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Marta Skorek[1]

"The Leaky Boundaries of Man-made States": Post-normal Science as an Approach to Inquiry into the Nature of Boundaries in Environmental Governance

Global environmental governance challenges, such as the climate crisis, ocean pollution, deforestation, desertification or biodiversity loss, are among the most pressing and complex issues in the contemporary world. Both real and constructed, the challenges need to be governed in a multi-level, multi-actor and multi-sector manner. The situation is further complicated by the fact that traditional science has lost some of its credibility due to oversimplified models and simplistic claims, illegal manipulation of information, and the inadequate handling of uncertainty and complexity in the process of making scientific predictions. However, the process of scientific knowledge production may also be approached through the lens of post-normal science (PNS), particularly in the context of complex environmental governance challenges. In connection with this, the aim of this theoretical study is three-fold: to highlight the complex nature of environmental governance challenges, to outline the major tenets of the post-normal approach to science, with special emphasis on the science-policy interface, and to demonstrate the appropriateness of PNS as an approach to inquiry into the nature of boundaries in environmental governance. Primarily intended as an introduction to PNS, the article summarizes the post-normal approach to scientific knowledge production and highlights its relevance to environmental governance challenges through the notion of boundary. For this reason, PNS has not been analyzed through a critical lens, while certain issues relating to its contextualization are beyond the scope of this article.

Keywords: boundary, environmental governance, post-normal science

1 University of Gdańsk, marta.skorek@phdstud.ug.edu.pl.

Introduction

Oh, the leaky boundaries of man-made states!
How many clouds float past them with impunity;
How much desert sand shifts from one land to another;
How many mountain pebbles tumble onto foreign soil
In provocative hops!
Need I mention every single bird that flies in the face of frontiers
Or alights on the roadblock at the border?

Wisława Szymborska, *Psalm* (1976)

As might be expected, boundaries identified in the context of environmental governance may come in various guises: ranging from natural borders (found to exist in nature, e.g. land-sea interface; ocean-atmosphere interface; sea-land air interface (Pyć 2011)), through lines drawn on a map to mark state borders (rarely coinciding with ecological boundaries), maritime zones (United Nations Convention on the Law of the Sea (1982)), and (macro-)regions (Götz 2016; Henningsen 2011), to protected areas (ecosystems mapped for protection) (Spalding et al. 2007). Furthermore, the concept of boundary in environmental governance may also be extended to cover the limits shaping our perception and practices regarding people-environment interactions, including:

- the nine planetary boundaries aimed at creating a safe operating space for humanity (Rockström et al. 2009);
- ecological thresholds (the point or level at which something begins or changes in ecological systems), tipping points (a point at which a system (ecological system) experiences a qualitative change, mostly in an abrupt and discontinuous way), and regulatory limits (decision thresholds or management thresholds) (Jax 2016; Scheffer 2009).

By no means exhaustive, the above list of various boundaries reflects human attempts to conceptualize a fluid, changing and complex environmental setting characterized by trans-boundary and multi-level forms of interaction (Pyć 2011). However, as nature does not respect man-made boundaries (e.g. the water cycle or migratory species), which has been aptly captured in the epigraph to this article, boundaries set in environmental governance need to be kept under critical scrutiny due to their both enabling and constraining effects.

While the former may include creating a safe operating space for humanity through the introduction of the nine planetary boundaries (Rockström et al. 2009), the latter may take the form of a separation between people and nature (the nature-society dichotomy) (Stibbe 2015), which may prove detrimental to the process of integrated environmental governance.

Taking the above into account, this article is informed by Thomas Lundén's view of boundaries as both necessary and negotiable, as "practical necessities rather than holy walls" (2004: 212), as well as Yoshifumi Tanaka's (2004, 2008) dual approach to ocean governance combining both zonal and integrated management approaches, to account for both the need to divide marine space into multiple jurisdictions and the fluid and dynamic ecological interactions and conditions typical of marine ecosystems. What is more, it is based on a close reading of research dedicated to post-normal science (PNS). This is in order to identify its major tenets as well as to provide an overview of research publications exploring the various dimensions which determine whether the post-normal approach may be more aligned than traditional science with the nature of the boundaries to be found in environmental governance. First, the article explores the nature of global environmental governance challenges, then it focuses on the major tenets of the post-normal approach to science, with special emphasis on the science-policy interface. Finally, the article underscores the appropriateness of PNS as an approach to inquiry into the nature of boundaries in environmental governance.

