A comprehensive appraisal of responsible research and innovation

From roots to leaves

Wiarda, Martijn; van de Kaa, Geerten; Yaghmaei, Emad; Doorn, Neelke

DOI
10.1016/j.techfore.2021.121053

Publication date
2021

Document Version
Final published version

Published in
Technological Forecasting and Social Change

Citation (APA)
Wiarda, M., van de Kaa, G., Yaghmaei, E., & Doorn, N. (2021). A comprehensive appraisal of responsible research and innovation: From roots to leaves. *Technological Forecasting and Social Change*, *172*, Article 121053. https://doi.org/10.1016/j.techfore.2021.121053

Technological Forecasting & Social Change 172 (2021) 121053

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

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

A comprehensive appraisal of responsible research and innovation: From roots to leaves

Martijn Wiarda *, Geerten van de Kaa, Emad Yaghmaei, Neelke Doorn

Delft University of Technology, Faculty of Technology, Policy, and Management, Department of Values, Technology, and Innovation, Jaffalaan 5, 2628 BX Delft, the Netherlands

ARTICLE INFO

Keywords:
Responsible research and innovation
RRI, Responsible innovation
RI
Bibliometric analysis
Knowledge base
Reference publication year spectroscopy
RPYS

ABSTRACT

Responsible Research and Innovation and Responsible Innovation, as academic endeavours, have grown substantially since their birth in the previous decades. They have been used as synonyms on a structural basis, and both concepts have been studied from various disciplinary backgrounds. This paper identifies Responsible Research and Innovation's and Responsible Innovation's shared research topics, knowledge base, and academic organisation as a common ground for scholars to further their individual or joint research. It does so by conducting a keyword analysis and a collaboration analysis, combined with a reference analysis of their academic literature. This paper discusses the most influential references in chronological order and sheds light on the accumulation of knowledge. The results suggest that Responsible Research and Innovation and Responsible Innovation have matured into an increasingly cumulative and interconnected research trajectory following the footsteps of similar, more mature research areas.

1. Introduction

Responsible Research and Innovation (RRI) and Responsible Innovation (RI) have gained increasing attention since their births in the previous decades (Owen et al., 2012; Owen and Pansera, 2019; Rip, 2016). They have often been described as inclusive and risk-mitigating approaches to innovation and research (R&I) activities in the process of broader techno-socio-economic transformations. The European Commission and a number of researchers expect that RRI can help to address the 'grand challenges' of society and create sustainable economic growth while minimising negative externalities of R&I (Von Schomberg, 2013). RRI as an academic endeavour is supported by the European Commission through its European Framework Programmes to better comprehend this approach, understand its implications, and potentially institutionalise this into our society (de Saille, 2015; Zwart et al., 2014). While RRI has largely flown out of the European policy domain (Owen and Pansera, 2019), RI stems from a longer tradition of science and technology studies (STS) and ethics and is thereby both an old and new concepts (Stilgoe et al., 2013). It can thus be argued that RI is a rather bottom-up research stream while RRI stems from a top-down vision (Loureiro and Conceição, 2019). Throughout both their existences, they have been criticised, opposed, endorsed, and transformed from various academic perspectives (Blok and Lemmens, 2015; de Hoop et al., 2016; Macnaghten et al., 2014; Nordmann, 2014; Stilgoe et al., 2013). As a result, their respective academic landscapes have grown significantly (Burget et al., 2016; Ribeiro et al., 2017). While RRI and RI are now often used as synonyms, some scholars argue that they remain different concepts (Owen and Pansera, 2019). This has caused confusion in an already multidisciplinary and complex dialogue.

Over five years ago, a few scholars attempted to create clarity in RI's and RRI's 'academic jungle' by conducting literature reviews (Blok and Lemmens, 2015; Burget et al., 2016; de Saille, 2015; Owen et al., 2013; Randles et al., 2015; Ribeiro et al., 2017; Timmermans, 2017; Zwart et al., 2014). After that, scholars have attempted to link RRI and RI to specific topics (Martinuzzi et al., 2018; Thapa et al., 2019) or to review its institutionalisation (Genus and Iskandarova, 2018). More recently, Fraaije and Flipse (2020) have provided a review in which RI is named 'RRI's cognate'. However, Shanley (2021) and Smolka (2020) subsequently argue the contrary, and use the term R(R)I to emphasise their shared community while appreciating their differences. However, few authors explicitly consider the different origins of RRI and RI.

Furthermore, while their interaction could be academically and

* Corresponding author.
E-mail addresses: m.j.wiarda@tudelft.nl (M. Wiarda), G.vandeKaa@tudelft.nl (G. van de Kaa), E.Yaghmaei@tudelft.nl (E. Yaghmaei), N.Doorn@tudelft.nl (N. Doorn).

https://doi.org/10.1016/j.techfore.2021.121053
Received 20 October 2020; Received in revised form 13 May 2021; Accepted 17 July 2021
Available online 28 July 2021

practically promising, it may still be worthwhile to explore what the two concepts have in common and whether we should leave room for differences as well. If their relationship is to be of value, then it is important to identify their common ground intellectually (theoretical) as well as organisationally (collaborative) for future research agendas and inbreed. No recent review has reliably identified the shared knowledge base of these fast growing academic communities nor have they assessed the vast evolution of their knowledge. This is plausibly the case due to a lack of available and reliable bibliometric tools and a lack of complete databases. These hurdles have now been overcome by the development of a relatively novel scientometric method called a reference publication year spectroscopy (Marx et al., 2014), which allows scholars to quantitatively identify the foundational knowledge on which RRI and RI rely.

This study aims to identify the shared foundation of the RRI and RI literature, and crudely assesses their overlapping topics of interest, collaborative development, and overall maturity based on a mixed quantitative-qualitative reference (bibliometric) analysis.

This paper contributes to the literature in several ways. First, it examines RRI's and RI's growth and cognitive- and collaborative developments, to subsequently reveal the conceptual state in which they find themselves. Second, by doing so, it creates awareness of RRI's and RI's academic organisation and shared literature as a starting point for promising future research directions and as input for a collective and consentaneous research agenda. Generally, such a consensus would aid in achieving a greater knowledge accumulation (Evans, 2007).

2. Method

2.1. Data collection

As input, we collected publication metadata from the database Web of Science (WoS). All titles, author keywords, keywords plus®, and abstract words of English articles published between 2010 and 2019 containing 'responsible research and innovation', 'responsible research and innovation', or 'responsible innovation' have been retrieved. The respective period has been chosen since 2010 forms a turning point that marks the upsurge of publications produced on the topics (Thapa et al., 2019). In addition, 2011 and 2013 are generally considered to be important years for RRI's and RI's development due to the influential contributions of Von Schomberg (2011) and Stilgoe et al. (2013). It thus allows us to take stock of the fields before and after these publications. Our data collection resulted in a sample of 508 articles (Table 1).

2.2. Data analysis

We analysed the articles by using the open-source R-package of Aria and Cuccurullo (2017) named Bibliometrix, which assists the data collection (loading and converting), analysis, and visualisation[1].

