



The turbulent age of innovation

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Abstract

The concept of innovation has entered a turbulent age. On the one hand, it is uncritically understood as ‘technological innovation’ and ‘commercialized innovation.’ On the other hand, ongoing research under the heading responsible research and innovation (RRI) suggests that current global issues require innovation to go beyond its usual intent of generating commercial value. However, little thought goes into what innovation means conceptually. Although there is a focus on enabling *outcomes* of innovation processes to become more responsible and desirable, the technological and commercial nature of these processes is rarely questioned. For these reasons, this paper poses the following research question: *what concept of innovation is implicitly taken up by the RRI discourse and what implications does this concept have for the societal purpose of RRI?* As a first step, we analyze the extent to which the concept of innovation in the RRI literature is uncritically presupposed to be technological. Subsequently, we examine the diverse meanings innovation has had over time and argue that while innovation originally had a political connotation it is only recently restricted to the meaning of technological innovation. We go on to show that even though the concept of technological innovation can contribute to the societal purpose of RRI, this requires certain conditions that are difficult to guarantee. Consequentially, we argue that future research should explore alternative understandings of innovation that better enable the overall feasibility of the emerging frameworks of RRI.

Keywords Innovation · Responsible research and innovation · Technological innovation · Commercialized innovation · History of innovation · Philosophy of innovation

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1 Introduction

Even though the concept of innovation has traveled through a rich history of different meanings, today it is uncritically understood as ‘technological innovation’ and ‘commercialized innovation’¹ (Godin 2008). That is to say, it has become remarkably common to associate innovation with the field of commercialized technologies. At the same time, the global issues of our age, such as climate change or epidemics related to lifestyle diseases, urge innovation to go beyond its usual intent of generating commercial value. In this respect, ongoing research under the heading Responsible Research and Innovation (RRI) calls for a political discourse of innovation in which innovation processes should primarily be concerned with generating the right impact, particularly with regard to the grand challenges of our time (von Schomberg 2013). Although the concept of innovation is thus widely understood in terms of commercialized technologies, recent frameworks of RRI have attempted to shift the focus toward formulating what a political discourse of innovation precisely entails and how it can be achieved in practice (cf. Owen et al. 2013).

However, little thought goes into what innovation itself means conceptually (Blok and Lemmens 2015). According to the Cambridge Dictionary, to innovate means “to introduce changes and new ideas.” Innovation is therefore a very broad concept. Changes and new ideas can be introduced at the level of science and technology, but also in other domains, such as management and education. The RRI literature suggests that innovation has a particular societal role, but this does not mean that innovation itself is understood as societal. While both policy makers and researchers focus on enabling *outcomes* of innovation processes to become more responsible and desirable, the technological and commercial nature of these processes is rarely questioned. Can technological innovation ever lead to more responsible types of innovation? Surely the imperative of economic growth inherent in the concept of innovation as it is currently understood is fundamentally at odds with a political discourse of innovation? To what extent does RRI, in order to attain its societal purpose, need to question the way innovation is widely implemented today?

One of the commonly used frameworks of RRI features four important dimensions: anticipation, reflexivity, inclusion and deliberation, and responsiveness (Owen et al. 2013; Stilgoe et al. 2013). In this view, innovators and institutions should anticipate the possible outcomes of innovation processes, reflect on their wider moral responsibilities, expand their engagement with particular stakeholders to members of the larger public, and they should do all of this in response to the values of society and its changing circumstances. The question is whether it is feasible to operationalize these dimensions in practice where the concept of innovation is largely understood in light of an intrinsic relation between technology and the market. This dominant view of innovation could restrict, for example, the dimension of reflexivity and allow the self-interested pursuit of economic gain to dominate. Similarly, inclusion and deliberation may be used to maximize profit, while responsiveness may simply amount to window dressing.

¹ Technological innovation and commercialized innovation are generally taken as one interwoven concept that refers to the commercialization of new technologies.

In order to open up the concept of innovation for further philosophical reflection within the emerging context of RRI, the present paper poses the following research question: *what concept of innovation is implicitly taken up by the RRI discourse and what implications does this concept have for the societal purpose of RRI?* In Sect. 2 we analyze the extent to which the concept of innovation in the RRI literature is uncritically presupposed to be technological. In Sect. 3 we examine the diverse meanings innovation has had over time and argue that while innovation originally had a political connotation it is only recently restricted to the meaning of technological innovation (Godin 2015). In Sect. 4 we go on to show that even though the concept of technological innovation can contribute to the societal purpose of RRI, this requires certain conditions that are difficult to guarantee. Consequentially, we argue that future research should explore alternative understandings of innovation that better enable the overall feasibility of the emerging frameworks of RRI.

