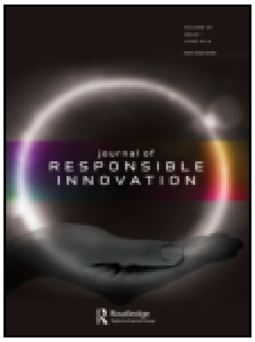

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RESEARCH ARTICLE

Responsible research and innovation: building knowledge arenas for glocal sustainability research

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In knowledge economies, the prevailing belief is that research and innovation are crucial for societal progress. The call for 'responsible' research and innovation is, however, an indication that the link between science and technology on the one hand and societal progress on the other is less unequivocal than many would like to think. This article wonders why the relationship between knowledge economies and 'responsible' research and innovation is not self-evident. It, consequently, proposes glocal sustainability research (GSR) – and an appropriate process architecture for GSR – as a translation of responsible research and innovation (RRI) and it suggests a type of knowledge arena – and some institutional preconditions for its institutionalisation – as a breeding ground for RRI.

Keywords: responsible research and innovation; knowledge economies; glocal sustainability research; knowledge arena

Introduction

The European Commission pleads for responsible research and innovation (RRI) in order to respond more effectively and urgently to the grand societal challenges, such as climate change, ageing population, food, water, materials and energy safety, public health, and security (European Commission 2013; von Schomberg 2013, 51–74). Why this plea? In the first part of this article, this call for 'responsibility' is linked to the observation that the sustainability performance of knowledge economies leaves, indeed, much to be desired and this despite the fact that knowledge economies dispose of huge amounts of scientific knowledge and technological know-how. It, consequently, looks for possible reasons for this astonishing observation. In the second part, it provides some preconditions for research and innovation systems to become 'responsible', namely (a) taking local needs, values, and opportunities as starting points to consider which combinations of new and old disciplinary and practical knowledge and know-how are appropriate to respond effectively to local manifestations of global challenges and (b) checking whether this normative content complies with global ethical principles of strong sustainability, equality, and a-growth, for example, as defined in the Open Working Group proposal for Sustainable Development goals (http://sustainabledevelopment.un.org/sdgsproposal, consulted 15/12/2014). Finally, it puts a particular type of knowledge arena (Cornell et al. 2013, 60–70) forward as a breeding ground for RRI.

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The sustainability performance of knowledge economies

Sustainable development became a global challenge as a consequence of human overconsumption. This overconsumption is due to globalising industrial and industrialising economies that are founded on a coercion for rapid monetary growth (Lietaer et al. 2012; Rees 2006, 220–225), but also on dominant sociocultural norms and expectations of late-modern 'developed' and 'developing' societies. Sustainable development will, hence, only be feasible in case (1) industrial and industrialising economies drastically reduce their use and consumption of natural resources, (2) nations are prepared to a fair distribution of their welfare, both nationally and internationally, and (3) citizens develop a new vision on human and planetary well-being (Peeters 2012, 287–298). In the words of Hans Bruyninckx, director of the European Environment Agency: 'The concept of a green economy requires us to reformulate fundamentally the way we produce, consume and live in a way so that our economic activities do not harm human health and the environment' (Bruyninckx 2014).

Globalising industrialised and industrialising economies do not, indeed, perform very well with respect to sustainable development, or according to its ecological or its socio-economic dimension (Rees 2006, 220–225).

Knowledge economies' ecological dimension

According to the European Environment Agency, total use of natural resources and production of waste increased by 34% between 2000 and 2007 and these increases are related to economic growth and increasing welfare. These increases have a considerable economic and ecological impact. Since easily accessible stocks nearly get exhausted, Europe is forced to seek mineral stocks that are less concentrated and less easy to access and fuels with a lower energy content. This implies that it can be expected that mining and use thereof will have a higher ecological impact per unit of produced material or energy. Since, finally, nearly 20% of the resources used within Europe are imported, it is exporting countries and regions that will to a considerable extent experience the ecological impacts of European consumption.[1]

Knowledge economies' socio-economic dimension

The socio-economic sustainability dimension is not very promising either. A report of the OECD mentions an increase of poverty and inequality in two-thirds of OECD countries (OECD 2011). Andrew Simms observes:

> During the 1980s, for every $100 added to the value of the global economy, around $2,20 found its way to those living below the World Bank's absolute poverty line. During the 1990s, that share shrank to just 60 cents. This inequity in income distribution – more like a flood up than a trickle down – means that for the poor to get slightly less poor, the rich have to get very much richer. It would take around $166 worth of global growth to generate $1 extra for people living on below $1 a day. (2008, 49)

A systematic replacement of human labour – another form of 'natural' capital – with technologies implies moreover that it becomes for an increasing number of people ever more difficult to find an attractive and inspiring job (Skott and Guy 2007, 124–131). Technological innovation does not seem to fit easily with the creation of jobs. On the contrary, further automation is blamed as being a main cause for increasing unemployment. This relationship has been put forward since the 1930s, but it only started to be taken seriously since the 90s – with the introduction and rapid spreading of computers (Rommetveit et al. 2013, 74–75). Brynjolfsson and McAfee (2011) argue:

> In each case, economic theory is clear. Even when technological progress increases productivity and overall wealth, it can also affect the division of rewards, potentially making some people worse off than they were before the innovation. In a growing economy, the gains to the winners may be larger than the losses of those who are hurt, but this is a small consolation to those who come out on the short end of the bargain.

Brynjolfsson and McAfee (2011) distinguish between three sets of winners and losers: high-skilled versus low-skilled workers, 'superstars' versus everyone else, and capital versus labour. They argue:

> Each set has well-documented facts and compelling links to digital technology. What's more, these sets are not mutually exclusive. In fact, the winners in one set are more likely to be winners in the other two sets as well, which concentrates the consequences.

Science's role in knowledge economies

In knowledge-based economies, organised knowledge production adds a coordination mechanism to the social system of societies, in addition to economic exchange relations and political control. The triple helix of university, industry, and government shape each other's expectations (Leydesdorff 2010). This entanglement of the science and innovation community with industry and government easily runs counter to researchers' critical distance from dominant beliefs and practices.

Confronted with grand challenges on the one hand and societal controversies on the other, evidence-based policy-making has not only, over the last decade, become a catch-cry and aspiration of governments. It also emerged as an academic movement which seeks to focus on 'what works' and so try to avoid the pitfalls of policy driven by ideology or values (Courtenay Botterill and Hindmoor 2012, 367–379). However, this urging for evidence-based policy overlooks that 'evidence-based policy' in fact often comes down to 'policy-based evidence' (Rommetveit et al. 2013). 'Knowledge is produced and projected in accordance with Society's perceived needs, and so a direct extension of power' (Lietaer et al. 2012; Rommetveit et al. 2013). Moreover, implicitly the idea of the universal validity of scientific knowledge and technological know-how largely influences research policy strategies to respond to global challenges: these strategies are, to a large degree, conceived as if top-down introductions of new technologies are the royal road to effective solutions.[2] Consider, in this perspective, efforts in many countries to define main areas of (mainly technological) research.[3]

At most objective, but not straightforwardly true

Scientific knowledge and technological know-how are, however, neither normatively nor empirically obviously founded. Scientific knowledge is at most objective, but never neutral. Scientific insights derive their objectivity from their recognition by peers from within a specific disciplinary community. Those peers acknowledge scientific insights when they recognise – given the disciplinary paradigm they are familiar with – the research methods and procedures used to obtain these insights as valid and when they can imagine that they, given a similar research layout (infrastructural conditions, selection of empirical data, financial or time restrictions, …), could themselves have obtained similar research results. In other words, scientific objectivity is a characteristic derived from an intersubjective judgement or an intersubjective decision.[4] Scientific insights are, in short, historically contingent conceptual constructs. Therefore, they can never be straightforwardly 'true' or 'false'; they can at most be 'accepted' or 'unaccepted' – for the time being (Kuhn 1962).