Global environmental governance challenges

Global environmental governance challenges (e.g. climate change, ocean pollution, desertification, deforestation or biodiversity loss), also known as complex sustainability challenges (Folke et al. 2021), represent some of the most complex and interdependent systems of the contemporary world. According to the World Social Science Report 2013, global environmental changes cover all the biophysical changes on the planet's land surface and in its oceans, atmosphere and cryosphere, many of which are driven by human activities (ISSC and UNESCO 2013: 3). Occurring across time and space, these challenges are of a highly complex, interconnected (interrelated), interdependent, and non-linear nature, which requires that they be handled at global, regional, and local levels. The complexity may well be illustrated with land-sea interactions, i.e. the constant interaction between the sea and the land in multiple ways and at different scales, which may take the following forms:

- land-sea processes: natural flows occurring at the land-sea interface (e.g. rivers carrying sediments to the sea);
- cross-system threats: a change in one system (i.e. the land or the sea) having a detrimental effect on another (e.g. toxic substances from industry making their way into the sea and contaminating the water);

- management and policy decisions: our (human) decisions taken with regard to managing both land and marine ecosystems having an overarching influence on the two previous categories (e.g. transboundary river management) (Pittman, Armitage 2016).

Therefore, their governance calls for both top-down and bottom-up initiatives, state and non-state actor engagement, as well as academic and non-academic ways of knowing, which is in line with Jan van Tatenhove's definition of governance as "a society-centered way of governing or steering, accentuating coordination and self-governance, manifested in different types of policy arrangements" (2011: 95). The situation is further exacerbated by the fact that in the context of complex environmental governance challenges "facts are uncertain, values in dispute, stakes are high and decisions urgent" (Funtowicz, Ravetz 1993: 744).

In order to tackle these challenges responsibly, both state and non-state actors need to rely on scientific knowledge that appears to be one of the most important legitimation strategies used in global environmental governance in general, and in climate change governance in particular. In fact, there are "few policy areas in which scientific expertise and data play such a central role; in which claims to scientific rationality are so crucial in justifying political programs and measures (…)" (Steffek 2009: 313). The aim of scientific expertise is to help stakeholders reconsider anthropogenic stressors on the environment and to facilitate their understanding of human-nature interactions by providing information and methodological tools as well as by raising public consciousness (Cortner 2000: 22).

Scientific expertise falls within the framework of authorization that constitutes one of the legitimation strategies proposed by Theo van Leeuwen (2008). The legitimacy for a given approach, procedure or course of action is established on the basis of authoritative claims as well as in reference to the authority of experts or relevant institutions (van Leeuwen 2008: 105). Although there is apparently no need for experts offering advice or recommendations to give reasons, today the authority of experts appears to be waning due to their professional autonomy being increasingly surrendered to policy-making processes and public access to information previously held secret by scientists as well as to a multitude of scientific solutions (van Leeuwen 2008: 107). According to Hanna J. Cortner (2000: 23), science is a social institution that may generate knowledge but may also contribute to regulatory discontent, which has both positive and negative effects.

As the status of scientific knowledge has clearly changed, the following sections of this article explore the transition from traditional to PNS, and highlight the complexity of science-policy interface as well as point to a significant compatibility between PNS and the nature of boundaries in environmental governance.

From traditional to PNS

Characteristics of the traditional approach

Traditionally scientific knowledge has been perceived as an objective, value-free, independent, apolitical and rationality-based practice which prefers technical solutions as first-order solutions (Cortner 2000: 21). The traditional approach to science is reflected in the modern model of legitimation based on the idea of complete separation between reliable and truth-telling science on the one hand, and a subjective and value-laden policy-making process on the other (Funtowicz, Strand 2007). In other words, scientists who are official knowledge producers with a privileged status, provide value-free expertise (usually of a quantitative nature) to policy-makers who formulate policy in accordance with values and preferences (Funtowicz, Strand 2007). However, such an approach separates scientists from citizens and science from the policy-making process, which may also result in undemocratic procedures and outcomes (Cortner 2000: 21). Furthermore, the modern model appears to be inadequate in the event of multiple uncertainties and complexities, including expert disagreement, as well as lack of scientific knowledge or conflict of interest in situations where experts are also stakeholders (Funtowicz, Strand 2007).