We used a keyword and a collaboration analysis as a bibliometric assessment to capture the cognitive and collaborative developments. Furthermore, we conducted a reference analysis to identify the shared knowledge base of RRI and RI as input for the review of the literature (Fig. 1).

Table 1
Document types in the collected sample from the WoS.

Document types	N.
Articles	449
Articles, Book chapters	45
Articles, Early access	11
Articles, Proceeding papers	3

[1] The Bibliometrix visualisation process is further supported by the tool VOSviewer.

2.2.1. Cognitive and collaborative developments

Cognitive and collaborative developments were analysed by conducting a co-word analysis (Callon et al., 1983) and a co-author analysis (Newman, 2004; Subramanyam, 1983; White and McCain, 1998). Both analyses are constructed by connecting author keywords or co-authors that return in the same document, resulting in the clustering and mapping of keyword and co-author structures in the form of networks. Hence, a sequence of annual networks provides insight in RRI's and RI's evolution. The sequence of keyword co-occurrence networks provides insight in the cognitive evolution through the semantics of author keywords. It additionally, provides insight in the way RRI and RI are, and are not, connected content wise. The co-author collaboration network visualises the evolution of the explicit academic collaborations and therefore provides information about the academic organisation of RRI and RI. Moreover, collaborations can stimulate the exchange of (tacit) knowledge (Katz and Martin, 1997) and by doing so, spur cognitive progression and interconnectedness (Phelps and Heidl, 2012). The years 2010, 2015, and 2019 have been visualised in this paper to illustrate their overall evolution in the past decade.

2.2.2. Reference analysis: RRI's and RI's common foundations

This study uses a reference publication year spectroscopy (RPYS) (Marx et al., 2014; Thor et al., 2016). This quantitative reference analysis method identifies the most influential contributions found in the reference lists of the 508 RRI and RI publications. In other words, the RPYS identifies the shared knowledge base of RRI and RI which has functioned as the foundation for their academic contributions. The method maps the data spectroscopy by computing the number of cited references per publication year of the 508 publications. Subsequently, it computes the deviation of each publication year from a 5-year median period to reveal the years that are cited exceptionally well relative to its time. Within the given year, the outlying references needed for the historical overview are then provided. The RPYS is further supported by a manual check on anomalies in most recent years (2010-2019) to ensure the inclusion of more recent influential contributions in which citation distributions are less skewed, and hence in which deviations are less noticeable.

The RPYS has become an increasingly popular method for identifying a topic's historical roots, and has been used in various fields (e.g., Khasseh and Mokhtarpour, 2016; Moral-Muñoz et al., 2020). This method has several benefits. It recognises anomalies in the reference citation distributions relative to its time (1). Moreover, it helps scholars to objectively and quantitatively find influential knowledge (2) in any explicit form (articles, book chapters, reports, etc.) (3), and to do so for literature that is significant to RRI's and RI's community as opposed to science in general (i.e. cited by RRI and RI articles vs cited by articles in general) (4). The fact that the knowledge base is not limited to publications in the WoS database is especially relevant for RRI, as the literature of interest generally contains many citations to non-journal papers, particularly in the period before the launch of the *Journal of Responsible Innovation* in 2014.

3. Results

3.1. Bibliometric analysis

3.1.1. Descriptive statistics

The 508 RRI and RI articles in our sample were published in 217 different sources, contained 1387 unique keywords, and were cited on average 8.9 times. To avoid confusion between the keywords provided by the authors and the words distilled from the title and the abstract, we refer to the former as the author keywords. This study found 1556 unique authors. The number of authors and articles increased consistently throughout the period (Fig. 2). The graph shows how RI was more

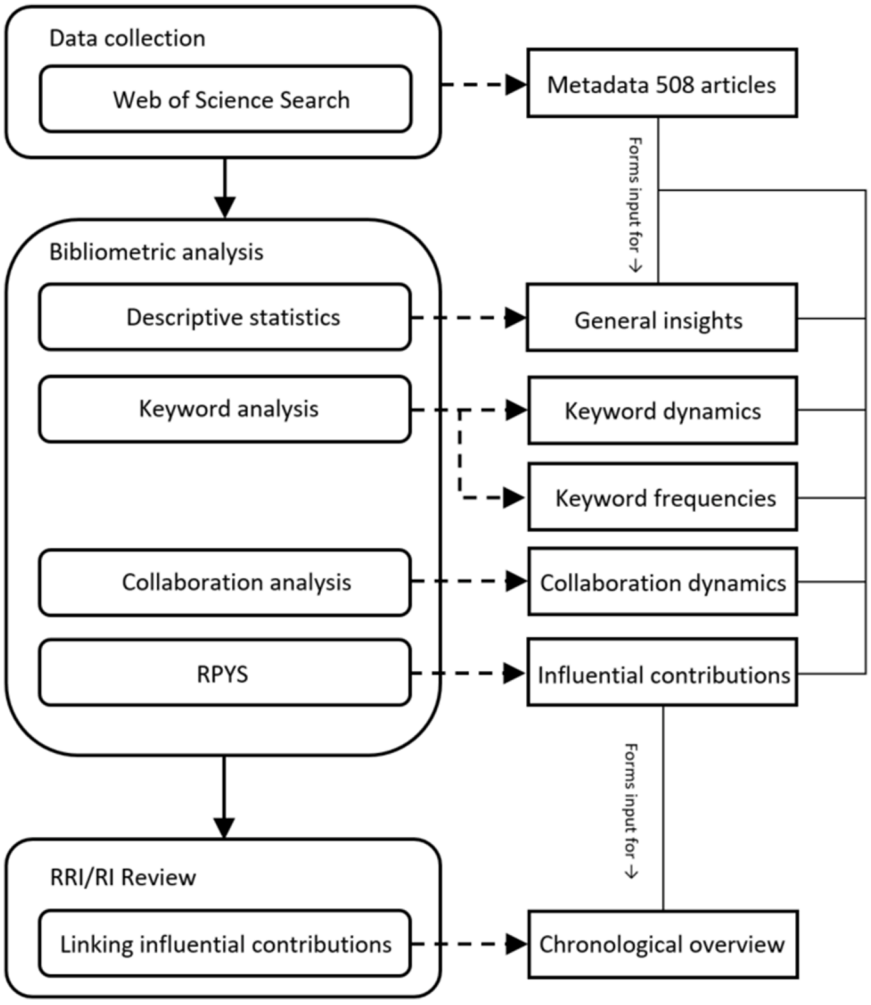

Fig. 1. Process-deliverable diagram of research method.