2 The concept of innovation in RRI

Responsible Innovation: Managing the Responsible Emergence of Science and Innovation in Society is a central book in the RRI literature (Owen et al. 2013). Its core theme is the ways in which the dimensions of RRI can be conceptualized and operationalized. These dimensions are very broad and vary throughout the book. In addition to the four dimensions described earlier, the book highlights, for example, the importance of democratically governing the purposes of innovation (Owen et al. 2013) and provides a theory about how by reflecting values of the EU the innovation processes will ensure that outcomes become ethically acceptable, sustainable, and societally desirable (von Schomberg 2013). Yet, while the book continually discusses how to achieve *responsible* innovation, the question of what innovation means is rarely raised. In the opening chapter, questions specifically revolve around *where* and *how* to innovate (Bessant 2013), thus overlooking the very question of *what* it means to innovate. To what concept of innovation are the four dimensions applied? What type of innovation processes is being democratized? These questions call for an investigation into what concept of innovation is presupposed to be self-evident by the RRI discourse. This is an important step as it enables us to ask whether *this* concept of innovation is at all compatible with the dimensions that the RRI discourse so eagerly endorses.

The opening chapter, entitled ‘Innovation in the Twenty-First Century,’ is written by John Bessant. He is a professor of innovation and entrepreneurship at Exeter University and is considered to be a top researcher in the field. In this chapter, he elaborates on the context in which the discussion of RRI has to take place, namely the changing environment and challenges of the twenty-first century. Even though he does not explicitly account for the concept of innovation as such, he does provide an interesting distinction between incremental innovation and radical innovation. In his words:

Innovation is about change and this can take place among a spectrum of increasing novelty. From simple incremental improvements – “doing what we do, but better” – through to radical, new to the world changes. (Bessant 2013, p. 1)

Noticeably, incremental innovation, ‘doing what we do, but better,’ and radical innovation, ‘doing something new,’ are both understood in terms of technological advancement. At the level of incremental innovation, Bessant specifically refers to improved technologies, that is, technologies that already exist but that have been made to supposedly work more efficiently: Windows 10 replacing Windows 8, for example. At the level of radical innovation, Bessant speaks of innovations that are completely new to the world technologies, such as the first speech recognition program. In both instances, innovation is therefore conceptualized as technological innovation.

This conception stretches further into later chapters of *Responsible Innovation*. This is certainly the case in ‘A Vision of Responsible Research and Innovation’ (2013), written by Rene von Schomberg, who as a Directorate General for Research at the European Commission introduced the concept of RRI at the level of the EU and thereby plays a dominant role in the RRI discourse. Here he characterizes innovation within a distinction that presupposes from the start that innovation is necessarily technological. On the one hand, he accounts for mere technical inventions, which specifically refer to the development of a new technology, such as Bartolomeu’s “machine for sailing through the air” (p. 52). On the other hand, R. von Schomberg accounts for modern innovations. Also in this respect the use of the term ‘technology’ continues to prevail. In fact, throughout the text, R. von Schomberg alternates between the words ‘innovation’ and ‘technological innovation’ as if they are self-evidently the same. For example, when speaking of the impact of innovations, he argues that “technological innovations are unpredictable” (p. 55). This association between innovation and emerging technologies is further illustrated by the particular innovations that R. von Schomberg takes into account, such as video-gaming technology, genetically modified organisms (GMOs), the electronic patient record system (EPRS), body-scanning technology, and nanotechnology. His view on innovation is also reflected in official documents of the European Commission, in which emerging technologies are considered to be the main innovations that shape our future (cf. Matter 2011).

Technological innovation prevails throughout any framework of RRI. In fact, the four dimensions—anticipation, reflexivity, inclusion and deliberation, and responsiveness—originate from public debates that explicitly concern new areas of technology (Owen et al. 2013; cf. Stilgoe et al. 2013). In other words, this framework is grounded in the presupposition that enhancing responsible innovation is ultimately a matter of creating responsible technologies. Similarly, Grinbaum and Groves (2013) argue that while innovation involves a “process of bringing something new into the world” (p. 119), in order to understand the meaning of responsible innovation we have to reflect “on the ethical significance of technological innovation” (p. 119).