This observation does not question the scientific ambition for objectivity: it is a good idea that scientists continuously expose their insights to the insights of their colleagues and adapt them in case they acknowledge the intrinsic value of critical comments. It does, however, imply that no definitive and unequivocal empirical foundation for scientific knowledge exists. Scientific knowledge – as all knowledge – remains susceptible to discussion, if not from within a particular disciplinary perspective, then at least from the perspective of other disciplinary paradigms or from non-scientific perspectives.[5] To conclude, knowledge always remains to a certain extent empirically underdetermined and, hence, never straightforwardly 'true'.

A(n) (un)critical factor of production

Science and technology are unavoidably value-laden. Our shared belief in the neutrality and societal value of science and technology emerged in the societal context of the seventeenth century, in which religious conflicts led to disaster and untamed culture and politics seemed easily to develop into dissent and violence (Rommetveit et al. 2013). In this context, scientific clarity appeared to be attractive. It is in this context that modern economics came into existence and that Bacon – philosopher, statesman, and scientist – promoted scientific advancement as a precondition for wealth and happiness.

Useful knowledge is, in Bacon's view, knowledge regarding causal relationships, because this type of knowledge provides us with power, that is, with opportunities to limit hazard and achieve positive effects. His conviction is, however, simplistic in at least two respects.

For whom the costs and for whom the benefits?

First, research policy strategies within knowledge economies more often than not assume, as Bacon did, that the subjects of scientific power can be considered a uniform and consensual 'we', that is, that everybody experiences and evaluates possible costs and benefits of scientific powers in the same way.

Consider – let us mention a rather extreme example – weapons of mass destruction. These are clearly meant to gain more power over one's 'enemies' and our 'enemies' are then those who we perceive as a threat for our future wealth and happiness. Much less extreme examples, but a day-to-day reality, are new and emerging technologies. These are, in the context of Western knowledge economies and from a political perspective, above all a means to maintain or strengthen – unavoidably at the cost of other regions or nations – one's competitive position in a globalised economy. Considered from an economic perspective, they are meant to claim a bigger part of the 'pie'.

The sustained controversy regarding genetically modified organisms provides a clear illustration. The gist of this controversy regards the belief that the model of industrial agriculture and, hence, also the business model of the biotechnological industry, is the only feasible road to feed world population. In this model – that undermines a prevailing practice of farmers to store, re-use, share, and improve their seeds and that threatens biodiversity because of a drastic reduction of the variety of agricultural crops – biotechnological knowledge, embedded into entities that transform into marketable products thanks to specific intellectual property regimes (IPRs), is a source of financial gains for a few enterprises and a source of financial loss for a lot of farmers. Prevailing research and innovation practices leave this crucial question – for whom the benefits and for whom the costs – unanswered.[6] Even worse, asking this question can destroy a research career: consider, for example, the vicissitudes of a Flemish researcher who acted (in 2011), during her private time, as a spokesperson for activists drawing attention to this question. She was consequently sacked by the University she was working for (http://threerottenpotatoes.wordpress.com/reinstate-her-now/)!

Systemic complexity

Bacon does not take causal complexity into consideration either. He only takes situations where one cause leads to one consequence as an example. This ideal type of scientific knowledge and technological know-how found translation in the academic organisation of scientific research via (a) an increasing specialisation and fragmentation of knowledge domains and, hence, an ongoing division into different (sub)disciplines and (b) experiments performed in laboratory contexts of which the boundary conditions are controllable and the results are quantifiable as exemplary for testing scientific validity.

Actual sustainability challenges are, however, complex. This implies that they can be considered 'wicked problems', which have, amongst others, the following characteristics (Vandenbroeck 2012):

(1) their framing is not unequivocal;
(2) a set of potential solutions exist;
(3) solutions are not simply true or false, but better or worse.

In complex situations, our knowledge is at most partial: we know some, but far from all causes and even less the possible interactions between various causes and initiatives, various actions and reactions. In such situations, ill thought-out application of scientific knowledge and technological know-how poses a risk: it can always lead to unexpected, irreversible, and undesirable consequences (which, often implicitly from a disciplinary perspective and explicitly from an economic perspective, are easily considered 'externalities' (McMurtry 2010)). Even stronger, many environmental problems are to be understood as manifestations of technological interventions in the world (EEA 2010, 2013). Most researchers, however, do not get to the question whether their scientific or technological intervention does effectively more good than harm (and who receives either the good or the harmful part). This is obviously related to the fact that current regulation and governance of knowledge and technology basically overlook and are not really bothered by the possibility (a) that the benefit–cost ratio may be smaller than 1 or (b) the distribution of benefits and costs is unfair (McMurtry 2010; Rommetveit et al. 2013). The emergence, since the latter part of the twentieth century, of a lively STS (Social Studies of Science) community and efforts to promote and perform 'post-normal science' (Funtowicz and Ravetz 1991, 137–152), risk and uncertainty research, technology assessment, foresight studies and transdisciplinary research did not change the fact that only a minority within the research community are in a position to act as if they acknowledge the non-neutrality and risks of scientific and technological bias and hubris[7] (Brandt et al. 2013, 1–15; Cornell et al. 2013, 60–70; Diedrich et al. 2011, 935–939; Jahn, Bergmann, and Keil 2012, 1–10).

Responsible research and innovation

Normative anchor points

'Sustainable development' pops up as a guiding principle in the mission statement of many public and private research organisations. Though the concept has been extensively discussed in global sustainability research (Clark and Dickson 2003, 8059–8061; Dedeurwaerdere 2014; Dietz and

Neumayer 2007, 617–626; Griggs et al. 2013, 305–307), in most cases the normative content framing this concept is hardly made explicit in Western research-performing organisations, neither to their employees nor to their stakeholders.

We argue in this section for strong sustainability as a normative anchor point for the ecological dimension of sustainable development, equality for its social dimension, and a-growth for its economic dimension.[8]

Strong sustainability as a normative anchor point for the ecological dimension

With respect to the ecological dimension of the research and innovation community's responsibility, the distinction between 'weak' and 'strong' sustainability is important. The 'weak' version is based on the vision that economic growth can be decoupled from an increasing use of natural capital (Dedeurwaerdere 2013). Corresponding indicators are based on the normative question of how many natural resources we can use now and how many we should invest in manmade technological capital in order to be capable to increase consumption later on – when non-renewable natural resources will be exhausted (Dietz and Neumayer 2007, 617–626). It presupposes that the degree of substitutability between renewable and non-renewable resources and between manmade and natural capital will always suffice to realise required utility. It hardly recognises absolute limits of stocks of natural resources.