According to Cortner (2000: 23), science is a very political practice charged with values held by scientists who not only follow the norms of their respective disciplines but also represent policy communities and institutions who have their own preferences and biases. Since the perceived accuracy of scientific knowledge fails to adequately address its socio-political dimension, it is crucial to dispel universally accepted myths and consider the following issues: arguable claims and results, problem framing, methodological assumptions, selection criteria, scientific model design, and the resultant interpretations involving value judgments made by experts as well as science as a socially constructed practice. Any commonly held misconceptions about the nature of science may generate skepticism toward science or even lead to the collapse of trust in scientific research work and its social role, which undermines its reliability in the public sphere. Therefore, "while [science] may be part of the problem, it must also be a significant part of the solution" (Cortner 2000: 22).

The main goal of PNS

The main goal of the post-normal approach to science is to address the issue of uncertainty and complexity in global governance issues and to ensure the quality of scientific research (Funtowicz, Strand 2007). Although until recently the traditional approach characterized by the rationality of reductionist natural-scientific research has been dominant, there is a noticeable move to a practice of science that manages irreducible uncertainties in knowledge and ethics, and which also recognizes different legitimate perspectives. Furthermore, such an approach to science reflects the workings of a democratic society based on extensive participation (extension of peer communities) and toleration of diversity (Funtowicz, Ravetz 1993: 754). Additionally, the need for transformative knowledge production has been highlighted in the World Social Science Report 2013, which encourages the creation of open information and knowledge systems. Such systems involve collaborative learning and problem solving, multiple sources of expertise generated by both scientists and non-academic knowledge holders who co-design, co-produce and co-implement new knowledge (ISSC and UNESCO 2013: 9).

Complex systems

Global environmental governance issues epitomize complex systems that combine not only environmental but also social, political, economic and cultural dimensions. The inseparability of social and environmental systems and challenges is directly linked to the nature of the environment as a single, complex and interconnected system which has a socio-ecological dimension (ISSC and UNESCO 2013: 4). Due to the complexity of the challenges, there are numerous trans-scientific questions, i.e., questions of fact formulated in the language of science but unanswerable by science, involved in public policy-making (Weinberg 1972: 209). Therefore, complex systems call for a form of integrated science that goes beyond traditional disciplinary boundaries and draws from various scientific fields. This, in turn, would not result in a loss of disciplinary autonomy but instead lead to the joint framing of problems, collaborative design, shared research questions, as well as common methodologies. It would also lead to the joint performance and application of research (ISSC and UNESCO 2013: 5, 12).

Different forms of uncertainty

Typical of the complex systems of global environmental governance and inherent in the construction of scientific expertise, both uncertainty and complexity are two major categories recognized by PNS. There are many sources of uncertainty: knowledge gaps, variability (the inherent randomness of natural systems) or expert subjectivity. Additionally, uncertainty may stem from linguistic uncertainty, communication patterns, and the problematic relationship between the properties of the message emitted and those of the message received (Maxim, van der