Another crucial characteristic of the presupposed concept of innovation in the RRI discourse is its inherent economic structure. Although Bartolomeu’s machine is referred to as a ‘mere’ technological invention, it is also stated that “modern innovations are distributed through market mechanisms” (von Schomberg 2013, p. 54). In other words, modern innovations are not simply conceptualized in terms of emerging technologies, but more specifically in terms of technological *products* that are essentially shaped by the successes they make on the market. This is confirmed by Bessant, who argues that radical innovation is managed by entrepreneurs and smart firms who set up “the competitive dynamics which *characterize* innovation” (Bessant 2013, p. 5,

Table 1 Table extracted from ProGReSS (2015, p. 4)

RRI principle	Definition	Identifiable through
Ethical acceptability	Research and innovation which respects fundamental values during its conduct and through its outputs	Code of conduct, ethics guidelines and sustained public engagement efforts
Sustainability	Research and innovation which meets the needs of the present without compromising the ability of future generations to meet their own needs	Environmental protection and health and safety
Societal desirability	Innovation which may benefit all without discrimination	For instance, tackling grand challenges

own emphasis). The terms ‘innovation,’ ‘technological innovation,’ and ‘technological products’ are used interchangeably throughout the RRI literature; again, as if they are self-evidently the same.

Technological innovation, understood to mean commercialized technologies, also plays a central role in EU-funded RRI governance projects, such as ‘Promoting Global Responsible research and Social and Scientific innovation’ (ProGReSS). The project aims to establish a global network for RRI involving academia, SMEs, international organizations, policy advisors, research funders, NGOs, and industry. Therefore, ProGReSS initially seems to go beyond the scope of commercialized technologies. In an attempt to ensure this, the project categorizes RRI into three building blocks: innovation should be (1) ethically acceptable, (2) sustainable, and (3) societally desirable. See Table 1 for an overview of how ProGReSS has interpreted these building blocks.

Beyond ethical acceptability and sustainability, ProGReSS focuses on what the project believes is the underexplored and least converging part of RRI, namely achieving societal desirability. The project aims to advocate a European normative model for RRI globally, using constitutional values as a driver to inform societal desirability. Accordingly, ProGReSS has delivered reports in which it describes and analyses how research funding can drive innovation toward positive outcomes, especially with regard to societal desirability. Through comparing innovation policies in Europe, the US, China, Japan, India, Australia, and South Africa, the project shows how, on the one hand, societal desirability differs from country to country. On the other hand, it stresses that we are ultimately globally linked through the societal desirability of tackling certain grand challenges, such as climate change. While ProGReSS thus admits that the definition of societal desirability is contested, defining it in terms of tackling the grand challenges “allows a comparison and a glimpse of how RRI could become a global framework where the attempt to guide innovation toward resolving humanity’s challenges functions as a common denominator” (ProGReSS 2014a, p. 5).

However, when it comes to understanding the concept of innovation itself, no such comparative scheme with a common denominator is suggested. Instead, ProGReSS unquestioningly reports on case studies that focus on the societal desirability of

technologies that are particularly economically beneficial (ProGReSS 2014b). These specifically involve synthetic biology, nanotechnology, and information and communications technology (ICT). With regard to ethical acceptability and sustainability, ProGReSS reports on these exact same technologies.

Res-AGorA is another EU-funded project that has the objective of developing a comprehensive governance framework for RRI (Lindner et al. 2016). Instead of providing top-down normative anchor points, which tend to contradict each other, Res-AGorA attempts to provide a framework in which responsibilities are reached through shared and agreed understandings. In order to reach shared responsibilities, during the project's three-year life cycle, Res-AGorA, practitioners, and strategic decision makers co-constructed an orientating governance framework called the "Responsibility Navigator" (Kuhlmann et al. 2015). Through ten identified principles and requirements—see Table 2—the Responsibility Navigator should support decision makers to govern research and innovation activities in a more responsible way. Unlike virtue-based frameworks of RRI, the framework of Res-AGorA acknowledges the contested definition of responsibility and the role it has within the different contexts of Europe. The project advocates for a constant renegotiation of and deliberation about what the definition of responsible should be.

While Res-AGorA is strategically different from ProGReSS, its overall focus is also on the 'what is responsibility?' aspect of RRI. Conversely, the research and innovation aspect is hardly explored. Instead, the ethics that are formulated specifically apply to economically beneficial technologies. The Responsibility Navigator is supposed to guide innovation processes through the application of ten principles, but most of these principles are exemplified and applied within the context of market-based technology (see Table 2).

The above analysis shows that the RRI literature does not yet consider the concept of innovation to be an object of reflection. Instead, innovation is uncritically presupposed to be technological. This is reflected in the vocabulary used to denote innovation and in the particular innovations to which the dimensions of RRI are applied. Upon closer examination, it becomes clear that within the context of RRI, technological innovation has two main characteristics. First, as the term itself implies, technological innovation refers to the creation of new technologies. Second, it is specifically concerned with technologies that contribute to the market, and can for this reason also be understood as commercialized innovation. It is important to note, therefore, that while the dimensions of RRI are broad and varied, innovation processes coupled with these dimensions are essentially limited to a technological and commercial context (Table 3).²

3 The history of innovation

Beyond the RRI literature, the concept of innovation also receives little attention. Serious investigations into what innovation means conceptually are scarce, although

² Even though this paper specifically explores the presupposed concept of innovation, it is important to note that the RRI literature is in fact concerned with *research* and innovation. It could therefore be interesting for future investigations to explore what role research plays in limiting the concept of innovation to a technological and commercial context.