The 'strong' version of sustainable development takes absolute limits of the earthly natural capital as a starting point (Dedeurwaerdere 2013). It assumes that possibilities to substitute are limited and that transgression of some absolute limits of natural capital poses a threat to the sustainability of societies. It does, in other words, acknowledge that tipping points exist, transcendence of which can cause irreversible damage (Barnosky et al. 2012, 52–58). These critical limits or tipping points are, admittedly, difficult to define. Therefore, various authors plead to preserve the functionalities of living systems in time by preserving their resilience and to keep every kind of capital (natural, cultural, institutional, social, and infrastructural/technological) intact. This does not imply a static but a dynamic vision on the specificities of the diverse kinds of capital.

Based on the complexity of sustainability challenges and the limited capacities of actual research and innovation systems to define tipping points and feasible and desirable ways to prevent societies to transcend them – climate change is an illustrative example – we argue that the 'strong' version of sustainable development should be the normative anchor point for the ecological dimension of RRI. This implies that the (theoretical) economic ambition of 'maximising utility of natural capital' should be replaced by a (practical) societal ambition of 'preserving resilience of life support systems'.

Equality as a normative anchor point for the social dimension

We cannot but observe that, despite the continuous flow of scientifically and technologically induced substitutions, the ecological footprint of industrialised and industrialising countries has but increased. Absolute decoupling between these economies and their use of natural capital is not realised. This has not only to do with the Jevons paradox,[9] but also with a direct relationship between environmental performance and global and national inequality (Dedeurwaerdere 2013). Inequality – in both income and power – does not only result in unequal access to ecosystem services, but also in unequal distribution of the costs of environmental degradation. As a consequence, inequality influences total use of natural capital. In the absence of social equality, a social driver is lacking to keep natural capital on a sustainable level (or to enable ecosystems to better serve human life capacities). Only in case a society guarantees its citizens access to a fair and reasonable part of ecosystem services can one expect citizens to take responsibility for ecosystems' maintenance and improvement (Dedeurwaerdere 2013; Shiva 2011, 23–27).

Lack of responsibility for life-supporting ecosystems should not one-sidedly be deemed a characteristic of the poorer part of the population (for whom options for choice are rather restricted). A study reviewing some historical examples of societal collapses concludes that in unequal societies

> the Elites – due to their wealth – do not suffer the detrimental effects of the environmental collapse until much later than the Commoners. This buffer of wealth allows Elites to continue 'business as usual' despite the impending catastrophe. It is likely that this is an important mechanism that would help explain how historical collapses were allowed to occur by elites who appear to be oblivious to the catastrophic trajectory […]. This buffer effect is further reinforced by the long, apparently sustainable trajectory prior to the beginning of the collapse. While some members of society might raise the alarm that the system is moving towards an impending collapse and therefore advocate structural changes to society in order to avoid it, Elites and their supporters, who opposed making these changes, could point to the long sustainable trajectory 'so far' in support of doing nothing. (Motesharrei, Rivas, and Kalnay 2014, 90–102)

A-growth as a normative anchor point for the economic dimension

'Strong' sustainability and equality require an 'a-growth' scenario. 'A-growth' is a concept introduced by Serge Latouche as an alternative for the religious belief in economic growth (Perez-Carmona 2013, 83–161). Latouche argues: 'we should be talking at the theoretical level of "a-growth", in the sense in which we speak of "a-theism", rather than "de-growth"' (2008, 8).

Robert Ayres already remarked years ago:

> None of the important economic actors, whether government leaders or private sector executives, has an incentive compatible with a 'no-growth' policy. No economic growth is evidently not a politically viable proposition for a democracy, at least in a world with enormous gaps between poverty and wealth. But 'no growth' is an imperative as regards extractive materials, energy and pollution emissions because economic activity is based on a material function. (Ayres 2008, 281–310)

And Alexander Perez-Carmona concludes laconically:

> And yet, unviable proposals do not transform theory and evidence into a myth. […] In choosing between tackling a political 'impossibility' and a biophysical impossibility, reason tells us to judge the latter to be more impossible and to take our chances with the former. (2013, 83–161)

Is the combination of economic growth and 'strong' sustainability really impossible? Until now, economic growth, as it is nowadays understood and institutionalised, did in any case not show the opposite.[10] Both Bernard Lietaer et al. and John McMurtry explain the inner logic that prevents industrial knowledge economies to consider a-growth as a normative anchor point for the economic dimension of sustainable development (Lietaer et al. 2012; McMurtry 2010). Both point to the present financial system as the ultimate seat of system rule.

> The core of the financial-rule mechanism is that over 95% of money and credit is issued by private financial institutions through individual and public debt contracts which are backed by 0–7% fractional currency reserves whose final guarantor is government and the public purse itself. (McMurtry 2010)

A financial system based on debt forces enterprises to 'grow' in order to pay off their debts. Technological innovation is a dominant strategy to grow, supported by public authorities.

Technological innovation allows entrepreneurs, indeed, to increase 'productivity' – that is, to make more or more expensive marketable products – and to reduce 'costs', for instance via replacement of 'expensive' human labour and via externalisation of environmental and social costs.

This creates a vicious cycle. Public authorities invite big, small, and medium enterprises continuously to innovate technologically, hoping that this will help to increase the economic 'pie', employment, and state revenue. Enterprises, in their turn, continuously call upon public authorities to commit larger budgets for (mainly natural-scientific and technological) research. For this, enterprises receive the support of both public and private research organisations as 'science itself is subjugated by the macro financial mechanism' (McMurtry 2010).

A systematic replacement of natural capital by technology is – as Herman Daly has been arguing for a long time – ecologically inefficient: the more technology one introduces as a replacement of natural capital (the substitution concept), the more natural capital one needs to realise this substitution (Perez-Carmona 2013, 122). Hence, the conclusion of 'trade-off between economic progress and environmental sustainability is a myth'.

To conclude, enterprises, public authorities, and research-performing organisations keep each other in a catch 22, based on the justification that scientific and technological innovation and considerable public funding of new and emerging science and technology are necessary to maintain economic growth and national welfare (Rommetveit et al. 2013). At the end, industry, government, the science community, and the wider public find themselves in the same financial straightjacket, which does not take account of the state of our common (ecological and social) life-supporting means.

The meaning and feasibility of the research and innovation community's 'responsibility'

Is it feasible for research and innovation communities within knowledge economies to act responsibly, if sustainable development is its guiding principle? A first part of the answer to this is that it *should*, even though it will not be easy. Nowadays and contrary to pre-modern times, scientific and technological powers are such that the natural conditions of human existence – both the nature of human beings and of their environment – are continuously altered, either gradually or suddenly. It is because researchers and innovators – together with wider society – are *capable* of gradual and radical changes, both in the short and in the very long run and both locally and globally, that they are – I follow Hans Jonas here – responsible. According to Jonas, acting on the base of scientific insights and technological know-how is acting in an ethically sensitive way. And since the effects of the collective actions of researchers and innovators do not remain restricted to here and now but extend widely in time and space, their responsibility means responsibility for the future (Jonas 1984, translation by H. Jonas, with the help of D. Herr of *Das Prinzip Verantwortung (1979)*).