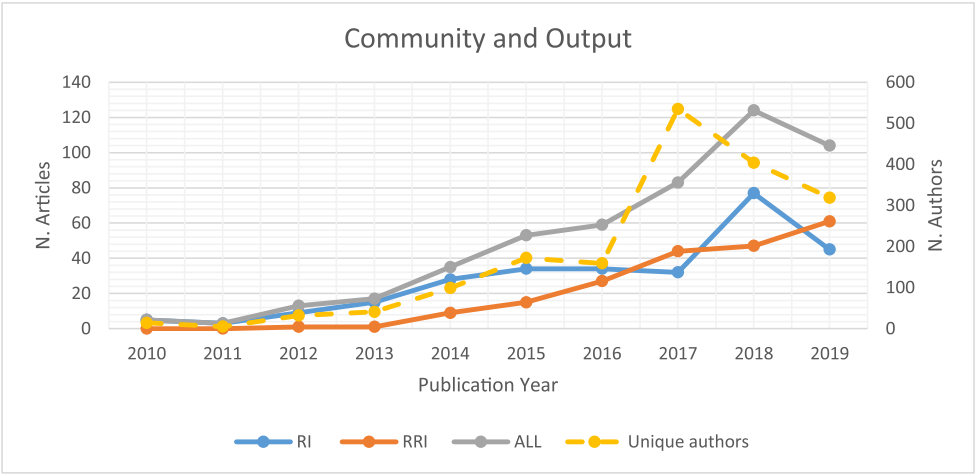

Fig. 2. Academic community size and output.

prevalent in the literature until 2016. In more recent years, RRI has grown to become a topic of academic concern of a similar magnitude.

3.1.2. Keyword analysis

Our keyword analysis aims to establish a semantic representation of RRI and RI. The most frequently used keywords, abstract words, and title words of RRI, RI can be found in the Appendix. Bibliometrix extracts terms and neglects stop words for abstract words and title words. The results show that RRI and RI predominantly focus on the governance and ethics of research and innovation. Industry related terms such as 'corporate social responsibility', 'industry' and 'management' score relatively low and could have received less attention. In addition, only

31 of the 508 articles contain the word 'case', suggesting a relatively small proportion of case studies, which seem to have been done more for RI than RRI. The keyword co-occurrence networks of 2010, 2015 and 2019 (Fig. 3) show that RRI and RI have gradually evolved and merged into interconnected clusters. Before the introduction of RRI's definition (Von Schomberg, 2011), the network mainly consisted of RI driven research (see the upper left panel in Fig. 3, showing the results for 2010). The network suggests that RRI has eventually situated itself in the RI literature. The topics 'public engagement', 'governance', 'emerging technologies' (e.g. nanotechnology and synthetic biology), and 'ethics' form the locus of their overlap. The 2019 network suggests that topics such as 'public engagement', 'governance', 'anticipatory governance', and 'social innovation' have received increased attention along other rooted topics such as 'ethics of research' and 'science and technology policy'. Weakly connected clusters visualised by network gaps and branches could indicate potential research opportunities. Some examples of this relate to 'education', 'big data', and the 'broader impact'.

3.1.3. Collaboration analysis

This study uses a co-authorship analysis to assess the collaborative developments in RRI and RI. The author collaboration networks in Fig. 4 show collaborations in the year 2010, 2015, and 2019 to illustrate the overall evolution of RRI's and RI's community. The first period was characterised by just a few isolated author groups dedicated to RI. The network has grown throughout the decade with the appearance of more authors and clusters. However, the network density decreased, indicating that many scholars work in isolated research groups. The majority of large clusters represent single papers published by a large number of, often EC funded, co-authors. For example, the dominant red cluster in 2019 is the result of a single article written by 39 authors from various organisations working on the STARBIOS2 project funded by the EC (Colizzi et al., 2019). Few authors in the network have taken in broker positions to mediate between clusters, and as a result, inter-cluster collaborations are rare. Collaboration statistics in Table 2 suggest that the percentage of inter-organisational collaborations has fluctuated around 50%, but does not show a consistent trend.

Overall, there have been frequent academic (inter-organisational) collaborations. However, few inter-cluster collaborations take place. As a result, many scholars work in small isolated groups. The few larger groups are often the result of one single multi-authored paper.

3.2. RRI's and RI's common foundations: a chronological overview

The earliest documents to be cited by RRI's and RI's body of literature were written by historical writers such as Francis Hutcheson (1725), Adam Smith (1759, 1776), David Hume (1777), Jeremy Bentham (1781), and Immanuel Kant (1785,1787). RRI's and RI's foundation thus lays predominantly in (moral) philosophy with early on links to sociology and economics. Schumpeter (1934) eventually strengthened links to economics. He introduced the concept of 'creative destruction' and is arguably one of the first to elaborate on the significant economic, if not societal, effect that can be brought about by innovation. Several years later Bernal (1939) analysed the link between science and socio-economic development, hence, pioneering 'responsible research' through linking science with morality by underlining scholars' broader societal impact. His view that scientists should establish stronger linkages with public affairs was considered to be controversial.

3.2.1. Science for society?

This discourse eventually found itself increasingly more in the context of warfare. Bush's (1945) report, Science, The Endless Frontier, solicited for a more centralised control of (basic) science in which a scholar's curiosity and the societal demand would meet. The report highlighted the government's responsibility for the progress of the nation, if not mankind. The devastating nuclear attack on Japan two weeks after the report was published, and the success of recent scientific breakthroughs (e.g. radar and penicillin) contingently enforced the message and drastically changed research policy. According to Charles Lindblom (1959), this synoptic approach of decision-making in US post-war policy practices was, in reality, less systematic and controlled ex ante than it seems. Lindblom suggested that policymakers were 'muddling through' due to their 'bounded rationality' resulting in non-comprehensive policy analyses and plans. He argued that it exemplified incrementalism, which here refers to an evolutionary public policy trajectory in which minor policy changes are designed and implemented in a gradual manner to attain a greater societal change. This is a process of trial-and-error in which one uses experience as input for future practices. Parallel to this policymaking debate, Michael Polanyi, provided a seemingly incompatible view with Lindblom's in his essay, The Republic of Science: Its Political and Economic Theory (1962). He described the scientific community as a system of mutually complementary actors that independently work on scientific initiatives and are focused on inter-determined intellectual objectives. It does not require external 'muddling' due to entrenched conformities, established by the constantly self-renewing academic authorities. He calls this community 'the republic of science' and advocates for autonomous scientists primarily driven by the satisfaction of their curiosity. As Polanyi (1962) claims: 'And as they [scientists] satisfy themselves, they enlighten all men and are thus helping society to fulfil its obligation towards intellectual self-improvement' (p. 64). This call for autonomy implies a direct opposition with Lindblom's interventionist 'muddling through' policy practice, and possibly distances science from society.

That same year, Thomas Kuhn (1962) published his influential book, The Structure of Scientific Revolutions , and provided a novel perspective on the progress of science. Kuhn argued that the scientific system is more complex than the, back then, prevailing perspective that knowledge develops by a consistent accumulation and thence is only incremental in nature. He explains that occasionally radical breakthroughs cause a scientific paradigm shift and form a major academic leap which creates numerous new research (and societal) opportunities. This, as Polanyi would likely agree, gives way for organisational change and the renewal of scientific authorities.

