Construction, co-production and beyond
Academic disputes and public concerns in the recent debate on nature and society

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Abstract

The debate on realism and constructionism has transferred to environment and science studies a long-standing philosophical controversy over the constitution of, and human cognitive access to, nature. Quite lively years ago, the dispute has been gradually sidestepped by approaches that, without merging into a full-fledged theory, counter the subject/object dichotomy and argue about the mutual constitution of knowledge and reality. As earlier, analysis and critique, academic questions and 'public' concerns, are closely intertwined. Co-production scholarship has addressed a number of issues at the crossroads of science and policy, offering a reply to the alleged weaknesses of constructionism. Cutting-edge approaches, with special reference to 'new materialism', are now moving forward, making a case for the liveliness and full agential role of matter. They build on different areas of scientific inquiry, where distinctions between living and non-living, material and symbolic entities are increasingly blurring. They tend, however, also to align with an emergent way of regulating the interface with the material world, which can be ascribed to the neoliberal rationality of government.

Introduction

Nature is one of the most complex, controversial concepts (Williams 1983; Soper 1995; Habgood 2002). Everything there is; what is opposite to culture; the fundamental character of entities. Coming to terms with such messy semantic space is no easy task. Then more questions arise. How do we get to know nature? To what extent and how do cultural frameworks affect our appraisal of the material world? The realism/constructionism debate has transferred to the sociological field a long-standing philosophical controversy, modern signposts of which are Descartes and Kant. Both have a dualistic understanding of human relationship with nature (mind and matter as distinct realms); both believe that mental processes are capable to build a veridical picture of reality, thanks to some sort of correspondence between mental and material states. Yet for the former mind has direct cognitive access to material reality; for the latter we have access only to phenomenal reality, that is reality as filtered by, or shaped according to, our perceptual capacities and cognitive categories.

Quite lively years ago, the realism/constructionism dispute has been increasingly sidestepped by approaches that take distance from both orientations, making a case for the 'co-production' of knowledge and reality, or the mutual constitution of epistemic and ontological states. In its turn, co-production is today increasingly accounted for according to new sorts of materialism. Throughout the debate, which develops at the cross-

roads of environmental sociology and science and technology studies (STS), the stakes are never solely academic. As often in sociology, 'public' concerns (Burawoy 2005) are constantly an issue. Different accounts of materiality and knowledge have performative effects which impinge on social groups, populations, ecosystems or the planet as a whole.

The article proceeds as follows. First, the realism-constructionism controversy is outlined, together with the emergence of a different outlook on the relationship between knowledge and the material world. The following section elaborates on the co-production framework – its similarities with, and differences from, other strands in social theory, and the way it intertwines academic and public concerns. The subsequent section elaborates on 'new materialist' developments in social theory, and confronts them with an emergent rationality of government of the biophysical world. The conclusion dwells on some open questions.

Realism and constructionism in environmental sociology and STS

The first environmental sociologists take issue with the sociological mainstream: its neat distinction between society and biophysical materiality and its almost exclusive focus on the former. To address ecological problems, they say, one needs to overcome this unwarranted divide. Both the 'new ecological paradigm' of Catton and Dunlap (1980), with its plea for a dialogue between social and natural sciences, and the neo-Marxist approach of Schnaiberg (1980), O'Connor (1973) and others, with its case for a reconsideration of the material basis of capitalist society, hold a fundamentally realist approach to cognition: there is a given material reality, of which we can get perfectible yet veracious knowledge, and the conditions of which affect our actual life.

However, an interest in the 'social construction of environmental problems' (Hannigan 1995) quickly emerges. Building on Durkheimian underpinnings, the influential work of Mary Douglas (e.g. Douglas and Wildavsky 1982) holds that different forms of social organization produce different visions of nature, risks and responsibilities. In the 1980s and 1990s many scholars turn to the study of environmental claims in their social dynamics and implications. Radically relativist positions are rare. Constructionists, instead, tend to profess agnosticism in regard to the biophysical aspects of ecological issues (Burningham and Cooper 1999).