The sense of this future-oriented responsibility is, to safeguard the humanity of the conditions of existence for both present and future generations, which is translated in this article into the three normative anchor points of strong sustainability, equality, a-growth. Repairing, maintaining, or improving humane conditions of existence should be the standard against which to evaluate performance of research and innovation activities.[11] RRI is, next to a future-oriented responsibility, also a goal-oriented responsibility. It comprises, hence, a consequentialist interpretation of responsibility, though this consequentialism does not depend so much on the predictive capacities of science,[12] but rather on the monitoring capacities of research. The second part of the answer to the feasibility question has to elaborate on *how* research and innovation systems can fulfil their combined future and goal-oriented responsibility. An adequate answer to this question presupposes acknowledgement of the limited descriptive, prescriptive, and predictive capacities of science with respect to glocal sustainability challenges.

The nature and role of 'RRI'

Locally situated

The combined future- and goal-oriented responsibility for sustainable development is a *total* responsibility. It does not only regard material needs, but everything that enables human beings to develop in a humane way (such as knowledge, social and moral skills, practical and cultural skills, societal structures and institutions, etc.). It is of a political rather than an economic kind. This means, first, that it asks whether specific research actions or innovation initiatives are good for the world (Grinbaum and Groves 2013, 119–142): it thus transcends by far (economically inspired) questions a) regarding the balance of costs and benefits that results from actions and initiatives and b) regarding individuals' liability for possibly harmful effects of the uncontrollable chain of actions and reactions emerging from his or her initial action or initiative. It is, second, a collective responsibility (Mitcham and von Schomberg 2000, 167–189): a responsibility shared by the various stakeholders confronted with a particular sustainability challenge.

Given the limitations of scientific knowledge to describe and explain the complexity of sustainability challenges in their totality, research and innovation can only be performed responsibly on the condition that its scope is reduced to a sufficiently concrete level (Kläy, Zimmermann, and Schneider 2014). Reduction of its scope is needed in order to clarify (a) the diversity of interpretations that the various stakeholders who are confronted with the challenge hold, (b) the combination of global and local causes and reasons for the challenge to come into existence and to persist, and (c) the diversity of projected futures that the various stakeholders consider a feasible, humane, and sustainable solution.

This implies that research and innovation should not any longer primarily focus on the development of new and emergent science and technology and on the vicissitudes of their societal introductions. The prevailing strategy should not be 'green' technology push: the guiding question should not be how to introduce new scientific and technological knowledge and know-how into society so that products and production processes become (ecologically and/or economically) more efficient. This strategy draws on the false promise of technological mastery that comes with scientific knowledge.[13] This misleading strategy induces the research community, consequently, to perform both anticipatory and retrospective, either or not integrated impact assessments (both on the technology and the policy level), which – I agree here with Grinbaum and Groves – is doomed to fail, because

> creative action and innovation *point forward*, opening up the world the past has created and adding new entities to it that change the way it works. The world that scientific understanding extrapolates into the future – with its gaze still directed toward yesterday – might tomorrow no longer exist. Innovation therefore creates a problem of knowledge.[14] (Grinbaum and Groves 2013, 119–142)

Research should rather focus on a specific – that is, locally concrete – manifestation of a global sustainability challenge. This is a societal demand-driven strategy. The guiding question becomes then: how can we realise – based on which combination of new and old disciplinary and practical knowledge and know-how – a locally feasible and globally justifiable humane and sustainable response to a context-specific sustainability challenge.

To conclude, sustainability research and innovation should be *glocal* in order to deal with the *descriptive and prescriptive limitations* of scientific knowledge and in order to re-empower both citizens and scientists (Swyngedouw 2004, 25–48). This would allow formal knowledge actors to act as much as a citizen than as a professional. Glocally oriented knowledge implies a reduction of the causal and normative complexity of sustainability challenges: it delimits the scope of research and innovation to a feasible, concrete level.

Transdisciplinary

In our globalised world, concrete manifestations of sustainability challenges have both global and local, historical and natural dimensions. That is why Hans Jonas pleads for *continuous* responsibility. Continuous responsibility is a responsibility which relates the past with the present and the future. It recognises what has been handed down from the past into the present and asks itself how to integrate this in the future of the people who will live in the future. It regards the tradition of a collective humane identity (Jonas 1984, translation by H. Jonas, with the help of D. Herr of *Das Prinzip Verantwortung (1979)*).

The notion of continuous responsibility suggests that responses to sustainability challenges should build on systemic insights into causes and reasons of their coming into existence (and, possibly, of their persistence). Insight in causes and reasons helps to formulate meaningful actions and initiatives to realise desirable solutions. Involvement of various stakeholders is crucial to co-construct systemic insights from a variety of perspectives and, consequently, for enlarging the scope of envisioned futures.

Local sustainability challenges cannot one-sidedly be solved from a particular disciplinary perspective, for two reasons. First, a disciplinary perspective always considers reality from a specific theoretical frame or paradigm and, consequently, challenges first have to be translated into disciplinary terms in order to make them fit for a scientific 'solution'. This translation is more often than not incompatible with stakeholders' understanding of the challenge. Second, increasing disciplinary specialisation and fragmentation easily leads to real-life challenges either being translated in a reductionist way or being neglected because the disciplinary perspective prevents professional knowledge actors to perceive it.

These disciplinary limitations do not imply that disciplinary perspectives are not useful or needed. Problem definitions of local sustainability challenges indeed always consist of a set of ideas regarding (a) causes and reasons for the unsustainability of phenomena and (b) possibly useful theoretical and practical ways to deal with them. Both causes and reasons can be either global or local or a combination thereof. Scientific knowledge actors are competent to deal with rather global causes and reasons and their consequences and with rather theoretical ways – these are ways that are deemed to have a rather global/universal validity – to intervene. In order to deal with the totality of causes and reasons, the research and innovation community should at least pay due attention to both natural sciences and social sciences and humanities as possible sources of inspiration for effective research and innovation activities.

Due attention should also be paid to grass roots initiatives. As niche initiatives, they often take little notice of some dominant institutions, structures, or cultures and they can bring in new visions, knowledge, and know-how that comply with local capacities and ambitions. In order to get the systemic analysis of the coming into existence/persistence of a local manifestation of a global sustainability challenge sufficiently adequate, why not support citizens who experience these local manifestations and who are already struggling to deal with them in ways (a) they deem consistent with their values and (b) which build further on their proper capacities and resources? In short, this is a plea (a) to attenuate the scientific ambition to present rather universal explanations and, consequently, prescribe rather de-contextualised innovations, but to click down research activities and innovation recommendations to rather local situations and (b) to behave as *knowledge partners* – who take a constructively critical but respectful stance towards citizens' practical knowledge claims and normative ambitions – instead of knowledge teachers.

Exchanges between local problem-solving initiatives and rather globally oriented professional knowledge and know-how can, moreover, improve the resilience of the research and innovation system: because it enlarges the variety of possible responses to sustainability challenges and because it challenges dominant approaches (Snick and Cortier 2012).

To conclude, glocal sustainability research (GSR) and innovation should be of a transdisciplinary kind. *Transdisciplinarity* helps the research and innovation community to deal with the *prescriptive limitations* of scientific knowledge and technological know-how. A transdisciplinary approach, again, allows the research and innovation community to fulfil its public (as a collective of citizens) rather than its professional (role) responsibilities (Mitcham and von Schomberg 2000, 167–189).