3.2.2. Innovation and its sociotechnical nature

After the 1950s, academic contributions were more related to innovation (management), partly elicited by Wiener's perspective on automation ethics (1954), and Everett Rogers innovation theory (1962). Wiener was concerned with the possible and uncertain effects of automation on society and implicitly linked this to Schumpeter's creative destruction (Wiener, 1954). Rogers's theory aimed to describe and explain the process of innovation diffusion and adoption. He identified diffusion determinants and taxonomised adopter groups based on their innovativeness. Wiener and Rogers thence pioneered the relationship between technology, sociology, and economics. Collingridge (1980) theorised that attempting to control a technology is difficult because its future trajectory, impact, and externalities cannot be accurately predicted during its early stages. However, controlling it ex post is increasingly troublesome when the above-mentioned outcomes become more fixed and noticeable. These impacts and externalities can take on political forms according to Winner (1980). He argued that technologies can (un)intentionally embody norms and values which can enforce power structures, systems, sources, and ideologies. In a similar vein, Jonas (1984) advocated the need for a halt on society's reinforced techno-political system. This was motivated by his perception that the need for everlasting economic growth through technological progress was steering civilisation on a destructive path, creating a fatal reciprocal relationship between society and the environment. Concurrently, von Hippel (1988) identified the democratisation of innovation through his concept of user innovation. He observed that in some industries, users, not manufacturers, were responsible for a substantial number of innovation practices. Users are cognitively distant from manufacturers and exhibit personal 'sticky' knowledge that manufactures do not possess.

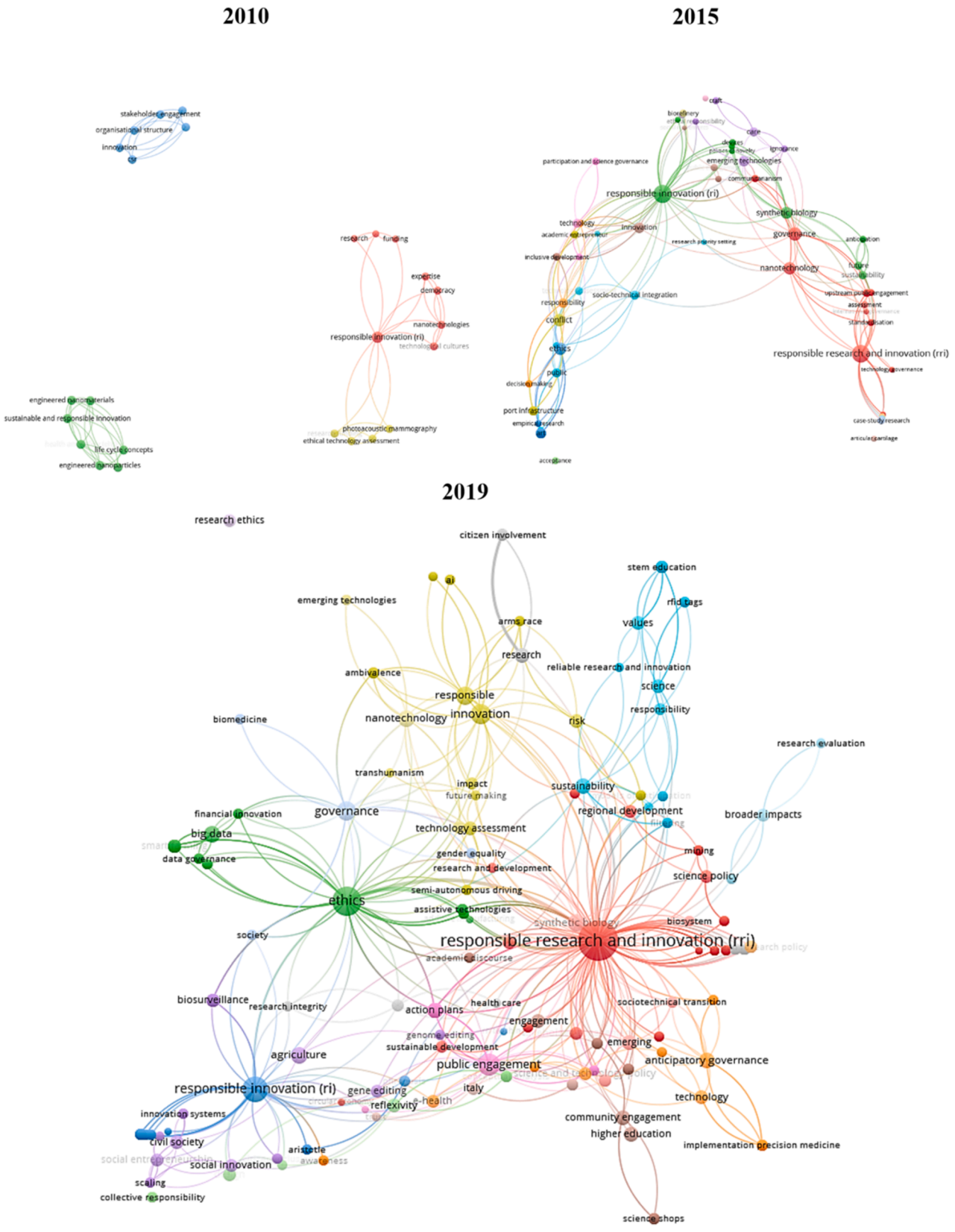

Fig. 3. Keyword co-occurrence networks (2010, 2015, 2019). Note: Nodes represent topics, and links represent the co-occurrence of topics in articles. Synonyms for Responsible Innovation (e.g. RI) and for Responsible Research and Innovation (e.g. RRI) have been aggregated to visualise the network more clearly.