As noticed by Hacking (1999), deconstructive analysis of factual claims often aims not only at confuting their alleged objectivity, but also at 'unmasking' their subservience to powerful interests. Thus, the constructionist turn is hardly surprising if we consider that 'public' purposes of social criticism are constitutive of environmental sociology since its beginning (Buttel 1997) – its birth owes much to the emergence of mobilizations against environment degradation and health and ecological 'side effects' of technology. Moreover, a 'social problems' approach allows the application of straightforward sociological equipment of concepts and methods. It is also in line with widespread 'post-structuralist' intellectual perspectives, with their focus on a deconstructive analysis of discourses. Realist sociologists, however, object that, beside and beyond well-known theoretical flaws of relativism (especially the self-contradictory character of the claim that every claim is relative), constructionism forecloses the possibility of an effective

critique of the existing order and its detrimental impacts on the environment and people, since by asserting that all arguments are culturally-dependent it puts their truth-value on a same level (Dunlap and Catton 1994).

Controversy develops in a comparable way in the STS field. Here the rise of constructionism is more directly connected with influential works in history and philosophy of science (Kuhn, Feyerabend, Lakatos etc.), which in different ways undermine conventional realist assumptions. Critical target of the 'sociology of scientific knowledge' (SSK) that emerges in the 1970s is Robert K. Merton's (1942) approach, by which what is suitable to sociological analysis is the life of scientific communities and the extent to which they follow science's peculiar institutional norms[1], but not the actual content of scientific claims. The 'strong programme' of SSK (Bloor 1976) attacks precisely this assumption, holding that scientific facts aren't any different to other cognitive products, being the result of socially negotiated understandings of the natural world. It is therefore legitimate, and indeed crucial, to scrutinize the social conditions affecting the formation of scientists' beliefs. Reactions to this standpoint from the realist side often build on the relativist paradox hinted above: by claiming the empirical validity of their research SSK scholars would forget to apply deconstruction to themselves (Ashmore 1989).

A new wave of studies, however, gradually shifts the focus of the issue. Following the pioneering ethnographic work of Latour and Woolgar (1979), in the 1980s and 1990s the interest of many scholars turns from questions of institutional organization and cognitive content to practices: the concrete activity of scientists. The observation of laboratory life shows that scientific facts are anything but neat evidences emerging from the experimental field. They rather stem from a network of relations, negotiations and compromises which connect technical equipment, biophysical entities, social world, scientists' ideas and interactions. The intermingling of scholars with the materiality of things becomes more relevant than interests, discourses and cultural frameworks. Main theoretical referent of this approach is Actor-network theory (ANT). According to its 'generalized symmetry' principle, all the elements in a network, human and nonhuman, must be treated in the same way, since their differences are produced by, rather than premised on, the relational network (cf. Latour 2005 for a recent restatement). In other words, 'the capacity of human actors to constrain non-human actants [= agents] in technological networks should not be granted higher status than the latter's ability to bind or discipline the former' (Jasanoff 1996, 396). In this way it is possible to take distance from mainstream versions of both realism and constructionism, refusing explanatory precedence to either nature or society. Truth and reality depend on contingent assemblages of heterogeneous entities; the dialectics of resistance and adjustment between people, theories, instruments and experimental phenomena (Pickering 1995). Facts are 'given' precisely because they are 'made'; objects are what, in the

[1] Namely, universalism (claims should be evaluated for themselves and not for those who utter them), communism (research results should be made public), disinterestedness (aspiration to knowledge should prevail over aspiration to power and money), organized skepticism (research results should be scrutinized by the relevant peer community).

artificial framework of the scientific experiment, is given the capacity to 'object', resist to what is said about them by producing 'proofs', 'reliable testimonies' (Stengers 1997).

The co-production framework

In short, 'the further constructionism moves toward the materialist end [of an idealism-materialism axis], the more […] it regards human actors as mutual constructed/constructing the other actors, including texts, graphs, buildings, money and machines' (Dean 1998, 191). The idea of construction changes along the way, morphing into the idea of 'co-production'. It is no longer a matter of premising social facts (institutions, discourses, values, interests) on natural facts, but of analysing the crystallization of knowledge into specific material, organizational, expressive states, acknowledging that 'the ways in which we know and represent the world (both nature and society) are inseparable from the ways we choose to live in it' (Jasanoff 2004, 2).

The term 'co-production' is just one of the many that circulate since the 1990s: cyborg, hybrid, assemblage, mutual constitution, conjoined materiality, and so on. Each of them has different genealogy and semantic nuances. As Sheila Jasanoff remarks, we are not in front of a coherent theory but an idiom, an area of thinking that shares some elements:

> One is the recognition that what we take to be matters of fact about the physical world are significant social achievements that may vary from one historical or cultural setting to another. Another is the understanding that supposedly inanimate technologies – such as genetic engineering, nuclear power plants, space telescopes or computerized databases – actually incorporate social beliefs and practices, such as legal rules or cultural judgments of fairness. Still another is that the capacity to produce particular forms of scientific knowledge and understanding is indissolubly linked with other kinds of social and political capacity (Jasanoff 1999, 67).