Action research

It is not only the descriptive and prescriptive capacities of knowledge that are restricted. We cannot be confident that actions and initiatives based on systemic knowledge insights will be sufficiently effective. The future always escapes the effectiveness of actions taken at a specific place and time (see Hans Jonas and Hannah Arendt). The results of actions are unpredictable and are out of actors' control, once they enter into a socio-technical web of further actions and reactions.

These predictive restrictions do, however, not imply an evasion from our total and continuous responsibility. It implies, in the words of Harremoës, 'the need, as a matter of cultural change, for society's institutions to enlarge existing notions of ethical responsibility to encompass these unknowns, which are predictable in principle even though not in specifics' (Harremoës et al. 2002). Institutionalisation of a precautionary attitude is a way to 'encompass these unknowns'. What could a suitable precautionary attitude with respect to our ambition for sustainable development consist of?

Rather than assigning considerable budgets to the performance of complex (*ex ante* or *ex post*) policy or technology assessments (that rely on knowledge's limited predictive capacities), why not make monitoring activities an integral part of glocal transdisciplinary research and innovation activities? Why not understand precaution as a procedure – rather than a principle – of (a) gathering empirical evidence and comparing this evidence with the ecological, social, and economic performance indicators that are included in projected visions of potential solutions to a glocal sustainability challenge and (b) adjusting research and innovation activities as long as a gap remains between empirical findings and projected sustainability targets?

A procedural approach to precaution differs widely from what Grinbaum and Groves describe as 'little more than a negative version of foresight-based consequentialism' which grounds decisions on worst-case scenarios 'which [indeed] still requires that we foresee what these might be, and that we make a judgement whether the benefits of acting are "proportionally" better than the potential hazards of doing so' (Grinbaum and Groves 2013, 119–142). The latter interpretation of the precautionary principle testifies to an economic interpretation of responsibility: it presupposes, next to fictive predictive capacities, that a neutral, impartial way exists of measuring out benefits and hazards against each other. The interpretation of a precautionary attitude as suggested here is, on the contrary, of a political kind: it considers whether the collective actions of both professional and non-professional knowledge actors contribute positively to the – locally specific – world these actors hope to live in and to hand over to their descendants.[15]

In short, GSR should take the form of action research in order to overcome knowledge's limited predictive capacities.

Knowledge arenas as breeding grounds for RRI

In present research and innovation systems, the definition of research and innovation agenda's and – projects is mainly the preserve of (academic, strategic, or industrial) research-performing organisations. The selection of research and innovation projects that effectively get funded, in its turn, mainly depends on the funding policies of public (regional, national, or international) funding organisations or on the funding strategies of universities, university colleges, and (large) enterprises.

The larger part of research projects that research-performing organisations propose are designed from a disciplinary perspective; they start from a rather reductionist interpretation of real-life challenges, and they aim at theoretical models and technological instruments and processes that are validated in specific laboratory contexts of which the boundary conditions are (made) susceptible to control. This rather limited variety of research projects consequently enters a financial/economic funnel: this implies that research proposals are predominantly filtered (1) according to the extent their results are deemed fit for monetary valorisation and (2) depending on the nature and extent of their technological – rather than sociocultural or systemic – ingenuity.

In order for RRI to counterbalance these prevailing research designing and funding strategies, research and innovation systems are in need of some adjustments. One adjustment could consist of institutionalising knowledge arenas that complement or, even better, transform present-day science–industry interfaces (Cornell et al. 2013, 60–70). The mandate of these knowledge arenas would be to stimulate the design, performance, and monitoring of GSR and to act as an observatory or clearing house for RRI activities.

In the next paragraphs, a process architecture – in need of further testing in regional/national contexts – is proposed and some preconditions for making knowledge arenas operational are described.

A process architecture for GSR

In previous sections, the concept of ‘responsible research and innovation’ is translated into the concept of ‘glocal sustainability research’, which takes the form of locally situated, transdisciplinary action research and which takes strong sustainability, equality, and a-growth as its respective ecological, social, and economic normative anchor points. This translation implies that

(1) the *focus* shifts from the ‘novelty’ of scientific and technological research activities to the factual and normative situational characteristics of local sustainability challenges;
(2) the *filter* shifts from the exact sciences as the dominant source of scientific knowledge and technological know-how, to the social sciences, the humanities, and the natural and engineering sciences as potential sources of knowledge and know-how;
(3) *responsibility* expands to both formal and informal knowledge actors as providers of both theoretical and practical insights and both global and local normative ambitions.

This translation of the concept of ‘responsible research and innovation’ complies with what Rommetveit et al. call ‘deep innovation’: it investigates the effectiveness of its activities with respect to the initial sustainability challenge; it takes the interactions between diverse dimensions of the sustainability challenge into consideration, and it constructively builds on the active involvement of various stakeholders.

From this translation, we can derive the various phases of the process architecture of RRI. The consecutive tasks are:

(1) investigating what the specificity of the local challenge precisely consists of according to the various stakeholders experiencing it and co-creating – together with these stakeholders – a common problem definition,
(2) describing both global and local causes and reasons for its coming into existence and for its persistence,

(3) co-envisioning, based on a considerations of the detected causes and reasons, a humane and sustainable future which is consistent with the locally specific factual and normative preconditions,
(4) considering which types of scientific and practical knowledge and know-how are needed to realise this envisioned future,
(5) co-designing and performing an experiment (i.e. action research), with the locally specific world as a real-life laboratory,
(6) monitoring – with the envisioned future as standard – the results of this experiment and adjust either the experiment, the envisioned future, or both when needed.

The mandate of knowledge arenas

Specific knowledge arenas – that is, units that consist of some staff members – are needed to manage GSR projects. The mandate of these knowledge arenas is

(1) to start up dialogues between persons, groups, organisations that engage themselves for specific glocal sustainability challenges,
(2) to support the co-definition of action-research projects that aim at solving the sustainability challenge,
(3) to support the composition of transdiciplinary project teams that are fit for the performance and monitoring of the co-defined research activities,
(4) to make ongoing research activities and results publicly accessible so that interested persons can question and comment on them,
(5) to document and archive project activities and results in order to make them accessible for further RRI activities.

Institutional preconditions for a knowledge arena

A suitable location within regional/national research and innovation systems. Knowledge arenas can be institutionalised in different ways within regional or national contexts. They could either be implemented within research-performing organisations, within research funding organisations, or they could be conceived as an independent organisation. Anyhow, they should act on the junction between the science community, policy, industry, and civil society.

In order to allow them to act as impartial and independent as feasible, it would perhaps – this certainly is a topic for further research – be best to institutionalise them so that they can act as a broker *between* various research organisations, rather than being institutionalised in each research-performing organisation separately. For, in case their communication strategy is implemented in an open and transparent way, this would allow that different perspectives, insights, visions, and interests are brought to the fore and enter into a constructive dialogue. It would, consequently, challenge research organisations to found and motivate their respective perspectives, insights, visions, and interests publicly and, hence, to transcend them to build shared visions, insights, and interests and to democratise processes of knowledge production and application.[16]

This plea for independent knowledge arenas does, however, not contradict that knowledge arenas that are institutionalised within research organisations can be important to test their room for manoeuvre, the boundary conditions that should be fulfilled to guarantee their appropriate autonomy and impartiality, and to test their relative advantages and disadvantages compared to knowledge arenas that are institutionalised in between different organisations and societal spheres.