Table 2 The ten guiding principles of Res-AGorA

Responsibility navigator	Example
<i>Principle 1: Inclusion</i>	Promoting inclusion to ensure “synthetic biology and its contribution to a range of societal objectives across health, well-being, environment, sustainability, and economic growth” (Kuhlmann et al. 2015, p. 17)
<i>Principle 2: Moderation</i>	Balancing research funding of the Science and Technology Advisory Council (STAC) so that the grand challenges can be tackled
<i>Principle 3: Deliberation</i>	Organizing workshops to test technological controversies (energy, climate change, and shale gas fracking; and the genetic modification of food) in different contexts
<i>Principle 4: Modularity and flexibility</i>	Opening “a large semi-public lab in the field of nanotoxicology ... committed to the highest ethical standards and the accommodation of societal concerns and needs, with recruitment procedures and training aimed at establishing and promoting a diverse workforce” (Kuhlmann et al. 2015, p. 23)
<i>Principle 5: Subsidiary</i>	Introducing a global governance body and initiating a conversation about how to standardize and upscale RRI by upholding “participative governance, orientation to societal challenges, and futures-oriented anticipation of technological development and the global political economy” (Kuhlmann et al. 2015, p. 25)
<i>Principle 6: Adaptability</i>	Institutionalizing ethical business practice in highly contested technological areas
<i>Principle 7: Capabilities</i>	Building the capabilities and awareness of researchers, starting with the young generation of researchers and their employing organizations. Nothing is said about what sort of researchers or what type of employing organizations this refers to
<i>Principle 8: Capacities</i>	A large civic society organization (CSO) should be established to encourage a more fundamental role for civil society in constructing R&I pathways, with earlier participation in technology assessment dialogues, and involving values-centered small and medium-sized businesses and social enterprises
<i>Principle 9: Institutional entrepreneurship</i>	A newly appointed president of an American university transformed the organization of the university to drive its students in a ‘responsible’ direction (e.g., sustainability). Res-AGorA uses this example to illustrate that principles 7 and 8 cannot be self-organized and require leadership
<i>Principle 10: Culture of transparency, tolerance and rule of law</i>	Emphasis on how governance mechanisms are required to reflect a commitment to democratic principles and to allow actions to be taken according to the rule of law

Table 3 An overview of the concept of innovation in RRI

RRI publications/projects	Responsible	Research and innovation
von Schomberg (2013)	Ethical acceptability, sustainability, and societal desirability (anchored in EU values)	Definition: ?? Examples: video-gaming technology, GMO, EPRS, body-scanner, nanotechnology
Owen et al. (2013)	Anticipation, reflexivity, inclusion and deliberation, and responsiveness Democratic governance	Definition: ?? Examples: case study on geo-engineering (cf. Stilgoe et al. 2013)
ProGRESS	Societal desirability	Definition: ?? Examples: synthetic biology, nanotechnology, ICT
Res-AGorA	Ten guiding principles (Table 2)	Definition: ?? Examples: synthetic biology, nanotoxicology

there are a few (cf. Godin 2008, 2015, 2016; Bontems 2014; Blok and Lemmens 2015). Almost any study related to innovation quite naturally departs from a technological and commercial understanding of the concept. Especially the commercial understanding of innovation becomes more and more dominant. Today innovation is uncritically seen as “the development of new ideas into marketable products and processes” (Stoneman 1995, p. 2); its essence lies in delivering value to customers (Carlson and Wilmot 2006). Perhaps the commercial character of the way innovation is widely understood is best captured by the words of American industrialist J. Paul Getty: “True innovation is coming up with a product that the customer didn’t even know they needed.”³

Innovation has not always been conceptualized in the current technological and commercial way. In fact, as Benoît Godin⁴ reminds us, innovation initially emerges in Ancient Greece with a political connotation and is fundamentally understood as “introducing change into the established order” (Godin 2015, p. 5). Consider, for example, the following citation from Plato’s *Republic*, in which Socrates despises the role of innovation in gymnastics and music:

Now, to state it briefly, the overseers of the city must cleave to this, not letting it be corrupted unawares, but guarding it against all comers: there must be no innovation in gymnastic and music contrary to the established order; but they will

³ Although this saying was never officially published, it is used across the internet.