Sluijs 2011: 485). It is noteworthy that uncertainty has three dimensions: substantive (the content of the knowledge itself covering problem framing, knowledge production, and knowledge communication); contextual (the context of knowledge production or use, i.e. "when and where" knowledge is framed, produced, communicated or used, and in which socio-economic and political conditions); and procedural (the processes of how knowledge is framed, produced, communicated, or used) (Maxim, van der Sluijs 2011: 488). The knowledge of these dimensions facilitates the identification of uncertainties in the form of imprecision as well as indeterminacies (large-scale uncertainties) concerning the reliability of classification systems (properties or criteria used to aggregate and classify things) (Wynne 1992: 126). However, even if a complete set of uncertainties has been identified, they are often "falsely reduce[d] (…) to the more comforting illusion of controllable, probabilistic but deterministic processes, [which] conceals the dimension of ignorance behind practical policy and technological commitments based on a given body of scientific knowledge" (Wynne 1992: 123). The situation is further complicated by the fact that scientists not only analyze the same volume of data "with different evaluative spectacles", but they also tend to use their theoretical and methodological approaches and commitments to create various sets of "natural" data or facts. As a result, their "normative responsibilities and commitments are concealed in the 'natural' discourse of the science, indicating the fundamentally negotiable definition of the boundary between science and policy" (Jasanoff after Wynne 1992: 125). This means that many relevant moral and social issues are not adequately described, which creates the impression of a "factual" scientific field as separate from a normative one (Wynne 1992: 125). The exclusion of uncertainty from policy-informing science and unwarranted scientific precision may have far-reaching consequences – they may undermine public confidence in science and result in conflicting power relationships (Maxim, van der Sluijs 2011: 482–483). Therefore, in order to account for the role uncertainty plays in scientific research and policy-informing processes, it is crucial to reconceptualize the interaction between natural knowledge and social commitments (moral identities, institutional demeanor, forms of social control) (Wynne 1992: 123–124).

The implementation of the precautionary principle

Since lack of full scientific certainty has gradually become acknowledged in the policy-making process, particularly in global environmental issues, there is a move towards precaution or a preventive approach as an additional policy-making component to address the issue of incomplete science (Funtowicz, Strand 2007). The implementation of the precautionary principle testifies to the acceptance of the inherent limitations of scientific expertise, tackles the issue of shifting the burden of proof to the polluter, and calls for the reshaping of the natural categories and classifications used in the production of scientific expertise. In other words, such a precautionary approach reconceptualizes scientific knowledge in social, moral, and cultural terms (Wynne 1992: 123, 124). According to Principle 15 of the Rio Declaration, the precautionary principle has been formulated as follows: "Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation" (Rio Declaration 1992). The precautionary principle is followed in the event that scientists are aware of the existence of a concrete and specific harm or risk although the scientific evidence available is not yet conclusive to satisfy the full scientific certainty standard (Funtowicz, Strand 2007).

An extended form of participation

Within the framework of PNS, the quality of scientific inputs to the policy-making process depends on the participation of an "extended peer community", i.e. all stakeholders (scientists, policy-makers, and the public) affected by a given environmental governance issue (Funtowicz, Ravetz 1993: 744). In other words, the extended peer community is represented not only by experts holding some form of institutional accreditation but also by all individuals having an interest in the resolution of the issue (Funtowicz, Strand 2007). The aim of this open dialogue is to discuss the quality of scientific evidence and policy proposals according to both scientific criteria and the non-expert knowledge of the world (Maxim, van der Sluijs 2011: 491).

Science-policy interface

While scientific expertise appears to be a prerequisite for solving environmental problems, and policy-makers depend on scientists for the provision of specialized knowledge (Steffek 2009: 313), the intersection of science and policy still poses many challenges. While it is common knowledge that science informs policy-making processes, the reverse may also be true in the event that scientific practices are regulated by policy decisions (Funtowicz, Strand 2007). Furthermore, scientific expertise is very often misunderstood, overestimated, and then institutionalized in policy-making. The science-policy interface usually relies on quantitative data to the exclusion of the qualitative aspects that "illuminate public debate and inform decision-making processes" (Maxim, van der Sluijs 2011: 483). However, the legitimacy and validity of scientific knowledge is contingent not only on its degree of fit with nature (that is negotiable) but also on its correspondence with the social world, which calls for a social discussion on the boundaries and conditions of scientific expertise with regard to social knowledge (Wynne 1992: 127). Although the problematic nature of the science-policy interface consists of a lack of consensus on the causal mechanisms in environmental governance areas, the scientific evidence base or the status of local community knowledge, the limitations of science (incomplete, erroneous and uncertain knowledge produced to meet economic objectives) may be partly addressed by the co-production of knowledge by scientists and users of knowledge (ISSC and UNESCO 2013: 21).

Discourse communities

According to Swales' model of a discourse community modified by Anna Jopek-Bosiacka (2010: 77), it may be characterized by the following: the commonality of public goals, the repertoire of genres, and a special (hierarchical) membership structure. However, in today's complex world drawing a clear distinction between scientists, policy-makers and the public (all relevant stakeholders), appears to verge on the impossible, as will be shown below.