Knowledge as a public good. Knowledge is a 'joint impact' or 'non-rival' good. It is a cluster of insights, of which *use* of a smaller or larger part of it does not imply its *consumption*: the cluster of insights does not diminish by using parts of it and it is even likely that use of parts of it will increase the whole of insights in case *use* of some insights results in the creation of new insights. That knowledge is a 'joint impact' good relates to the characteristics of knowledge itself. Use of knowledge by some does in principle not jeopardise use of the same knowledge by others. Knowledge is at the same time a 'non-exclusive' good: one cannot simply prevent persons or organisations that dispose of certain knowledge from using it. Knowledge only becomes less or more exclusive via the institutionalisation of IPRs. IPRs define who and under which conditions have rights to access, use, and manage specific knowledge, to market it, and to exclude others from these rights (Hess and Ostrom 2001; Maskus and Reichman 2004, 279–320). It is, in other words, IPRs that define whether knowledge is rather a public or a private good (and the distinction between both is less strict than is usually thought). More important than this distinction are the concrete clauses of which IPRs are composed. These clauses define the rights and duties of the owners of IPRs and the concomitant rights and duties of those who do not own them (Deblonde 2001).

Here are some tasks for public authorities. They should ensure that the resources needed to develop knowledge and know-how to deal effectively with sustainability challenges are provided – in case the research and innovation challenges do not fit with the perceived private interests of individual persons or organisations or in case private persons or organisations do not dispose of the necessary resources to perform the necessary research and innovation activities – and that the benefits arising from research and innovation activities are redistributed in a fair and reasonable way to the funding community (Maskus and Reichman 2004, 279–320). One aspect of both these tasks is the reconsideration of prevailing IPRs.

According to Maskus and Reichman, internationally prevailing IPRs – as stipulated in the Agreement on Trade-Related Aspects of Intellectual Property Rights (the TRIPS-Agreement) – are mainly beneficial for those – 'a de facto "knowledge cartel"' – who invest in monetary terms in the appropriation of IPRs, not those who contribute most to the production of new knowledge and know-how or make most use of it. In this 'knowledge cartel', SMEs and public research organisations are, amongst others, strikingly underrepresented. This way, present TRIPS-Agreement risks, paradoxically, preventing further liberalisation of global markets.[17] The availability within the public domain of original data and scientific information decreases at a moment in time that the possibilities to connect local and distributed knowledge- and databases via ICT are more extended than ever. Not only privately but also publicly financed results become less accessible. Also public research organisations are more and more aiming at monetary valorisation of their research results, so that some opportunities for research and innovation activities get lost and their costs increase.[18]

Moreover, current TRIPS-Agreement is not favourable to the provision of public goods such as health, education, scientific research, agriculture, and environment. They diminish the power of public authorities to realise public goods via adjustments of national legislation: nations are allowed to

> [formulate and amend] their laws and regulations, adopt measures necessary to protect public health and nutrition, and […] promote the public interest in sectors of vital importance to their socio-economic and technological development [… if] consistent with the provisions of this [TRIPS] Agreement. (Robert Howse quoted in Maskus and Reichman 2004, 279–320)

International IPR standards are in need of revision in order to realise a proper balance between private and public interests. Also within the European (scientific) community concerns arise regarding the negative effects of prevailing IPR policies (Maskus and Reichman 2004, 279–320). On the one hand, barriers to invest in the production and distribution of knowledge should be lowered to a reasonable level and appropriate IPRs should be defined to compensate for these investments in a fair and reasonable way. On the other hand, IPRs should create opportunities via digital communication technologies to connect producers and users of scientific knowledge and technological know-how in a global knowledge pool.

Juridical and economic insights in a publicly appropriate international system of IPRs still are in full development (Maskus and Reichman 2004, 279–320). The European Commission already invites public research organisations to reformulate their knowledge exchange strategies and it promises to stimulate further research in IPRs.[19] It, however, remains to be clarified how (and to what extent) these initiatives are linked to 'strong' sustainability ambitions.

Appropriate remuneration strategies. Next to the problem of defining publicly appropriate IPRs in order to reduce the costs of sustainability research and innovation, also the question regarding equitable, fair, and reasonable remuneration strategies to compensate those – both professional and non-professional, theoretical and practical experts – who contribute to sustainability research and innovation activities remains to be answered. Unless I overlook some research domains and topics, a brief literature search suggests that this question remains nearly untouched within the scientific community. I propose this as a new research topic to be opened in the 'endless frontier' of science.[20]

A suitable business model for knowledge arenas. Finally, in order to guarantee the continuity of knowledge arenas, funding should be provided in order to compensate for its operational costs. Here again, further research is needed in order to define a suitable business model. Potential funding organisations can be public and private research organisations, and also research units within civil society organisations and public administrations.

For universities and university colleges, investing in a knowledge arena could be an attractive way to provide societal services (which is the third role of universities and university colleges, next to performing research and providing education). For companies, it could be an attractive way to take up their corporate social responsibility. Moreover, both public and private research organisations can be compensated for their investments in knowledge arenas. They can be a productive source of inspiration for developing research proposals and consortia, because they allow one to get a better feeling with the (sustainability) insights and expectations of various societal and scientific actors. They can also help researchers to extend and consolidate their stakeholder network and to valorise their research results more efficiently. Co-design, performance and monitoring possibly – this should be tested in real-life experiments – will result in more efficient use of research time and resources. Researchers participating in co-design, performance, and monitoring will probably have to spend less time with bridging the so-called valley of death or with convincing stakeholders of the usefulness of research results, because together with the design and performance of transdiciplinary research projects, researchers also create stakeholder support for their results.

For other stakeholders – policy-makers, civil society organisations, citizens' groups – it is less clear whether, when, and in which way it is attractive to invest in knowledge arenas and how they can be rewarded for their investments. As with crowdfunding strategies, this should probably be considered case-by-case and, here again, this is a research domain that is rather recently opened for exploration.

Conclusion

Based on an analysis of the sustainability performance of knowledge economies and of the nature and role of research and innovation in such economies, this article suggests 'glocal sustainability research' as an ethically feasible translation of the concept of 'Responsible Research and innovation'. GSR urges the research and innovation community to take a different *focus* – local sustainability challenges rather than new and emergent science and technology – different *glasses* – a combination of natural and social sciences and of humanities rather than a predominance of natural and engineering sciences – and to include a wider variety of practitioners – both theoretical and practical experts within the science community, policy, and civil society rather than a restriction to members of public and private research organisations. In order to stimulate RRI, knowledge arenas are proposed as breeding grounds.

Several questions remain in order to institutionalise the proposed translation of RRI. One type of questions regards, for instance, the definition of fair and reasonable IPRs and of fair and reasonable remuneration strategies for those who contribute to GSR and innovation. Another topic regards the quest for appropriate business models to make knowledge arenas operational.