⁴ As a professor and researcher at INRS (Institut national de la recherche scientifique, Montreal, Canada), Benoît Godin is currently conducting a long-term research project on the intellectual history of innovation, from Antiquity to the present. We acknowledge the extensive findings he has made, and consider them as the main source of inspiration for writing Sect. 2.

guard against it as much as they can, fearing that when someone says “Human beings esteem most that song. Which floats newest from the singer” someone might perchance suppose the poet means not new songs, but a new way of song, and praises that. Such a saying shouldn’t be praised nor should this one be taken in that sense. For they must beware of change to a strange form of music, taking it to be a danger to the whole. For never are the ways of music moved without the greatest political laws being moved, as Damon says, and I am persuaded. (Plato 1991, 424b–424c)

It is important to note here that innovation does not refer to the simple introduction of new music but to the introduction of a new *way* of making music. For Socrates, a new way of making music may lead to new laws and ultimately change the political order. By playing this dangerous, subversive, and revolutionary role, Socrates thus shares a political understanding of what innovation means. Aristotle carries a similar understanding of innovation as he places the concept within the context of changes brought to political constitutions (Aristotle 1984). Aristotle further emphasizes the subversive role of innovation when he accuses Plato of innovating the supersensible world (Evangelio 2006), an innovation that would radically change the course of Western philosophy.

The political connotation of innovation continues to dominate in the period from the Reformation to the nineteenth century (Bontems 2014; Godin 2015). Throughout this era the concept is mostly used to denote radical changes that ruin, trouble, and dissatisfy the state (cf. Burton 1976). In this respect, the Catholics of the time see the Reformation as a dangerous innovation (Godin 2016). Hence, similar to how innovation was understood in times dating back to Ancient Greece, during this later period innovation is fundamentally understood as a political concept used to denote whatever threatens the established order.

Although historically the concept of innovation has been understood as subversive and revolutionary, it is to a lesser extent also referred to in a more positive sense. As opposed to Plato and Aristotle, Xenophon, for example, says that innovation increases revenues for the city of Athens (Xenophon 2013). Likewise for the Romans, and later on for Renaissance thinkers such as Machiavelli (1961) and Bacon (1625), innovating ultimately means contributing to the stability of society rather than to its destruction (Bontems 2014). Nevertheless, up until the nineteenth century, it is the subversive and revolutionary understanding of innovation that dominates over any other of its connotations (Godin 2015).

As Godin’s historical analysis reveals, it is only after the beginning of the nineteenth century that the concept really starts to have a positive connotation. This is mainly because innovation now gradually enters a context in which progress and utility are widely praised. In response to this new context, innovation becomes an honorable concept (Godin 2015). Whereas in the preceding centuries the term innovation had mostly appeared in religious and political pamphlets, it now increasingly appears in books, scientific journals, and magazines aimed at the general reader. In this literature the subversive aspect of the concept has disappeared and the concept is instead used to denote the achievements of and developments made in mechanics, mathematics, geography, astronomy, and basically all the useful arts and science (cf. Pigott 1792;

Table 4 An overview of the concept of innovation throughout history

Historical period	Worldview	The concept of innovation
± 380 BC–1800	The ideal of maintaining stability	Innovation as political (subversive and revolutionary)
± 1800–1850	The ideal of achieving progress	Innovation as associated with the achievements made in all types of spheres of society (e.g., mechanics, mathematics, geography, astronomy, science)
± 1850–today	The ideal of achieving technological and economic progress	Innovation as technological and commercial (over the last 60 years referred to as technological innovation)

Robinson 1782). Noticeably, throughout this period the concept of innovation does not yet designate any intrinsic relation between technology and the market, as is implicit in the way we commonly understand innovation today. It is used to characterize new technologies such as mining (Blavier 1806) and printing (Comte 1877), but is by no means restricted to them, let alone to their commercial value.

The field of commercialized technologies only enters the daily discourse of innovation insofar as the domain of mainstream economics becomes more prominent. Especially after political economists such as Joseph Schumpeter introduced the term ‘technological innovation,’ the concept of innovation generally becomes defined in terms of technological goods and products (Godin 2015). Over the last 60 years, mainstream economics has become so dominant that it has largely taken over the entire discourse of innovation. The concept is now claimed to first and foremost pertain to the business world, and is even said to originate in a tradition of economic analysis (Staudenmaier 1985; Cajaiba-Santana 2013).