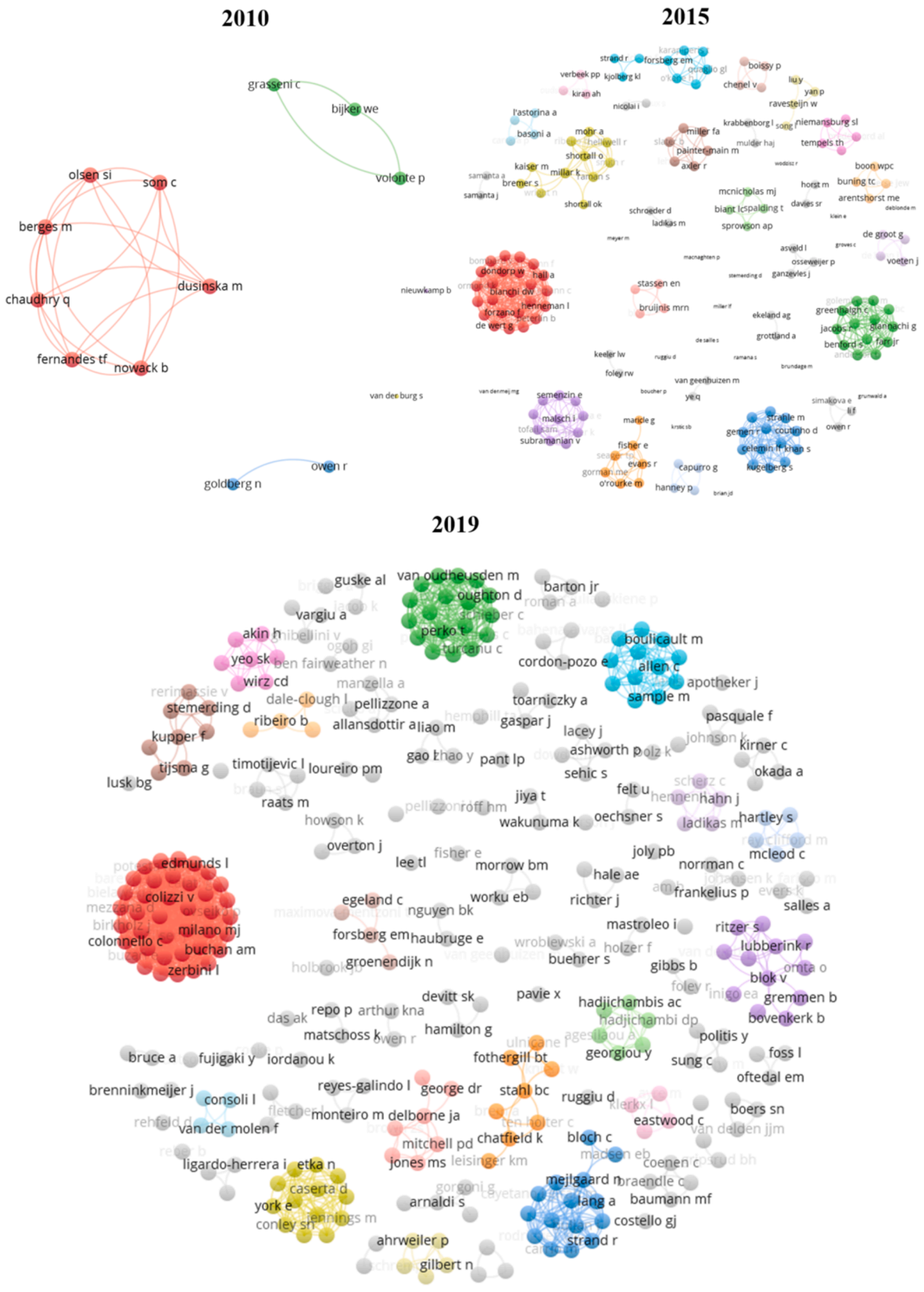

Fig. 4. Author collaboration network (2010, 2015, 2019). Note: Nodes represent authors, and links represent collaborations through co-authorships.

This information asymmetry forces some users to innovate in order to meet their own demands.

3.2.3. Reflexive modernity, technology assessment, anticipatory governance, and more

The sociologist Ulrich Beck (1992) took a different angle. He focused on the concepts of risk society and reflexive modernity. Risk society

Table 2
Collaboration statistics.

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Article count	5	3	13	17	35	53	59	83	124	104
N. multi-author articles	3	2	7	10	27	34	41	70	98	71
% multi-author articles	60%	67%	54%	59%	77%	64%	69%	84%	79%	68%
N. single-author articles	2	1	6	7	8	19	18	13	26	33
Mean authors per articles	2.8	1.7	2.5	2.8	3.7	3.3	2.7	6.5	3.3	3.1
Mean collaboration size	4.0	2.0	3.7	3.4	3.4	4.5	3.4	7.5	3.9	4.1
N. international collaborations	2	0	5	5	12	18	12	24	30	22
% international collaborations	40%	0%	38%	29%	34%	34%	20%	29%	24%	21%
N. inter-organisational collaborations	3	0	5	9	18	25	27	45	63	43
% inter-organisational collaborations	60%	0%	38%	53%	51%	47%	46%	54%	51%	41%

refers to the fundamentally different way modern society responds to anticipated risks, whereas reflexive modernity is described as a recent societal condition in which modern civilisation reassesses and shapes itself. At around the same time, Rip, Schot and Misa (1995) introduced Constructive Technology Assessment (CTA). CTA developed out of a longer tradition of technology assessment, focusing on including a wider set of stakeholders in the anticipation of plausible consequences of new technologies and technological developments (Schot and Rip, 1997). As such, they linked Beck's risk society to participation in decision-making on technological risks. Rowe and Frewer (2000) extended the topic of inclusive anticipatory approaches by evaluating public participation frameworks more holistically. They argue that both the process and acceptance of participatory decision-making should be considered for the selection of situational appropriate participation methods. Guston and Sarewitz (2002) developed real-time technology assessment as a more suitable tool for the continuously co-evolving sociotechnical decision process. Barben et al. (2007) advocated the need for more varied methods, materials, ideas, theories, etc. (referred to as research ensemble by Hackett et al., (2004)) from a wide range of researchers and policymakers inside and outside of the relevant field of interest. Barben et al. (2007) argue for the integration of these research ensembles in Guston and Sarewitz's (2002) concept of anticipatory governance. This 'ensemble-isation' forms the core practice of anticipatory governance. It goes further than anticipation simpliciter, as it includes empirical studies and analytics, and explicitly embraces imagination, uncertainty, and the proclivity to gain insight from experimentation.

In the first decade of this century, methods related to responsibility and ethics gained traction especially in the field of nanotechnology. Although nano-ethics questions were considered, it was argued that the broader New and Emerging Science and Technology (NEST) ethics might be more fruitful. NEST ethics addresses the emerging technology's uncertainty regarding its future capabilities, their implications, and the revision of moral routines in the light of this new technology. Hence the dynamics and interactions of these aspects caused a co-evolution of the technology and its corresponding ethics (Swierstra and Rip, 2007). Erik Fisher (2007) conducted a case study on this co-evolution in the field of nanotechnology by incorporating a real-time assessment of research practices, attempting to enhance the reflexivity of scientists. He noticed that an increased reflexivity could lead to room for negotiation about research practices, and hence to alternative decisions. More case studies that integrated ethics in research and innovation activities followed (Owen and Goldberg, 2010; Robinson, 2009; Schuurbiers, 2011). Notable is Robinson's (2009) contribution for introducing the terms RRI and RI for the first time in one academic article.[2]

3.2.4. *RRI as a framework*

In the meantime, the European Commission sensed the need for a change in the scientific system (Felt et al., 2007; Sutcliffe, 2011; Von Schomberg, 2011). It was evident that the previous decades had caused public unease with science-based technologies and that there was a need for further democratisation of science and governance and for solutions to societal challenges. The EU moved from risk governance to innovation governance with a stronger emphasis on civic engagement. This could spur (risk mitigating) innovations, stimulate the knowledge economy, while simultaneously increasing the credibility of the scientific system (Felt et al., 2007; Sutcliffe, 2011). Credibility of public participation and engagement depends on the underlying competing rationales (i.e. normative, substantive, or instrumental) and the respective power positions of associated actors. The normative rationale concerns the 'right thing to do', without considering its implications per se. Contrarily, a substantive rationale is motivated by the outcome and implications. Lastly, an instrumental imperative adheres to the outcome as well, but is little linked to broader societal values, but rather to the actor's own pursuit (Stirling, 2008).