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Notes

1. http://www.eea.europa.eu/soer/synthesis/synthesis/chapter4.xhtml.
2. The European Commission in its research framework programme Horizon 2020 set aside a budget of 623 million euros for research in the human and social sciences. This amount represents 1.8% of the total budget for research, with a success rate of the submitted proposals of 3.6%! Paul Gillespie, author of *The hard business of funding soft science*, remarks 'compared to 46 per cent for nanotechnology, so the priorities are clear' (http://www.irishtimes.com/news/world/the-hard-business-of-funding-soft-science-1.1389261; consulted 30/09/2013).
3. These clusters are in Flanders Logistech (on logistics, transport, supply chain management), I-health-tech (ICT and healthcare), Meditech (healthcare, nutrition, prevention, and treatment), Nanotech, Sociotech (i.e. ICT for socio-economic innovation), and Ecotech (see http://www.vrwi.be/pdf/clusterbrochure-en.pdf, consulted 10/12/2014).
4. Otto Neurath, member of the Wiener Kreis of logical positivists, clearly argues – in 'The Lost Wanderers of Descartes and the Auxiliary Motive' (1913) – why theoretical thinking is a kind of action. And he mentions as a characteristic of action, whether practical or theoretical, that it is unavoidably based on a decision since the agent always lacks complete insight (Cohen and Neurath 1983).
5. Brian Wynne, director of the British Centre for the Study of Environmental Change (University of Lancaster), shows in his well-known article 'May the Sheep Safely Graze?' how scientific insights cause economic damage to farmers in the aftermath of the Chernobyl accident (1986) and how scientists ignore lay expertise and interpret it as being 'irrational' and 'ignorant' (http://en.wikipedia.org/wiki/Brian_Wynne).
6. According to McMurtry, the meta program of what is nowadays assumed to be economic – in particular – and scientific – in general – rationality consists of (a) self-maximising strategies – instead of life-maximising strategies of choice – in (b) conditions of scarcity or conflict over – instead of in the historical dynamic of social organisation which continually transforms towards adequate provision or non-scarcity when not blocked against doing so by ruling privilege – (c) desired payoffs – instead of life-capacitating vocation – at (d) minimum costs for the self – instead of life-value efficiency – to (e) succeed or win – instead of a mutual quest to prevail over limits to human life capacities (McMurtry 2010).
7. The concepts 'hubris' and 'bias' are not used here as psychological or moral categories, but as characteristic of actual science and innovation systems.
8. These normative anchor points do not necessarily fit easily with two of the five normative anchor points derived from the Treaty on the European Union, as presented by René von Schomberg: namely, 'promotion of scientific and technological advance' and 'competitive social market economy' (2013, 51–74).

9. The Jevons paradox describes the effect that a technological innovation which increases efficiency, and hence causes that one need less of a certain resource to realise a similar effect (e.g. less fuel needed per km travelled by car), has a global result of an increased use of this resource (e.g. because people travel more km by car).
10. The global ecological creditor and debtor map (2007) of the Footprint Network, which compares the Ecological Footprint of consumption within each country's boundaries with globally available biocapacity, is illustrative in this respect (http://www.footprintnetwork.org/images/uploads/Ecological_Footprint_Atlas_2010.pdf, consulted 5/1/2015).
11. This is one of the three meanings Rommetveit and co-authors assign to the concept of 'deep innovation' (Rommetveit et al. 2013).
12. My defence of consequentialism differs from Grinbaum and Groves' argument that the limited predictive capacities of scientific knowledge results in a lack of moral capacity, which they call a 'deficiency that is *inherent to the culture of consequentialism itself*' (Grinbaum and Groves 2013, 119–142).
13. Grinbaum and Groves explain – referring to Nordmann's concept of 'naturalized technologies' – why technology cannot deliver on its promise:

    > In societies that have become thoroughly dependent on advanced technologies, the background of human action has changed. No longer coherently imaginable as Nature, eternal, and unchanging, it has become an amalgam of natural processes and technological artefacts that intimately interact with them. (2013, 119–142)

14. The – within research communities – frequently used strategy to compare the – (above all) ecological and economic – characteristics of (the life cycle of) one product or process with those of other products and processes, in order to allow society to select the 'best' ones, is, hence, but of little help to contribute positively to sustainability challenges.
15. In order to enforce the resilience of science and innovation systems, also the monitoring results – i.e. the effectiveness – of the variety of the solutions tried out by a diversity of local communities could be documented, archived, and made accessible to both professional and non-professional knowledge actors. This documented and archived variety is, in its turn, a useful database for further research on more and less resistant causes and reasons for glocal sustainability challenges and on more and less successful innovations.
16. Of course, since the specificity of citizens' and organisations' perspectives, visions, and interests is at least partly related to the peculiarities of their cultural, political, and economic context, transcendence thereof depends on opportunities to transform some restrictive contextual determinants. Looking for and/or creating such opportunities can be considered a main role of responsible research and innovation activities.
17. The legitimacy of the General Agreement on Tariffs and Trade (GATT) and the Agreement Establishing the World Trade Organisation rests on the faith in a further liberalisation of markets as a way to increase – via free competition – societal benefits (Maskus and Reichman 2004, 279–320).
18. Consider, as an example, recent figures in the Netherlands: since the 1980s the number of patents requested by public research organisations increased with more than a factor of 14 (Horlings et al. 2013).
19. See, for instance, http://ec.europa.eu/research/era/optimal-circulation_en.htm and http://openaccess.be/2013/10/14/report-14102013-ewi-focus-group-on-open-access/.
20. The concept of 'endless frontier' refers to the famous 1945 report of Vannevar Bush to the president of the USA.

References

Ayres, R. 2008. "Sustainability Economics: Where Do We Stand?" *Ecological Economics* 67: 281–310.

Barnosky, A. D., E. A. Hadly, J. Bascompte, E. L. Berlow, J. H. Brown, M. Fortelius, W. M. Getz, et al. 2012. "Approaching a State Shift in Earth's Biosphere." *Nature* 486: 52–58.

Brandt, P., A. Ernst, F. Gralla, C. Luederitz, D. J. Lang, J. Newig, F. Reinert, D. J. Abson, and von Wehrden, H. 2013. "A Review of Transdisciplinary Research in Sustainability Science." *Ecological Economics* 92: 1–15.

Bruyninckx, H. 2014. "Greening the Entire Economy; Not Just a Handful of New Sectors." *EEA Newsletter* (2014/1), March 17.