Professional discourse communities

It appears to be virtually impossible to draw a clear line separating scientific communities from policy-makers. Scientists are often perceived as government advisors or even lobbyists working for the government (Saltelli, Funtowicz 2014: 79). Their expertise is either used to legitimate politicians' decisions or disregarded when it runs counter to political aims. Additionally, experts tend to be viewed as political actors who resort to manipulation and shape the public agenda according to their interests (Cortner 2000: 23). It is noteworthy that the traditional division between scientists providing the means and politicians deciding the ends does not correspond to reality, since scientific means usually have non-scientific implications that need to be evaluated in social, moral and political terms. Therefore, the interaction between the scientist and the politician tends to be far more complicated than the traditional model suggests (Weinberg 1972: 209). Although attempts have been made to counteract conflicts of interest by introducing the demarcation model which acknowledges expert bias and specifies the values in action in scientific knowledge production, a clear division between the institutions (and individual scientists) that provide scientific knowledge and those entities that apply it is no longer viable. It appears to be impossible to conclusively separate facts from values due to the complexity and indeterminacy of complex systems that reject "the ideal of isolated scientists having access to a 'God's eye view' [as] unrealistic, and probably undesirable" (Funtowicz, Strand 2007).

The public: extended peer community

The role experts play in the area of global environmental governance cannot be overestimated (Steffek 2009: 316). However, there is a gap between scientific discourse and the language used by lay people, which may pose a serious challenge to efforts of legitimization. Scientists tend to use their own particular reference system and style of reasoning, which confers on them the authority to provide their expertise on environmental issues. However, the discourse used by scientists may result in the exclusion of lay people from environmental governance processes (Steffek 2009: 316–317). It is noteworthy that science is often relied upon to provide arguments supporting specific policies. According to Jens Steffek, "[as] speakers in a discourse, individual scientists and institutions embodying expertise have particular standing" (2009: 317). As the authority of scientists and their claims may also be subject to contestation, other sources of authority, including ethical values, are often invoked to challenge scientific knowledge.

The attempt to assign to the public and scientists completely separate roles: determining goals, and deciding on the means to achieve them, respectively, may result in the marginalization of the public in the policy-making process and in the use of predominantly technical criteria for decision making (Cortner 2000: 25). However, due to its inherent uncertainties, the process of generating scientific knowledge for public policy should be open to an intense social examination of the evidence collected, and to the negotiation of the knowledge construction process, yet without the scientific truth being determined by social choice (Wynne 1992: 126). Such an approach is clearly in line with the model of extended participation based on the idea of an extended peer review community comprised of both expert and non-expert stakeholders. As a result, citizens perceived as both critics and creators are given a chance to evaluate scientific methodologies in the knowledge production process, which may result in quality assurance and the democratization of science (Funtowicz, Strand 2007).

Problem framing

The framing of a governance problem is one of the most important stages in the process of knowledge production. The most common challenges include incorrectly framed analyses, issue mischaracterization or "lamp-posting", i.e., analyzing the least relevant but easiest to analyze uncertainties and parameters (Saltelli, Funtowicz 2014: 84). Furthermore, the issue of problem framing is further complicated by the preference for a technical framing of political problems that are dealt with in isolation from values, human behavior, prevention or open discussion, and solved using technical measures regarded as more "politically palatable" (Cortner 2000: 24). Nevertheless, the framing of a problem involves the selection of safety measures, species, scope of time and place, expert communities and non-expert stakeholders, various viewpoints and even consultation between scientific disciplines. When a problem is incorrectly framed due to an error or poor judgment, it may impair the whole scientific research process. As a consequence, it influences the outcome of scientific recommendation and the resultant policy. However, the acceptance of a given framing approach always entails a certain degree of arbitrariness, constraints related to the selected methodology, and the appropriation of knowledge by science, which may lead to the possible misuse of scientific expertise in the policy-making context (Funtowicz, Strand 2007).