In the environmental sociology field the idea of co-production is captured to some extent by the concept of 'coevolution' of social and ecological systems (Norgaard 1997), by which environmental factors affect the fitness of particular elements of social systems, which in turn affect the fitness of particular aspects of ecosystems. Think, for example, of the relationship between availability of oil, development of capacities to extract it and of endothermic engines that use it, and diffusion of liberal values of individual freedom (of movement, enterprise etc.) with their connected lifestyles; or, today, between persistence of these lifestyles, new techniques of extraction of shale gas/oil, and global warming.

There is no denying, however, that STS scholarship holds the front line in the elaboration of the co-production framework. The lack of precise theoretical underpinnings entails for it to intersect various strands in social theory. For example, critical realism advances a stratified account of reality which for some scholar offers valuable grounds for benefitting from both realist and constructionist accounts (Carolan 2005). Critical realism regards the world, as empirically experienced and observed, as a product of human perception and sense-making of events and phenomena, yet the underlying material grounds and causal mechanisms are

assumed to exist and operate independently of human appraisal and speculations. Science is crucial to this account, in the sense that the very possibility of science is regarded as a testimony to the presence of this sort of structure of reality (Bhaskar 1975). For critical realists, moreover, causality is to some extent bidirectional: social relations and culture are rooted in biophysical processes, yet they may backfire on them. For example, people and things can move quickly thanks to the energy contained in oil, yet increased mobility causes pollution. However, if reality is stratified, the ontological status of, and relationship between, elements located in different strata are necessarily asymmetric. The co-production approach, on the contrary, tends to understand reality as a horizontal network of cognitive, normative, social and material elements, none of which has ontological or causal precedence over the others. In this account the layout of cities or the design of cars is a cause of pollution on a same level as our aim to meet friends or need to go to work.

Recent strands in Marxist political ecology can also be connected with the co-production framework. Marx talks of labour as 'a process by which man, through his own actions, mediates, regulates and controls the metabolism between himself and nature. […] Through this movement he acts upon external nature and changes it, and in this way he simultaneously changes his own nature' (Marx 1976, 283). So not only nature but also human nature is a historical product. Building on this insight scholars like David Harvey (1996) and Neil Smith (2010) talk of 'production of nature', in the sense that the natural realm has been increasingly remoulded according to human goals and valuations. Today little, if anything, of the accessible material world survives pristine. Techno-scientific advancement enables an ever-deepening alteration of the properties of nature to intensify its productivity. Think, for example, of traditional selective procedures in comparison with the AquAdvantage™ salmon, genetically modified to grow quicker, reaching market size in 16 to 18 months rather than three years. Yet the idea of production of nature does not completely match the co-production outlook. For Harvey and Smith the engine of nature's historical dynamics is human action. For Latour, instead, agency is equally distributed among humans and nonhumans; nor is it possible to talk of nature and society in general, but only of networks of particular human and non-human agents. For Marxist scholars, moreover, a logic (the logic of capitalism) underlies the production of nature in modern times. Co-production scholarship, instead, usually detects only the immanence of practices that connect entities of any sort, human and nonhuman, material and discursive.

The shift from construction to co-production has significant implications for the connection between academic and 'public' concerns. Similarly to environmental sociology, social criticism or unmasking purposes have been since the beginning relevant to STS, with scholars being often implicated in supporting the weaker (less powerful, credible, authoritative) parties in controversies (Ashmore and Richards 1996). Yet, as the critical atmosphere of the 1960s and 1970s against science's compromises with politics and business fades, STS undergoes an inward turn. Micro-studies of laboratories or the internal dynamics of scientific diatribes gain growing attention, while the broader social and political connections of science shift to the background. Many scholars feel they lack capacity, mandate and interest in public sociology. Even works such as Donald MacKenzie's (1990) study of nuclear missile guidance, where 'accuracy' takes shape at the crossroads of science and politics, offers 'notably less full-blooded portraits of political institutions and

practices than of scientific ones' (Jasanoff 1999, 63). Deconstructive approaches, moreover, are hardly understandable or attractive to decision-makers or scholars trained in 'hard' sciences. What could they do with the apparent reduction of techno-science achievements to a matter of textual interpretations, or with a seeming relativism that places all factual claims on the same footing? The resulting negative stigma leads to repeated attacks – the so-called 'science wars' of the 1990s – from scientists and intellectuals committed to ridiculing the 'post-modern narratives' of science (Sokal and Bricmont 1998).