Brynjolfsson, E., and Andrew McAfee. 2011. "Why Workers Are Losing the War Against Machines." *The Atlantic*, October 26.
Bush, V. 1945. *Science: The Endless Frontier*. Washington, DC: United States Government Printing Office.
Clark, W. C., and N. M. Dickson. 2003. "Sustainability Science: The Emerging Research Program." *Proceedings of the National Academy of Sciences* 100 (14): 8059–8061.
Cohen, R. S., and M. Neurath. 1983. *Otto Neurath. Philosophical Papers 1913–1946*. Dordrecht: Reidel.
Cornell, S., F. Berkhout, W. Tuinstra, J. D. Tábara, J. Jäger, I. Chabay, B. de Wit, et al. 2013. "Opening Up Knowledge Systems for Better Responses to Global Environmental Change." *Environmental Science & Policy* 28: 60–70.
Courtenay Botterill, L., and A. Hindmoor. 2012. "Turtles All the Way Down: Bounded Rationality in an Evidence-Based Age." *Policy Studies* 33 (5): 367–379.
Deblonde, M. 2001. *Economics as a Political Muse. Philosophical Reflections on the Relevance of Economics for Ecological Policy*. Dordrecht: Springer.
Dedeurwaerdere, T. 2013. *Sustainability Science for Strong Sustainability*. Université catholique de louvain and Fonds National de la Recherche Scientifique, FSR-FNRS.
Dedeurwaerdere, T. 2014. *Sustainability Science for Strong Sustainability*. Cheltenham: Edward Elgar.
Diedrich, A., P. Upham, L. Levidow, and S. van den Hove. 2011. "Framing Environmental Sustainability Challenges for Research and Innovation in European Policy Agendas." *Environemental Science & Policy* 14 (8): 935–939.
Dietz, S., and E. Neumayer. 2007. "Weak and Strong Sustainability in the SEEA: Concepts and Measurement." *Ecological Economics* 61 (4): 617–626.
EEA. 2010. *Accelerating Technological Change: Racing into the Unknown*. European Environment Agency.
EEA. 2013. *Late Lessons from Early Warnings: Science, Precaution, Innovation*. European Environment Agency.
European Commission. 2013. *Options for Strengthening Responsible Research and Innovation*. Publications Office of the European Union.
Funtowicz, S., and J. R. Ravetz. 1991. "A New Scientific Methodology for Global Environmental Issues." In *Ecological Economics: The Science and Management of Sustainability*, edited by R. Costanza, 137–152. New York: Columbia University Press.
Griggs, D., Mark Stafford-Smit, Owen Gaffney, J. Rockström, M. C. Öhman, P. Shyamsundar, W. Steffen, G. Glaser, N. Kanie, and I. Noble. 2013. "Policy: Sustainable Development Goals for People and Planet." *Nature* 495 (7441): 305–307.
Grinbaum, A., and C. Groves. 2013. "What Is "Responsible" about Responsible Innovation? Understanding the Ethical Issues." In *Responsible Innovation. Managing the Responsible Emergence of Science and Innovation in Society*, edited by R. Owen, J. Bessant, and M. Heintz, 119–142. Chichester, UK: Wiley.
Harremoës, P., D. Gee, M. Macgarvin, A. Stirling, J. Keys, B. Wynne, and S. Guedes Vaz. 2002. *The Precautionary Principle in the 20th Century. Late Lessons from Early Warnings*ct. London: Earthscan.
Hess, C., and E. Ostrom. 2001. "Artifacts, Facilities, and Content: Information as a Common-Pool Resource." Paper presented at Conference on the Public Domain, Duke Law School, Durham, North Carolina, November 9–11.
Horlings, E., T. Gurney, J. Deuten, and L. van Drooge. 2013. *Patentaanvragen door Kennisinstellingen*. Rathenau Instituut.
Jahn, T., M. Bergmann, and F. Keil. 2012. "Transdisciplinarity: Between Mainstreaming and Marginalization." *Ecological Economics* 79: 1–10.
Jonas, H. 1984. *The Imperative of Responsibility. In Search of an Ethics for the Technological Age*. Chicago: The University of Chicago Press.
Kläy, A., A. B. Zimmermann, and F. Schneider. 2014. "Rethinking Science for Sustainable Development: Reflexive Interaction for a Paradigm Transformation." *Futures*.
Kuhn, T. S. 1962. *The Structure of Scientific Revolutions*. Chicago: The University of Chicago Press.
Latouche, S. 2008. *Farewell to Growth*. Cambridge: Polity Press.
Leydesdorff, L. 2010. "The Knowledge-Based Economy and the Triple Helix Model." *Annual Review of Information Science and Technology* 44: 367–417.
Lietaer, B., C. Arnsperger, S. J. Goerner, and S. Brunnhuber. 2012. *Money and Sustainability. The Missing Link*. Devon, UK: Triarchy Press.
Maskus, K. E., and J. H. Reichman. 2004. "The Globalization of Private Knowledge Goods and the Privatization of Global Public Goods." *Journal of International Economic Law* 7 (2): 279–320.

McMurtry, J. 2010. *Reclaiming Rationality and Scientific Method. The Life-Coherence Principle as Global System Imperative*. Accessed January 14, 2014. http://www.globalresearch.ca/reclaiming-rationality-and-scientific-method/21302

Mitcham, C., and R. Von Schomberg. 2000. "The Ethic of Scientists and Engineers: From Occupational Role Responsibility to Public Co-responsibility." In *Research in Philosophy and Technology*, edited by P. Kroes and A. Meijers, 167–189. Amsterdam: JAI Press.

Motesharrei, S., Rivas, J., and Kalnay, E. 2014. "Human and Nature Dynamics (HANDY): Modeling Inequality and Use of Resources in the Collapse or Sustainability of Societies." *Ecological Economics* 101: 90–102.

OECD. 2011. *Draft OECD recommendation on assessing the sustainability of bio-based products*. Paris: OECD Directorate for Science, Technology and Industry, Science and Technology Policy Division, Biotechnology Unit. Accessed January 14, 2014. http://www.oecd.org/science/biotech/publicconsultation-draftoecdrecommendationonassessingthesustainabilityofbio-basedproducts.htm

Peeters, J. 2012. "The Place of Social Work in Sustainable Development: Towards Ecosocial Practice." *International Journal of Social Welfare* 21: 287–298.

Perez-Carmona, A. 2013. "Growth: A Discussion of the Margins of Economic and Ecological Thought." In *Transgovernance*, edited by L. Meuleman, 83–161. Heidelberg: Springer.

Rees, W. E. 2006. "Globalization, Trade and Migration: Undermining Sustainability." *Ecological Economics* 59: 220–225.

Rommetveit, K., R. Strand, R. Felland, and S. Funtowicz. 2013. "*What Can History Teach Us about the Prospects of a European Research Area*?" edited by A. Saltelli, Reference Report by the Joint Research Centre of the European Commission. Luxembourg: Publications Office of the European Union. http://www.uib.no/sites/w3.uib.no/files/attachments/histera_final_report_25_2_0.pdf

Shiva, V. 2011. "Equity: The Shortest Way to Global Sustainability." In *European Research on Sustainable Development. Volume 1: Transformative Science Approaches for Sustainability*, edited by C. C. Jaeger, D. Tàbara, and J. Jaeger, 23–27. Berlin: Springer.

Simms, A. 2008. "The Poverty Myth." *New Scientist* 200 (2678): 49.

Skott, P., and F. Guy. 2007. "A Model of Power-Biased Technological Change." *Economics Letters* 95 (1): 124–131.

Snick, A., and E. Cortier. 2012. *Wijze Wetenschappen. Een antwoord op de grote maatschappelijke uitdagingen*. Instituut Samenleving & Technologie, Vlaams Parlement.

Swyngedouw, E. 2004. "Globalisation or 'Glocalisation'? Networks, Territories and Rescaling." *Cambridge Review of International Affairs* 17 (1): 25–48.

Vandenbroeck, P. 2012. *Working with Wicked Problems*. Brussels: King Baudouin Foundation.

Von Schomberg, R. 2013. "A Vision of Responsible Research and Innovation." In *Responsible Innovation*, edited by R. Owen, J. Bessant, and M. Heintz, 51–74. Chichester, UK: Wiley.

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