The European Commission supported 'Science in Society' programme (FP7), which embodied the initial centralised response to the above-mentioned challenges. In the context of this programme, Von Schomberg (2011) provided the first contemporary definition of RRI: 'Responsible Research and Innovation is a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view on the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products (in order to allow a proper embedding of scientific and technological advances in our society)' (p. 9). This is thus a definition from an inherently European Union context with an emphasis on ethical acceptability, sustainability, and societal desirability. These normative dimensions originate from the EU's fundamental values (rights and safety), its sustainable development objectives (economic, social, and environmental), and the Treaty of the European Union (quality of life, equality, etc.) (Von Schomberg, 2011, 2013, 2014). In addition to this definition and normative ends, he provided a vision on what RRI should not be. Irresponsible research and innovations are classified as practices and outcomes resulting from an (often single) actor that is unaware of the social environment or unable to resolve its respective conflicts. Although Von Schomberg suggested a RRI definition and its normative ends, he recognised that there was no consensus on these, nor was there an agreed approach on how to institutionalise the concept into practice (Owen, 2014; Von Schomberg, 2013). Owen, Macnagthen, and Stilgoe (2012) were one of the first to recognise a broader trend in policy and academia towards this new concept (2012). Stilgoe et al. (2013) argued that the RRI definition and focus areas of Von Schomberg's European perspective might not be in line with the values of other cultures and other areas of innovation. Instead they develop a prospective notion of responsible innovation that draws from governance developments and integrates responsibility on a purpose and process level as opposed to conventional modes of governance that merely emphasis the (right) outcomes of research and innovation processes. They stated: 'Responsible innovation means taking care of the future through collective stewardship of science and innovation in the

[2] Brundage and Guston (2019) state that the term RI is introduced earlier, but the RPYS found these contributions not to be influential enough for RRI/RI's contemporary discourse to be included in this review.

present' (Stilgoe et al., 2013, p. 1570), and placed 'anticipation', 'reflexivity', 'inclusion', and 'responsiveness' as central interconnected dimensions in their framework.

'Anticipation' of research and innovation requires actors to raise the 'what if…' question (Ravetz, 1997) and is concerned with possible broader impacts and their probabilities. Foresight, (constructive) technology assessment, and scenario planning are examples of methods that serve this dimension. 'Reflexivity' urges actors to transparently assess the alignment of their role and their moral responsibility. Examples are codes of conduct, moratoriums, and the introduction of social scientists and ethicists in research and innovation practices. 'Inclusion' relates to the wider participation of actors and in particular the proactive, early, and genuine seizing of diverse forms of perspectives, feedback, and other forms of information. It is hence in line with the more widely accepted and adopted notion of open innovation (Chesbrough, 2003). Focus groups and citizens' juries are examples of appropriate tools. 'Responsiveness' requires the capability of actors to steer research and innovation trajectories in reaction to new information through e.g. niche management, regulation, and standards (Stilgoe et al., 2013). The above-mentioned umbrella terms can embody a diverse gamut of mechanisms of which its usability is context dependent. This research ensemble of various dimensions and its respective mechanisms can be mutually reinforcing, as well as conflicting. Increased inclusion, for example, might lead to greater reflexivity and more effective anticipation (Stilgoe et al., 2013).

3.2.5. *RRI and RI: From concepts to emerging research trajectory*

To further strengthen RI, Guston et al. (2014) recognised a need for a new, dedicated, and inclusive journal that could help to nurture and communicate this endeavour. They presented the *Journal of Responsible Innovation (JRI)*, as a centralised channel to 'articulate and discuss the many unsolved questions surrounding RI' and invite 'new and surprising perspectives from scholars and practitioners who take an interest in reflecting on and debating RI' (p. 3).

According to Van Oudheusden (2014), some of these unsolved questions relate to the seemingly non-political nature of RRI/RI while, in reality, its deliberation is inherently linked to politics. He highlights the paradox that 'no one actor is in control, but everyone is implicated, has agency and therefore is responsible, interconnected in complex networks, at multiple scales and in numerous ways' (Van Oudheusden, 2014, p. 196). This view emphasises the need for a better understanding of systems and their power distribution. The author pleads for a higher RI-politics proximity and for greater comprehension of its institutional side. The discourse should not merely deal with responsibilities of single actors, but also the (ir)responsibilities associated with, and induced by, systemic structures. This raises the question of how structures can be altered, and thus how RI processes can actually be designed and integrated to induce institutional change (Macnaghten et al., 2014). In addition, early on, some scholars identified that RRI and RI were largely built upon, or in, the northern (especially European) socio-political context (Owen et al., 2013; Rip, 2016; Stilgoe et al., 2013; Wong, 2016) and might be disconnected from other political, cultural, or economic circumstances and practices (Macnaghten et al., 2014; Wong, 2016). A more local and contextual deployment of responsibility in innovation is required, which should also take into account its relationship with less high-tech focused innovations (e.g. social innovation) which, in some cases, might be more relevant for less developed regions (Bock, 2012).

Lubberink et al. (2017a, 2017b) compared RI and social and sustainable innovation and concluded that although these ambiguous concepts overlap to a certain extent, they are different. Social innovations are predominantly concerned with creating social value while sustainable innovations are aimed at integrating conservation and development. RI predominantly distinguishes itself through the ethical reflection on relevant norms and values and makes use of a variety of sociotechnical integration approaches to do this (Fisher et al., 2015). And although social and sustainable innovation have made their way into practice, it is highly questionable whether RRI and RI can attain the same. Their implementation, in its most ideal form, seems somewhat unrealistic according to various authors (Blok and Lemmens, 2015; de Hoop et al., 2016; de Saille, 2015; Nordmann, 2014; Van Oudheusden, 2014). For instance, RI's democratic governance and deliberative engagement of research and innovation in the industry appears unattainable due to actors' information asymmetries upon which many firms rely for their competitive advantage (Brand and Blok, 2019). Moreover, actors are realistically limited in the number of stakeholders they can include in their practices (Lubberink et al., 2017a). The associated mutual responsibility is questionable due to the different risks (and potential gains) they share (Blok et al., 2015; Blok and Lemmens, 2015). The motives, goals, power, and visions of actors are heterogeneous, which challenges collective responsiveness, co-responsibility, and coordinated interaction (Raman et al., 2014; Stirling, 2008; Taebi et al., 2014; Thapa et al., 2019; Van Oudheusden, 2014). Hence, some scholars favour a more realistic and pragmatic modification of RI's framework and plead for more research on its implementation, its effectiveness,and its eventual institutionalisation in industry (Blok et al., 2015; Blok and Lemmens, 2015; Brand and Blok, 2019).