Simultaneously, however, deconstructive modes are increasingly adopted by corporate interests, to undermine the basis for health and safety legislation. This trend gains salience after the 1992 Rio Earth Summit, reaching its apex under the G.W. Bush administrations. Basically, the strategy is to highlight scientific uncertainty or disagreement to argue that there are no 'sound science' grounds for attributing liabilities or establishing restrictive regulations (Freudenburg et al. 2008). In a number of trials around the world about the harms caused by the exposition to asbestos, vinyl chloride and a host of other substances, the line of defence is to show that protective measures were not taken, or were postponed, because of insufficient or controversial scientific evidence. Equally telling is the contestation of global warming and/or its anthropic origin on the part of individual scholars or, more frequently, corporate-sponsored think-tanks. Evidence collected is obstinately rejected as inconclusive and fostered by a 'danger establishment' of scientists, journalists, bureaucrats, politicians and environmentalists allegedly interested in exaggerating problems or prejudicially adverse to innovation (cf. Lomborg 2001 for an example of this position).

In this context, it is not surprising that prominent voices in the constructionist camp begin to warn against the 'running out of steam' of critique (Latour 2004). The reorientation of a broadening scholarship from constructionism to co-production and the connected reconsideration of the role of matter in social affairs can be regarded also as a reply to such problem. This especially if we consider that, since the mid-1990s, scholarly interests moves 'decisively "beyond the lab" to analyse – in all their messiness, variability, and volatility – the broader dimensions of public engagement with science: […] matters like the downstream consumption and everyday grappling with science and technology; the engineering of communication across epistemic gulfs within "knowledge societies"; and the fundamental intertwining of science, the state, and the market' (Epstein 2008, 166).

The co-production framework, we have already noticed, displaces to a significant extent the realism-constructionism controversy. The establishment of valid knowledge depends on a complex ensemble of scientific and extra-scientific, human and nonhuman, material and ideal factors. Objectivity is a consequence rather than a cause of scientific work. However, this does not happen because of a dominance of the social over the biophysical world, or because the latter can never be accessed in its actual being, but because the material world is ontologically (and not just epistemologically) plastic. There is no single way to describe it because there is no single way in which it gives itself; or, the way it presents itself is related to the way we come or choose to experience it. 'Knowing, the words of knowing, and texts do not describe a pre-existing world [but] are part of a practice of handling, intervening in, the world and thereby of enacting one of its versions – up to bringing it into being' (Mol and Law 2006, 19). The traditional subject/object dichotomy is

replaced by a play of interchangeable roles. Beside ANT and Latour, feminist thinking plays here a major role for its critique of naturalism, essentialism and objectivity (Haraway 1991; Butler 1993). Michel Foucault's concern for the historical dynamics of power/knowledge is also central. For him the alternative between realism and constructionism is meaningless, since 'the types of objects in their domains […] come into existence only contemporaneous with the discursive formations that make it possible to talk about them' (Rouse 2003, 96). Co-production scholarship, moreover, is close to Foucault's view by which power is a property of relations, rather than of actors, and it operates at the micro-level as the capacity to structure the field of action – hence it has a productive, rather than coercive, character.

In the co-production literature academic and 'public' concerns intertwine in at least three different respects. First, co-production means *co-operation between situated knowledges*. The polemic target is the dominant division of labour between experts and laypeople, where the former have exclusive jurisdiction over facts and solutions to problems (Irwin 1995; Wynne 2008). The plea here is for a 'democratization' of science, in the sense that its application to policy issues often requires an extension of the deliberating community to all affected parties and an extension of the facts deemed relevant to anecdotal and experiential evidence.

Second, co-production refers to *variations in the public response* to technoscience. Technological determinism is contrasted with accounts by which technical development is the result of the reciprocal influence of physical, commercial, political, organizational and cultural elements (Bijker 1995). Also, the 'deficit model' of the public understanding of science – by which citizens' frequent distrust and diffidence would be due to their scientific illiteracy and exaggerated expectations – is contrasted with detailed accounts of the way in which the implementation of technologies intertwines with power unbalances, as well as of how people's concern for the rationale and distributive effects of innovation remains largely unaddressed by policy approaches that are typically focused on risk, safety and quality assurance, under the assumption of the generalized benefits of techno-science advancement (Felt and Wynne 2007).