Knowledge communication

One of the major sources of uncertainty resides within communication. Linguistic uncertainty may take the following forms: uncertainty in content (leading to inexact propositional content), epistemic (the degree of belief assigned to a proposition), conditional (the truth of one statement conditional on the trust in another), and inferential (logical inference). Moreover, it may result from the selective use of references from the available scientific literature, disregard for critical remarks, the rejection of knowledge produced by other stakeholders, the use of irrelevant arguments to the issue at hand, and word choice (ambiguity, vagueness, lack of context, overgeneralizations). It may also stem from preliminary results being presented as well-established facts or even the illegitimacy of the sources of information used (Maxim, van der Sluijs 2011: 483, 485). Therefore, it appears to be crucial to communicate scientific knowledge in a manner corresponding to the needs and interests of particular users, as well as to avoid the selective use of scientific expertise or uncertain information to promote favorable outcomes.

PNS methods

The rationality-based approach to science involves reliance on scientific arguments and the verification of knowledge by empirical methods, using models to analyze quantifiable and "unbiased" factual data. Crucial as they may seem, they should also be supplemented by contributions made by other stakeholders who are in a position to question their assumptions and to identify biases and inconsistencies, in addition to the application of experiential knowledge which can be shared by the public (Cortner 2000: 25). Narrowly defined complex problems that are "reduced to manageable proportions" tend to have little relevance in the area of environmental policy-making (Cortner 2000: 26). Another methodology-related problem concerns the reliability of scientific models that are often contested on the grounds of poor modeling practices, model misuse and its negative impact on the policy-making process.

Such models are said to create an illusion of accurate predictions about natural phenomena and to lack transparency, which may significantly undermine the legitimacy of science as a tool for policy-making. Although global governance issues constitute extremely complex systems involving many uncertainties, scientific models are saturated with crisp numbers and targets. Furthermore, they may be challenged due to the many implicit and value-laden assumptions underlying scientific analyses itself (Saltelli, Funtowicz 2014: 82).

Values

Due to the fact that value judgments made in the course of a scientific research process are hidden by scientific jargon, the inherently value-laden aspect of the process is usually overlooked, which eliminates the need for public discussion (Cortner 2000: 24–25). The value-free approach to natural knowledge is reinforced by the discourse of objective natural determination that disregards social, moral and cultural values (Wynne 1992: 127). Since the scientific research process is primarily based on computer models using mainly quantitative methodologies, social values (such as justice, legitimacy, and equality) are not incorporated into the process, which creates the impression of value-free scientific expertise (Cortner 2000: 25). However, it is noteworthy that scientific knowledge may create power asymmetries and confer privileges, which challenges the democratic nature of the policy-making process (Steffek 2009: 313).

Discussion – implications for environmental governance by rethinking its boundaries through the application of PNS

While the post-normal approach to science is not a panacea for all the complex environmental challenges that exist, it nonetheless points in certain directions along which it may be reasonable to look (for sensitizing concepts see Blumer 1954: 7). By integrating uncertainty, complexity, and extended peer communities into the process of scientific knowledge production, it is largely consistent with the fluid nature of boundaries identified in environmental governance, the need to account for different legitimate perspectives, and the concept of social-ecological systems to be studied as an integrated whole (Folke et al. 2016). In other words, embracing the post-normal approach may result in the emergence of a holistic and integrated science as well as a civic and participatory science, one which is suitable for inquiry into the fluid boundaries of environmental governance.

The call for a more holistic and integrated scientific approach recognizes the nature of ecosystems as open, changing, and complex systems whose management requires that all interactions (including human activities) occurring within them be taken into account (for ecosystem-based management see Söderström 2017). Such an approach explores the dynamic interactions of their social, political, economic, biological, and physical features. It also considers human-beings and their values and preferences (social justice, economy, human health, and national security) to be integral parts of ecosystems (Cortner 2000: 26), which is clearly in line with the concept of a social-ecological system (Folke et al. 2016). What is more, the aim of an integrated science which engages experts working across disciplinary boundaries is to "drop the artificial distinction between the biophysical and social sciences and the hard and soft sciences, and speak just of science" (Cortner 2000: 27), which may pave the way for transdisciplinary forms of approaching environmental governance challenges (Finke 2017) or even undisciplinary ones (Haider et al. 2017), where early-career researchers with interdisciplinary backgrounds would work together to address the complex nature of today's sustainability challenges. Apart from scientific models to be assessed in terms of modeling, data acquisition or expert elicitation (Saltelli, Funtowicz 2014: 81), the holistic approach to scientific expertise needs to include multiple sources of knowledge, such as experiential and empirical knowledge, qualitative and quantitative data, as well as observations made by local community members (Cortner 2000: 27). All of the above features of PNS are in line with the nature of complex environmental challenges, whose governance requires an integrated social-ecological systems perspective "emphasiz[ing] that people, communities, economies, societies, cultures are embedded parts of the biosphere and shape it, from local to global scales" (Folke et al. 2016).