Several case studies have been conducted in an attempt to implement RRI/RI approaches and reflect on their implications (Aicardi et al., 2018; Iatridis and Schroeder, 2015; Owen and Goldberg, 2010; Schuurbiers, 2011; Stahl et al., 2017). At the same time, policymakers are urged to make explicit commitments to RRI/RI through policy experiments considering the valuable experiences it will provide (Balmer et al., 2016; Owen, 2014) for, what Lindblom called, the process of 'muddling through' (1959). The learning process is undeniably an essential component in anticipatory governance (Guston, 2014; Owen et al., 2013), and in RRI/RI in general. It could, for example, provide valuable lessons on how to facilitate inclusive processes (Taebi et al., 2014) and further strengthen additional rationales needed for wider public participation (Stilgoe et al., 2014). This can provide rich information on the values of stakeholders and lead to an increased acceptance of innovations, although this is influenced by the way innovations are framed to the public (Boucher, 2015). Guston tried to expand the discourse of inclusion and broader anticipatory governance (2014). He argues that the inclusion of formerly excluded actors might not mitigate all negative impacts but could lead to slight adjustments of the innovation (process) towards the 'right impacts'. Similar to Nordmann's (2014) view, this is a more nuanced expectation of anticipatory governance, and arguably of RRI/RI in general.

In conclusion, throughout history, the academic discourse evolved from 'if' science should be governed to 'how' this should be done. After the 1950s, an increased emphasis on the nexus of innovation and science with society emerged. Afterwards, the sociotechnical nature of innovation was revealed, which followed by contributions on reflexive modernity, anticipatory governance, and technology assessment. It is from this knowledge disposition that RRI and RI arose as the result of seminal contributions such as that of von Schomberg (2011) and Stilgoe et al (2013). Furthermore, our analysis of RRI's and RI's cited references from the last decade confirms Owen's and Pansera's (2019) observation that their concepts stem from different background even though they are frequently interchangeably used. Since their introduction, RRI and RI have been heavily debated and are still facing many questions, challenges, and research opportunities regarding its implementation, evaluation, and institutionalisation. Following recent contributions that are described above, scholars seem to disagree whether RRI's and RI's can be implemented in practice in its most ideal state. Only future research will reveal how collective stewardship of science and innovation could manifest itself in R&I practices and if it can take care of the future.

4. Discussion

This study used a RPYS to identify the contributions that gave rise to

RRI and RI research of the last decade. It revealed the knowledge accumulated on science, innovation, governance, ethics, and society on which it is constructed. Evidently, RRI and RI are heterogeneous in nature and greatly lean on both diverse fundamental, as well as, novel knowledge. Remote contributions in the past have stimulated the birth of new, often isolated, disciplines that have incrementally increased their mutual proximity over time, leading to greater theoretical coherence in the historical overview. Based on the contributions identified by the RPYS, this study finds that the term RI and RRI were first combined by Robinson (2009). However, it is only later that they became structurally interconnected topics after the seminal contributions of von Schomberg (2011) and Stilgoe et al (2013). Von Schomberg's contribution was policy oriented while Stilgoe et al's contribution was academic in nature. It seems to confirm Owen and Pansera's (2019) argument that while both topics have been introduced with different backgrounds, they have become increasingly interconnected and frequently used interchangeably. Our keyword co-occurrence analysis confirms RRI and RI's structural interaction. Isolated clusters of topics became increasingly interconnected and gave way for new research opportunities and combinations. In addition, as the time in-between influential years (years with citation anomalies found by the RPYS) becomes shorter when moving from the past to the present day, one can argue that the rate of (influential) knowledge accumulation has increased exponentially. With the upsurge of relevant knowledge combinations, the funding support of the European Union, and the creation of the *JRI,* it is not surprising that RRI and RI have attracted many new scholars which have boosted the community's collective productivity.

RRI and RI are often compared with adjacent research areas e.g. (political) corporate social responsibility, (Iatridis and Schroeder, 2015; Martinuzzi et al., 2018; Van de Poel et al., 2017; Voegtlin and Scherer, 2017), and sustainable and social innovation (Lubberink et al., 2017a, 2017b). Other scholars have conducted bibliometric analyses for these adjacent fields, which allow us to roughly compare RRI's and RI's joint productivity (quantity not quality) to give us a sense of their maturity. These analyses suggest that RRI and RI together show productivity levels comparable with corporate social responsibility in 2009 (Ferramosca, 2019), social innovation in 2014/2015 (Kaya Ozbag et al., 2019), and green innovation (close to sustainable innovation) in 2008 (Albort--morant et al., 2017).

This comparable size and productivity in combination with the dramatic growth and interconnectedness of the keyword co-occurrence network presented in this paper, can be used as a strong argument that RRI and RI have grown into an increasingly cumulative research trajectory and represent a constellation of interconnected ideas. Here, RI plausibly lends a heritage of ethics and STS knowledge, while RRI provides significant funding from the EC. Their synergy moves them in the footsteps of other more mature research areas. However, most RRI and RI scholars generally seem to work in small, isolated, and increasingly national clusters. While explicit knowledge can still be exchange via traditional means (i.e., academic publications), the lack of collaboration between different clusters may limit the flow of tacit knowledge (Polanyi, 1966) and can therefore slow down the maturation of the field as a whole.

When considering our qualitative analysis, it can be concluded that the academic discourse evolved from 'if' science should be governed to 'how' this should be done. At a later stage, its link to innovation became increasingly clear. After the 1950s, the debate emphasised the nexus of innovation and science with society. The sociotechnical nature of the innovation process was exposed and gave rise to contributions on reflexive modernity, anticipatory governance, and technology assessment. From this knowledge composition, the first influential RI contributions arose (Owen and Goldberg, 2010; Robinson, 2009). Although Robinson (2009) is the first to both mention RI and RRI in one article, the keyword co-occurrence network shows that RRI has only truly situated itself in the discourse of RI after 2010. In addition, it shows how their content interacts through topics such as public engagement in emerging technologies. Over time, RRI's and RI's research has touched and/or expanded on concepts like social innovation, anticipatory governance, ethics of research, and science and technology policy. The results suggest RI to be an adaptive and reflexive form of open innovation that embraces uncertainty through collective anticipation (process) while RRI is a normative European perspective on responsibility (outcome). The keyword analysis suggests that there are slightly more articles on RRI than RI in our sample (as can be found in the appendix). Although various principles of EC's '6 RRI keys' (public engagement, open access, gender, ethics, science education, and governance) return as prominent topics in research, namely public engagement, ethics, governance and science education, its seems to generally overlook principles like open access and gender.

The overview presented by this paper distinguishes itself from other historical overviews on RRI/RI (Brundage and Guston, 2019; Shanley, 2021) by relying on multiple quantitative methods (co-word analysis, co-author analysis, and RPYS) and going further back than the last decade. Utilizing such a different lens is important as the overlap and interconnectedness of RRI/RI's movements remained unclear (Brundage and Guston, 2019). The overview shows that both RRI and RI have been heavily debated since their introduction, and that they still face many questions, challenges, and research opportunities. These predominantly relate to the implementation[3], evaluation, and institutionalisation of their frameworks and values in practice. It is necessary to respond to these inquiries for both whole (innovation) systems and individual actors. This resonates with the multi-layered dynamics of responsibility (Fisher and Rip, 2013), and the collective, and role responsibility distinction (Grinbaum and Groves, 2013). The system level requires answers on how to deal with its politics, systemic barriers, sociocultural (and economic) differences, and actor interactions. It is furthermore concerned with how RRI and RI can be realised in a market-driven environment where there is unequal distribution of actors' power and responsibility, and a difference in their motives, goals, visions, and perspectives. At the actor level, some of the same challenges still apply, but additionally a great uncertainty needs to be addressed on whether (and how) industrial actors will benefit from RRI and RI practices. Some scholars are sceptical and wonder whether RRI and RI can be implemented in their most ideal state (Brand and Blok, 2019; de Hoop et al., 2016; Lubberink et al., 2017a).