Third, co-production means *science/policy interface*. The aim here is to deconstruct dominant narratives by which the implicit social contract of science entails either that the latter is a direct addressee of, and answer to, policy questions and social needs (so-called 'linear model'), or that at least a rigorous analysis of problems is the exclusive realm of scientific expertise, whatever the policy choices subsequently drawn from such analysis (so-called 'decisionist model'). In the co-production framework, on the contrary, scholars insist that there is a 'continual interpenetration of political choices or commitments and the production of reliable knowledge. […] The state's instrumental goals, the knowledges and practices adopted for achieving them, and the applicable standards of credibility and legitimacy are all constructed together through a unitary process of ordering the world' (Jasanoff 2005, 23). As a consequence, a connection can be established between decision-stakes and scientific uncertainty: the higher the former, the higher the latter, or the degree of certainty demanded for deciding (Wynne 1992). Hence, conflicts are inevitable and cannot be resolved with just 'more science'. On the contrary, 'those who make scientific assertions in fora of public deliberation would have to accompany those claims with a statement of value preferences and private interests relevant to the dispute' (Sarewitz 2004, 400).

A new ontology of nature and society

To sum up, co-production scholarship regards its innovative accounts of the constitutive link between society and nature, human and nonhuman agency, as capable to circumvent many criticisms addressed to constructionism, from both an academic and a 'public' viewpoint. As for the latter, if deconstructionist narratives are used by reactionary arguments against ecological threats, if appeals to uncertainty become means to rebut adversary positions, and if unwelcome scientific claims are delegitimized as partisan positions, co-production scholars purport a 'post-constructionist' sort of realism, which rejects the idea of truth as correspondence to an immutable world but rejects as well the idea that language or discourse is the constitutive feature of phenomenal reality. Such realism may arguably provide valuable assets, for example, against the 'organization of denial' (Jacques et al. 2008) of climate change, with its flimsy arguments about the lack of evidence of global warming or its anthropic causes.

Things become trickier, however, if we look at two recent intersecting processes: the further evolution of the co-production framework into a full-fledged 'new materialism', and the emergence of a novel way of governing the interface with the material world. In regard to the former we can focus on feminist scholarship, since it offers a prominent case for the agential power of humans as counterbalanced or even overwhelmed by the capacity of nonhuman nature to 'resists its incorporation into particular political-economic spatial forms' (Braun 2008, 668).

Introducing a collection of essays devoted to 'new materialisms', Diana Coole and Samantha Frost remark that 'everywhere we look […] we are witnessing scattered but insistent demands for more materialist modes of analysis and for new ways of thinking about matter and processes of materialization' (Coole and Frost 2010, 3). The underpinnings of this move are twofold. First, 'new physics and biology make it impossible to understand matter any longer in ways that were inspired by classical science' (Coole and Frost 2010, 5), overwhelming 'the ability of cultural theorists to critically digest and engage them' (Kirby 2008, 7). Second, this poses ethical and political questions in front of which 'the dominant constructivist orientation to social analysis is inadequate' (Coole and Frost, 2010, 6). Feminism has successfully challenged all sorts of appeals to the facticity and prescriptiveness of nature. Yet nature is not necessarily 'a repository of conservative political investments' (Kirby 2008, 8). Matter is anything but 'inert, stable, concrete, unchangeable and resistant to socio-historical change' (Hird 2004, 224). On the contrary, it exhibits agency, inventive capacities, generative powers. Matter is 'not a thing but a doing' (Barad 2003, 822); an incessant process of becoming. Texts and signs can also be reconfigured as 'substantively or ontologically material. […] "Life itself" is creative encryption' (Kirby 2008, 9); a continuous rewriting of itself.