Arguably, the history of innovation teaches us that the meaning of innovation shifts according to the dominating worldview of the context in which it emerges. In times when the ideal of maintaining stability is most prominent, innovation is considered a threat to society and thus widely labeled as a pejorative concept. As the ideal of maintaining stability is replaced by the ideal of achieving progress, both within and beyond technology, innovation gradually starts to have a positive connotation. After the industrial revolution, and with the rise of mainstream economics, the commercial value of new technologies becomes more acknowledged than ever before. This ultimately leads to the current dominance of technological innovation, a concept that presupposes an intrinsic relation between technology and the market; overshadowing the original political character it once had (Table 4).

4 RRI and the Call for an Alternative Concept of Innovation

Taking the findings of Sects. 2 and 3 into account, it is clear that with the emergence of RRI, innovation has entered a turbulent age. On the one hand, by presupposing

innovation to be technological, RRI can simply be seen as the product of a history in which the ideals of technological and commercial progress have continued to be prioritized. On the other hand, the RRI literature repeatedly stresses the political context of today: innovation needs to go beyond its usual intent of generating commercial value and should instead be concerned with generating the right impact, particularly with regard to the grand challenges of our time, for which we all share responsibility (von Schomberg 2013). Given the indeterminacy of the right impact and the complexity of these grand challenges, it becomes all the more urgent to develop a political discourse of innovation in which the ethical acceptability, sustainability, and societal desirability of innovation processes are ensured in an inclusive and democratic way (Owen et al. 2012; European Commission 2015). In this respect RRI promises to be revolutionary. Therefore, to a certain extent, RRI reawakens the political origins of innovation; this in striking contrast to what its presupposed concept of innovation suggests.

The question is whether the call for a political discourse of innovation is undermined by the ideals of technological and economic progress inherent in the way innovation is currently at play in the RRI literature. To what extent does RRI, in order to attain its societal purpose, need to question these ideals and thereby rethink the current—technological—concept of innovation? In what ways could an alternative concept of innovation be more successful in confronting today's grand challenges? In light of these questions, the purpose of this final section is twofold. First, we account for how the presupposed concept of technological innovation affects the feasibility of RRI. In this respect, we offer an analysis of the way in which this concept of innovation can be both beneficial and detrimental with regard to the societal purpose of RRI. Second, on the basis of this analysis, we philosophically reflect on the ways in which an alternative understanding of innovation could be more fruitful.

On the one hand, the imperative of economic growth inherent in technological innovation is said to be fundamentally at odds with the imperative of solving today's societal and environmental issues. Arguably, this focus on economic growth is the main source of today's increasingly unequal distribution of wealth (cf. Rolston III 2012; Naudé and Nagler 2016), and as "the root cause of many environmental problems" it stands "in direct conflict with sustainability" (Huesemann and Huesemann 2011, p. 256). The latter is confirmed when examining the relatively recent increases in pollution, waste disposal, water shortage, global warming, deforestation, natural resource depletion, loss of biodiversity, and public health issues, increases that can be considered to be the results of technological and economic progress attained through innovation (Huesemann and Huesemann 2011; Purdy 2015).

On the other hand, technological innovation is said to be perfectly compatible with the ideal of solving today's societal and environmental issues. Many technocrats claim that technological innovation will simply overcome these issues, as it has in the past. This is shown in the history of Venice. Ever since its founding, "[s]aving Venice has meant creating Venice, not once, but many times" (Shellenberger and Norhaus 2011, p. 9). Each recreation of the city would come with "a series of pretentious, costly, and environmentally harmful technological gambles" (Shellenberger and Norhaus 2011, p. 9), which would then be solved by once more recreating the city, and so technological innovation "helped transform a town of humble fisherfolk into the city we know today" (Shellenberger and Norhaus 2011, p. 9). The optimism illustrated

here indicates that it is counterproductive to question the concept of technological innovation in frameworks such as RRI, because it enables the desirable future that these frameworks ultimately call for.

The ongoing faith in technological innovation is further justified when considering the role it can play in restoring the ecological system of planet earth. In the face of an accelerating pace of environmental destruction, technological innovation can, for instance, aid in the conservation of nature by providing new ways for forests, wetlands, and diverse species to exist amid a wide range of modern, human landscapes (Kareiva et al. 2011). Similarly, the introduction of green nanotechnology has been shown to enhance environmental sustainability in at least two respects. First, it includes the development of clean technologies that “minimize potential environmental and human health risks associated with the manufacture and use of nanotechnology products” (Shah et al. 2014, p. 157); and second, it encourages the “replacement of existing products with new nano-products that are more environmentally friendly throughout their lifecycle” (Shah et al. 2014, p. 157). Another example of a technological innovation that promises to tackle current environmental issues is the electrolysis of water. Having now reached a commercialized status, the electrolysis of water is considered to be a crucial technology in the production of hydrogen, a transport fuel used in vehicles that have a fuel cell or an internal combustion engine; using hydrogen is likely to overcome the concerns related to greenhouse gasses and other polluting emissions (Badwal et al. 2014). Examples such as these illustrate the success that technological innovation can achieve with regard to confronting the grand challenges of our time, and to a certain extent thus dismiss the need for frameworks such as RRI to articulate an alternative concept of innovation.