The need for the redefinition of global environmental changes as a social problem requires the co-design, co-production and co-delivery of knowledge in open knowledge systems as well as the use of context-sensitive and qualitative social science knowledge about the world marked by its cultural, socio-economic, and intellectual diversity (ISSC and UNESCO 2013: 24, 26). In order to establish legitimacy for their policies, governance institutions are expected to convince relevant stakeholders that their actions are "necessary, morally justified and conducive to [their] welfare (…)" (Steffek 2009: 314). Such an inclusive approach requires that scientists and stakeholders understand how assumptions and outcomes are connected, and how and by whom the information is produced and communicated. Furthermore, it calls for the rejection of pseudoscience, which conceals uncertainties in input data, and for the inclusion of the views held by relevant stakeholders as well as for comprehensible communication patterns (Saltelli, Funtowicz 2014: 83).

The interest in legitimation in the area of environmental governance reflects the move from government to governance (Steffek 2009: 314), where governance denotes a cooperative and non-hierarchical form of political steering, very often engaging both public and private actors (Steffek 2009: 313). Owing to its de-centralized, non-hierarchical, inclusive and flexible nature, the society-centered way of governing may contribute to a successful policy-making process (Steffek 2009: 314). As such an aim cannot be reached in an exclusively top-down manner, it is also crucial to incorporate a bottom-up approach to governance (ISSC and UNESCO 2013: 26). This approach is in line with the call for a more civic science within the framework of which relevant stakeholders are involved at each stage of the research work, where the process of scientific knowledge production involves participatory research designs and democratic deliberation, and grassroots knowledge is given more prominence. Furthermore, the aim of civic science is to "supplement, not replace, the standard analysis of efficient means to given ends with qualitative discussions of the means themselves" (Fischer after Cortner 2000: 27), as well as to ward off the risk of breeding technocracies which – owing to their overreliance on expertise – may change the status of citizens (local communities) from authors of political outcomes to mere stakeholders (Steffek 2009: 313).

Conclusions

The institution of science appears to be in dire need of transformation encompassing holistic and integrated science, meaningful public involvement, collaborative decision-making, and adaptable institutions, as well as the creation of a more civic science (Cortner 2000: 21). Additionally, a clear distinction should be made between the scientist as an analyst and the scientist as an advocate when discussing the issue of the role of scientific advocacy in policy-making processes. Although scientists are community members making value-laden judgments, their primary task is to inform citizens about the risks and benefits generated by envisaged solutions without advocating any particular option (Cortner 2000: 28). Furthermore, the legitimacy of the traditional model based on its strong division between facts and values should be challenged by a new approach to complex system governance "inviting citizens into the co-production of knowledge, and experts into the co-production of politics" (Funtowicz, Strand 2007: 11).

It is of course beyond the scope of this article to determine whether PNS is a new way of doing science or just a sensitizing concept meant to alert us to the existence of certain complex issues (Wesselink, Hoppe 2011). However, the post-normal approach to science is based on several concepts that correspond exceptionally well with the fluid, non-linear and overlapping nature of boundaries that can be identified in environmental governance. More importantly, such an approach to scientific knowledge production and all of its implications may provide researchers with a mission to "take down the boundaries that circumscribe academia, and let the real world in". It also urges scientists to go the extra mile and to "walk over the fence themselves and go out there, where scholarly works end and society starts, where privileged, esoteric reflections do not count but the green spaces that are being suffocated by pollution (…) where the Arctic is melting (…)" (Harper 2016: 100).

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