In this context, more than the co-production of world and knowledge, one is confronted with a farewell to any distinction between observed and observing agencies, things and words, ontology and epistemology. Karen Barad's 'agential realism' is exemplary of this view. She regards phenomena as 'the ontological inseparability of agentially intra-acting components. That is, phenomena are ontologically primitive relations

– relations without preexisting relata' (Barad, 2003: 815). Phenomena, in other words, are not representations of things but things as such. Simultaneously, we are confronted with the reversal of a long-standing view by which social criticism had to focus on discourse, as the crucial field of the struggle for domination and emancipation. Indeed the case is made for replacing the traditional approach to critique, with its ultimately ineffective focus on 'errors and points of contention' (Grosz 2005, 27), with affirmative standpoints that build on thingness and corporeality. These are to be regarded as sites of resistance, creativity and hope, ethically relevant in their being the result of choices that materialize particular states of reality. In the words of Claire Colebrook,

> Nature, far from being that timeless essence that might once have been used to halt human liberation – in claims, say, that women are naturally passive – is actually that which can introduce dynamism and radicalism into claims regarding what may or may not be human. Once nature is accepted as a dynamic, active, and unpredictably open, we have arrived at a liberating anti-humanism (Colebrook 2008, 74).

Again, as we can see, academic and 'public' issues appear intertwined. Compared with ANT and similar approaches, however, new materialism provides the fluid, ever-changing character of matter with a more 'solid', 'foundational' aspect. 'It is difficult to imagine Bruno Latour, or those in his orbit, speaking of nature as a ground', remarks Nigel Clark (2011, 45). Actually, in several cases – which include feminists (Hird 2009), sociologists (Clark 2011) and philosophers, especially the emergent field of 'speculative realism' (Bryant et al. 2011) – we are confronted with a departure from the trademark symmetry principle of the co-production framework, towards the acknowledgment of a radical asymmetry in the relationship between humans and nature, the active existence and incessant becoming of the latter (from bacteria to geological processes, to humans' own bodily existence) being depicted as independent of, indifferent to, or overarching human appraisal and action.

Yet more can be said if feminist new materialism's blurring of ontology and epistemology is put in a broader perspective. In a sense, we can regard it as a last step in a century-long path. This path includes physics, with Heisenberg's indeterminacy principle (observation and physical state of particles, their position and momentum, are not independent); economics, with Keynes's notion of 'personal probabilities' (the subjective estimates on which entrepreneurs base their decisions); and statistics, with Leonard Savage's approach to probability in terms of the agent's state of knowledge. These developments, however, did not touch the modern tenet by which uncertainty or indeterminacy constitute a limiting factor for human agency. The rise, in the second half of the 20th century, of the themes of complexity, chaos and non-linear dynamics in physics, chemistry, biology, meteorology, economics, computer science and so on, has strengthened this view, which resonates also in risk governance. Major controversies and regulatory failures (agricultural gene technologies, electromagnetic fields, food scares etc.) paved the way to the 'precautionary principle', for which inconclusive scientific assessments of unquantifiable threats should not prevent from deciding on urgent issues, and to the recognition of the need to handle consensually the divergent meanings and

perspectives often associated with such threats (cf. Stirling 2003 and IRGC 2008 for an advanced version of this approach). Current risk governance approaches, in other words, regard precaution and inclusion as replies to the *problem* of uncertainty or indeterminacy.

It is against this background that the novelty of new materialism can be appreciated in full. New materialism does not regard indeterminacy as constraining non-determinability, but as enabling non-determination. Indeterminacy, ambivalence or contingency, in other words, take a positive, emancipatory connotation; they are opportunities, rather than problems. What is remarkable, then, is that this outlook matches an equally innovative way of addressing the interface with the material world that has gained salience in recent years. A few examples may clarify the point.

First example is carbon trading, as flourished especially in the framework of the 1997 Kyoto Protocol on climate change. The possibility of markets in permits to emit greenhouse gases (GHGs) or in credits earned by not emitting them rests on the operators' acceptance of a conversion rate between CO_2 and other GHGs: the 'global warming potential' (GWP), as established by the International Panel on Climate Change (IPCC)[2]. Reducing one's CO_2 emission or buying credits sold by someone else who, somewhere in the world, is reducing another GHG is assumed as equivalent – physically, thus also financially (MacKenzie 2009). Therefore GWP is an abstraction, like money, since it works as an exchange rate. Yet it is also something bound (not) to happen in the atmosphere, an (allegedly) prevented physical thing or phenomenon. In short, GWP is an ontologically indeterminate entity, oscillating between reality and virtuality, matter and symbol, concreteness and epistemic construction.