However, it is in fact in the call to *steer* innovation that the presupposed concept of technological innovation in RRI becomes questionable. The emergence of RRI and the use of the term ‘responsible innovation’ suggest that in fact innovation is not always that responsible (Blok and Lemmens 2015). Due to the negative impact that innovation can have on society and the environment, the aim of RRI is to ensure that innovation is ultimately steered into a responsible and desirable direction to avoid the creation and use of harmful technologies and to encourage the introduction of technologies such as the ones described above. The question is whether technological innovation can be steered in the way RRI suggests and in what ways an alternative concept of innovation could be more fruitful in this regard.

One of the problems with steering technological innovation is that it requires a mutual agreement concerning the direction it needs to be steered in. While RRI to some degree presupposes a consensus with regard to the grand challenges, in practice the various stakeholders involved in processes of technological innovation often differ in their definition of what exactly these challenges are and in their approach to solving them (cf. Kroesen et al. 2015). These differences are mainly due to opposing agendas and motives of, for example, for-profit and nonprofit organizations (Yaziji and Doh 2009). As a result of power imbalances—the engineers who build the technology or the company that funds it naturally tend to have more power than, for instance, the wider public—the differences among stakeholders are not always collectively dealt with and they often end up in conflict (Bryson et al. 2006). In practice, therefore, processes of

technological innovation do not easily adhere to the common ground from which the RRI literature departs.

Another problem with steering technological innovation is that RRI calls for complete transparency among all stakeholders involved in this process. From a business perspective this call for transparency can be said to be naive, because it is undermined by the competitive advantage a new technology needs in order to succeed on the market (Blok and Lemmens 2015). To achieve this competitive advantage, companies rely on information asymmetries, that is, additional knowledge they have about business opportunities that other companies are unaware of. In the context of RRI, companies seek such information with regard to finding new solutions for existing and anticipated grand challenges. However, transparency among the involved stakeholders evidently entails a reduction of these information asymmetries, thereby taking away the main source of competitive advantage. In the field of commercialized technologies, therefore, the ideal of achieving a transparent collaboration among all stakeholders involved is simply unrealistic (Blok and Lemmens 2015).

Furthermore, the unexpected outcomes of emerging technologies bring into question the extent to which technological innovation *can* be steered into a responsible and desirable direction. Even though incorporating the different dimensions of RRI in the innovation process may decrease unforeseen societal and environmental consequences, this is not guaranteed (Rammert 1997). During the development of biofuel for example, the involved stakeholders argued that because it is inherently renewable, locally produced, and less polluting, its introduction to the market would promise responsible and desirable outcomes. However, as a result of the increased demand for biofuels, farmers had to grow more crops for biofuel production, which in turn led to an increase in the price of food. An increase in the price of food was not initially anticipated and now brings into question whether the introduction of biofuels was in fact responsible and desirable, especially considering that people in developing countries were negatively affected by this unexpected outcome (Blok and Lemmens 2015). In other words, the ideals of RRI cannot be attained insofar as the outcomes of technological innovations cannot be known. Unknown outcomes are in fact a crucial characteristic of technological innovation (Rammert 1997), so the feasibility of RRI can be contested in this regard.

The difficulties described above indicate that the presupposed concept of technological innovation needs to be widened; they also call for future research on RRI to philosophically reflect on how an alternative concept of innovation could better enable the applicability of its frameworks. To this end, we propose that future research investigates a concept of innovation in which the differences among stakeholders do not hinder the societal purpose of RRI, and can perhaps even be empowering (cf. Blok 2014). Moreover, this alternative concept of innovation should originate from sources that do not need information asymmetries. Finally, it should overcome the fundamental uncertainty that comes with technological innovation. In doing so successfully, innovation processes would be more ready to be steered in the way RRI suggests.

