives may have had some validity in the past for the economies of the wealthier nations expanding in an ‘empty’ world. At present this proposal only demonstrates lack of understanding of the biophysical roots of the economic process and the seriousness of the sustainability crisis.

A minority opposing perspective, informed by the biophysical roots of the economic process (a sub-components of the biosphere) sees the more than doubling of the population in 50 years and the level of consumption per capita as a reason for concern, and argues that it is high time to open a serious ideological and scientific discussion about the biophysical and political constraints limiting the current pattern of economic growth.

This belief is reflected in a family of narratives belonging to “Houston we have a problem” class (popularized in the movie Apollo 13), suggesting we should start immediately a socially robust and rigorous assessment of the knowledge claims about the political feasibility, viability and desirability of proposed policies, in order to move as soon as possible to a post-growth caring economy.

Author statement

The authors have equally contributed to the conceptualization and writing of the paper.

Declaration of competing interest

None.

Acknowledgement

The help of Bruna De Marchi and Sandra Bukkens is gratefully acknowledged. We also wish to thank Angela Guimaraes Pereira and the anonymous reviewers for their useful suggestions and comments.

This research has been supported by the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 689669 (MAGIC). The Institute of Environmental Science and Technology (ICTA) has received financial support from the Spanish Ministry of Science, Innovation and Universities through the "María de Maeztu" programme for Units of Excellence (MDM-2015-0552). This work reflects the authors' view only; the funding agencies are not responsible for any use that may be made of the information it contains.

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