The second example comes from biotechnologies. Patenting biological matter was forbidden until 1980, when in a crucial ruling the US Supreme Court stated that a genetically modified bacterium is human-made, that it is a new 'composition of matter', and that whether an invention is alive is legally irrelevant[3]. By regarding a living entity as an artefact if its basic functional parameters can be controlled (thus reproduced), biotech patents establish a correspondence between information and matter, so that rights in property over information can be subsumed into rights in property over the organisms incorporating such information, and vice versa (Carolan 2010). Again we are in front of ontologically ambiguous entities, oscillating between materiality and virtuality. A further ontological ambiguity stems from the claim that patented artefacts are indistinguishable from nature for any practical purpose (including the need of specific regulation). Artefacts are thus simultaneously identical to and different (more usable, more valuable) than natural entities.

Similar ambivalences can be found in the so-called 'data-driven' research. Emergent techniques of biometric profiling, for example, apply algorithms that associate huge amounts of data, often of disparate character (biological traits, behaviours, places, events etc.), generating unforeseen knowledge (Amoore 2009).

[2] For example, the GWP of trifluoromethane (HFC-23) is 11,700. This means that one tonne of HFC-23 is equivalent to 11,700 tonnes of CO_2. However, estimates of the atmospheric effects of different GHGs include significant amounts of speculation.

[3] This approach has spread worldwide via the WTO's agreements on intellectual property rights.

Fundamental research in biology is also increasingly driven by data mining and processing (Calvert and Fujimura 2011). The status of this knowledge is tricky. Does it belong to the realm of discovery (of previously unnoticed relationships within the data) or of invention (of meaningful associations among data)? And is it just knowledge, or the production of reality – for example a forthcoming disease?

We may ask why these ways of performing techno-science have developed now, and if, as it seems, they share some inner logic. The answer cannot but consider that recent years have witnessed a generalized institutional change in neoliberal direction (Baccaro and Howell 2011); a shift that represents the unifying trait of the host of social, political and economic transformations often synthesized with the word 'globalization'. Actually, neoliberalism deploys a particular rationality of government which, as Pat O'Malley (2004) and other scholars have documented, departs from the modern understanding of risk and uncertainty. Calculations of risk become the exception, while reasoned bets over unpredictable futures are the rule. Uncertainty is premised on entrepreneurial creativity, which requires intuition, foresight, flexibility, experiential judgment, rules of thumb and so on. In this picture – precisely as with new materialism – indeterminacy does not mean constraining non-determinability, but enabling non-determination (Pellizzoni 2011). Turbulence and contingency, as produced by global trade, innovation-based competition, floating exchange rates and ecosystems dynamics, do not mean uncontrollability, but lack of limits, room for manoeuvre, opening up of possibilities. Rather than paralyzing, the eventuality of future, or the subjectivity of expectations, enables the construction of purposefully designed task environments where new opportunities take shape. Life is accounted for in terms of complex adaptation and emergence, a condition which enhances danger and insecurity but is also 'at the heart of what is positive and constructive' (O'Malley 2010, 502).

Conclusion: open questions

New materialist elaborations of the co-production approach build on a sort of 'post-constructionist' realism which seems to represent an eventual, somehow pacifying outcome of the realism/constructionism diatribe, with the profound divisions it has entailed between natural and social sciences and within the social sciences. Even people's engagement in the public sphere, traditionally regarded as a fully discursive phenomenon, is now increasingly scrutinized in terms of material conditions and influences, as related to settings, technical devices and things of any sort that play a role in the enactment of participation (Marres and Lezaun 2011).

However, the end of the story is likely not in sight yet. New materialists might be too eager to embrace the accounts of nature provided by cutting-edge physics, biomedicine, life and earth sciences, with their tendency to blur distinctions between natural and technological, material and immaterial, organic and inorganic stuff (Keller 2011). In their effort to disentangle themselves from constructionism, they seem to downplay the symbolic, metaphorical content of scientific insights. As Judith Butler remarks, 'encryption can be used as a metaphor or model by which to understand biological processes, especially cell

reproduction, but do we then make the move to render what is useful as an explanatory model into the ontology of biology itself?' (quoted in Kirby 2008, 10).