Since frameworks of RRI explicitly prioritize political ends, it would be valuable for future research on RRI to enquire into a political understanding of innovation. Even though such an understanding was historically given a negative connotation for its disruption of the established order, in today's context it could open up ways of

responding to today's grand challenges that move beyond a merely technological and commercial orientation. It is in this direction that Blok (2019) develops a political dimension of innovation in which the direction of the innovation process is essentially determined by a political agenda. In this view, the innovation process is no longer set by commercial ends, but rather by, for example, the Paris agreement on mitigating global warming and the UN Sustainable Development Goals. This enables a more encompassing understanding of innovation that could also, for instance, draw attention to social innovations that are currently overshadowed by their commercial alternative. Instead of, for example, limiting the discussion of the overconsumption of meat to the possible benefits and implications of in vitro meat, this broader concept of innovation may also include considering *innovative* ways of simply empowering non-meat protein sources and may further enlarge the scope to apply, for instance, user-based innovations, open source and peer-to-peer (p2p) innovation strategies. Hence, by employing a political understanding of innovation, societal and environmental issues would no longer have to solely depend on technological and commercial solutions, thereby enabling RRI to primarily respond to its political ideals.

In this final section we have come to realize that even though technological innovation may possess characteristics that hinder innovations from contributing to human welfare and environmental sustainability, these very same characteristics also ensure that innovations enhance such a contribution. Upon closer examination, however, it is particularly in the call to steer innovation that the presupposed concept of technological innovation in RRI becomes questionable. The question is no longer what characteristics innovations must have in order to *be* responsible and desirable, but what characteristics innovations must have in order to be *steered* in a responsible and desirable direction. In this respect, we have argued that because processes of technological innovations come with fundamental differences of opinion among the involved stakeholders, information asymmetries, and unpredictable outcomes, the ideal of steering processes of this nature is somewhat naive. On the basis of this insight we have shown how future research on RRI can investigate an alternative concept of innovation that better enables the applicability of RRI and—departing from our historical analysis—have exemplified this by relating the political origins of innovation to ongoing research that adopts a more encompassing understanding of innovation.

5 Conclusion

The departure point of this paper lies in the observation that even though scholars committed to RRI continually attempt to formulate precisely what a political discourse of innovation entails, little thought goes into what innovation means conceptually. Uncritically understood as technological innovation, today it is widely associated with the field of commercialized technologies. The analysis in Sect. 2 showed that this conception is reflected throughout the RRI literature, in which the terms 'innovations,' 'technologies,' and 'products' are used interchangeably. This was further confirmed by the examples provided, which among others include synthetic biology, nanotechnology, and ICT.

By examining the different understandings of innovation over time and how they alter according to the dominating worldview of the context in which they emerge, Sect. 3 attempted to enable a more comprehensive grasp of the definition of a concept that today is widely considered to be self-evident. In this respect, we learned that innovation did not originate in economic analysis, as is commonly claimed. From antiquity to the Reformation, innovation is seen as a pejorative concept that threatens one of the most prominent ideals of that period: maintaining a stable society. Since innovation may destabilize the established order, it is given a political connotation. Only insofar as the ideal of stability is replaced by the ideal of progress does the concept of innovation receive a more positive connotation. It is not until the more specific ideals of technological and economic progress are introduced that the concept of innovation develops into what we know it to be today: technological innovation.

Based on the findings made in the first two sections, Sect. 4 noted that with the emergence of RRI, the concept of innovation has now entered a turbulent age in which it is given a political role, yet at the same time restricted to a technological and commercial context. On the one hand, the tensions between the imperative of economic growth and the imperative of solving today's grand challenges bring into question whether the ideals of RRI can ever be realized insofar as the concept of innovation is presupposed as technological. It is clear that ever since innovation has been understood in terms of technological and economic progress, it has contributed to today's increasing social inequality and is one of the leading causes of the present environmental crisis. Conversely, the very same concept of innovation that is said to hinder the societal purpose of RRI is also said to help achieve it. Technological innovation has been proven to overcome societal and environmental issues in the past, and the introduction of, for instance, green nanotechnology promises to do so in the future. The optimism illustrated here indicates that it is counterproductive to question the concept of technological innovation in frameworks such as RRI, because it does in fact enable the desirable future that such frameworks ultimately call for.

Upon further reflection, however, we showed that it is in fact in the call to steer innovation that the presupposed concept of technological innovation in RRI becomes questionable. We argued that it is somewhat naive to democratize innovation processes in which differences among stakeholders are inevitable and information asymmetries a requisite, and whose eventual outcomes are unpredictable. For this reason, we call for future research on RRI to explore an alternative concept of innovation—one that does justice to the political origins of innovation and that thereby possesses characteristics that are less susceptible to the flaws diagnosed in technological innovation. A political understanding of innovation does not necessarily have to exclude technological innovation, which to a certain extent has been shown to have the potential to contribute to the societal purpose of RRI. However, when the innovation process is essentially set by a political agenda, rather than by commercial ends, it enlarges the scope of innovation in a way that means it is directed to the needs of the world rather than being restricted to those of the market.

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