Being too quick in abandoning critique, also, is not necessarily a good idea, if we just reflect that, outside particular intellectual settings, constructionism is far from hegemonic. 'The forms of naturalisation are continually changing, [but] naturalisation, as a key cultural pattern of projection, has not stopped' (McNeil 2010, 434). More generally, in current power games over the biophysical and social world realism and constructionism, appeals to the stability of nature or to the plasticity of human encounters with the biophysical world, increasingly take the shape of tactical moves chosen according to circumstances, rather than strong intellectual standpoints (Pellizzoni 2011)[4]. In the public sphere, therefore, new materialist arguments run the risk of being captured by positions that they do not necessarily support (and indeed often explicitly oppose). This is precisely the issue, pointed out in the previous section, of the convergence between new materialism and the neoliberal approach to the biophysical world. Admittedly, neoliberalism understands human agency as expansive and appropriative to unprecedented levels, whereas new materialism regards it as humble, defective and respectful in its encounters with the world. However, the idea of an incessant becoming and the emphasis on ethical commitments are undeniably aligned with the neoliberal case for an unlimited production of reality and for a replacement of contentious politics with an 'active', 'responsible' citizenry (Pellizzoni and Ylönen 2012). The risk of capture, therefore, is anything but remote.

In posing these questions one has not necessarily to focus only on new materialist ontologies. Other topics or perspectives are of no lesser interest. For example, the case for public participation in policy-making – a key tenet of co-production scholarship, as we have seen – is now facing a sort of 'democracy paradox' (Lövbrand et al. 2011), by which the institutionalization of deliberative arenas in environment and techno-science fields is regarded with growing scepticism by many of its original supporters (Felt and Wynne 2007; Felt and Fochler 2010; Irwin et al. 2013). This scepticism includes not only the way problems, tasks and solutions are produced and allocated, but also the materialization, within deliberative settings, of physical realities ('genes', 'nanomaterials', 'climate', 'energy reserves'…) and involved publics ('consumers', 'the nation', 'people all over the world', 'future generations'…). Similarly, the ambiguity of 'green' policies which, as in the case of biofuels and carbon markets, often entail the alignment of organized environmentalism with government and business, is a matter of growing concern (Rutherford 2007; Blok 2011; Levidow et al. 2012). Furthermore, the extent to which new mobilizations (local protests, critical consumerism etc.) constitute effective challenges to neoliberal rule, resisting capture by its depoliticizing logic, remains an open question – think, for example, of how scientific arguments and ethical commitments become increasingly relevant to oppositional actions (Drake 2010; Ottinger 2010; Pellizzoni and Ylönen 2012).

[4] Just think of the uses of the precautionary principle. Still a favourite of environmentalists and techno-sceptics, it has been applied to justify 'preventive wars' ('if we wait until we'll be sure about intentions of attack, then it will be too late'), and, as hinted above, is implicit in corporate 'sound science' arguments ('we should not take restrictive decisions that could turn out wrong in the future'). So today precaution can be invoked in support of any sort of action or inaction.

As one can see, intellectual elaborations and political implications, academic and 'public' concerns, intertwine once more in social science outlooks on the relationship between humans and the biophysical world. The exercise of critique has become more difficult and insidious, but probably more needed than ever.

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Short Biography

Luigi Pellizzoni is an associate professor in Environmental Sociology at the University of Trieste, Italy, where he also teaches Sociology of participatory processes. Teaching appointments include Sociology of Science at the International School for Advanced Studies (SISSA), while scientific appointments include lectures, keynote speeches, collaborations, and visiting scholarships at various institutions (European Commission DGResearch;World Health Organization; Ecole des Hautes Etudes en Sciences Sociales (EHESS), Paris; Centre for the Study of Environmental Change, Lancaster University, UK; etc.). He is presently in his second term at the European Sociological Association (ESA)'s Executive Committee. He has a long research experience in international projects (European Commission's FP IV, V, VI, and VII and Interreg programs, etc.) on environmental and technoscientific issues (GMOs, electromagnetic fields, food risk, chemical, nuclear and natural hazards, etc.), social conflicts, and public participation. In the last years he has been especially committed to addressing the environmental and technoscientific underpinnings and implications of the 'neoliberalization of society'. Recent publications include: Neoliberalism and Technoscience. Critical Assessments. Farnham: Ashgate, 2012 (editorship, with Marja Ylönen); Conflitti ambientali. Esperti, politica, istituzioni nelle controversie ecologiche. Bologna: Il Mulino, 2011 (editorship); 'Strong will in a messy world. Ethics and the government of technoscience'. NanoEthics, 6 (2012); 'In search of community. Political consumerism, governmentality and immunization'. European Journal of Social Theory, 15 (2) (2012). 'The politics of facts. Local environmental conflicts and expertise'. Environmental Politics, 20 (6) (2011); and 'Governing through disorder: Neoliberal environmental governance and social theory'. Global Environmental Change, 21 (3) (2011).

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