4.1. Implications

This study found that scholars collaborate frequently, but predominately in small and isolated clusters. This can obstruct the flow of knowledge, particularly tacit knowledge. This limited exchange of knowledge can hamper RRI's and RI's accumulation and therefore limit its progress.

We would like to advocate an increase in the number of case studies. Only 31 of the 508 articles in our sample contained the word 'case'. While case studies might not always use the words 'case study' and go by different names such as 'pilot study' (e.g. Owen and Goldberg, 2010), our results in combination with the review of Schuijff and Dijkstra (2020),), suggest a rather low number of case studies (particularly for RRI). This is especially valid in light of the broad, diverse, and still explorative nature of contemporary RRI and RI. Some recent examples of helpful exploratory case studies are those from van de Poel et al (2020), Long et al (2020), and Oftedal et al (2019). In our opinion, case studies are vital for the identification of potential propositions that, by means of larger and more comprehensive studies, can lead up to tested RRI specific theories. More explorative research by means of case studies thus seem an area for future research.

Based on our qualitative analysis, distinct discourses from a variety

[3] Fraaije and Flipse (2020) review relevant contributions to RRI's and RI's implementation.

of perspectives take place and address the practices of industries, governments, and public research institutes. The AIRR framework (Stilgoe et al., 2013) appears to be the most widely used conceptual framework. On the contrary, no practical approach for implementation seems to have gained clear dominance yet, as a broad spectrum of such methods is used[4]. his plurality of approaches (as well as discourses, perspectives, concepts, etc.) could be explained by the heterogeneous community and the inherently context-dependent, but broadly applicable nature of RRI and RI. This in combination with the affiliated core framework of Stilgoe et al. (2013), which operates at a higher abstraction level, gives way for heterogeneous debates, studies and interpretations. As a result, this diversity could explain the fragmented character of the provided collaboration network. It could impede the convergence of academic contributions, the effective accumulation of knowledge and would strengthen Genus' and Stirling's appeal (2018) for more concrete frameworks.

Although RRI and RI exhibit various research streams that could indicate the emergence of novel research streams worth encouraging through research policy, it is beyond the scope of this paper to reliably identify the most promising ones. Nevertheless, the results suggest a clear distinction between research at the level of the innovation system and research at the actor level. This could be a sensible starting point for the progression of RRI's, RI's or joint research.

4.2. Limitations

This study is bound to some limitations that relate to the data collection. While the use of few keywords in an inherently incomplete database may leave out some relevant RRI literature, our use of RPYS partly compensates for this by allowing for a more comprehensive identification of contributions, in any form, inside and outside of the database, and for a more systematic way of collecting relevant references, without having to make subjective choices as to which articles to include. The RPYS is further supported by an additional manual check on anomalies in most recent years (2010-2019) to ensure the inclusion of more recent influential contributions. Undeniably, there may be other contributions that the RRI and RI community rely on and which have proven to be valuable for their progression. In addition, the publication data does not reflect so called 'invisible colleges' (Crane, 1972) and hence only captures codified phenomena. The exact effect of these uncodified aspects is something for further study.

The keyword analyses identify the interaction of content between RRI and RI. However, their interchangeable use could decrease the semantic reliability as authors may refer to one but mean the other. Nevertheless, our keyword analyses show a clear upsurge of RRI's usage. The coming years will show if this trend will persist.

5. Conclusion

Since the birth of RRI approximately a decade ago, scholars have gazed into the past searching for existing knowledge for contemporary enquiries. While RRI and RI efforts seem to have different origins, RRI more top-down and RI bottom-up, RRI seems to have placed itself in the literature of RI which might have caused some conflation of the concepts. This paper has identified the shared knowledge base of RRI and RI by conducting a systematic quantitative reference analysis. It discussed these in a chronological order and consequently described the evolution of knowledge that now forms RRI's and RI's shared foundation. It underlined the convergence process of knowledge in which distant theories were bridged and developed into increasingly more coherent research trajectories. RRI and RI truly lean on the shoulders of giants with historical roots in (moral) philosophy, economics, and sociology. Influential contributions in the past were concerned with 'if' and 'how' science (and innovation) should be governed. This subsequently gave rise to contributions on reflexive modernity, anticipatory governance, and technology assessment.

The RRI and RI frameworks have been criticised, opposed, endorsed, and transformed which has stimulated their discourse. This study concludes that RRI and RI have matured into an emerging, intertwined, and increasingly cumulative research trajectory that embodies a constellation of interconnected ideas. This is based on its topic interconnectivity, community size, collective productivity, own communication channels, and the presence of its own academic questions, challenges, and research opportunities. These opportunities predominantly relate to the implementation, evaluation, and institutionalisation of RRI and RI frameworks and values in practice at the (innovation) system level and individual actor level. The system level requires answers on how to deal with its politics, systemic barriers, sociocultural (and economic) differences, and actor interactions. It is furthermore concerned with how RRI and RI can be realised in a market-driven environment where there is inequality in actors' power, in the distribution of responsibilities, and a difference in actors' motives, goals, visions, and perspectives. Some of these challenges still apply at the individual actor level, but additionally a great uncertainty needs to be addressed as to whether, and how, individual (industrial) actors will benefit from RRI and RI practices as opposed to solely how society will benefit. For this reason, some scholars are highly sceptical, and plead for more realistic expectations of RRI and RI.

Together, RRI and RI show productivity levels similar to that of Corporate Social Responsibility, Green Innovation and Social Innovation in the years 2009, 2014/2015, and 2008 respectively. Admittedly, RRI and RI are still in their infancy, but support for their research has increased substantially and, hence their coordination requires further consideration. Accordingly, this study indicates that (1) RRI/RI might be collaboratively fragmented, which could be detrimental for the exchange of especially tacit knowledge, (2) few empirical case studies have been conducted, (3) no practical RRI/RI approach for implementation has gained dominance so far, presumably partly due to the heterogeneous community, and the context-dependent, and broadly-applicable character of RRI/RI. (4) RRI and RI seem to be conceptually interconnected causing conflation. Although, they overlap in some aspects (such as public engagement for, and governance of, emerging technologies) they remain different in others. These four barriers limit RRI's and RI's distinct and joint progression. From a policy perspective, this study therefore appears well-timed, and we suggest that these barriers should be addressed. This could be done by stimulating collaborations and empirical studies in distinct research streams (e.g. at the systemic and actor level). Enabling a collective consensus on the appropriate research ensembles for specific contexts would aid in achieving a more effective knowledge accumulation when considering RRI's and RI's inherent situational approaches. The scientific community should reflect on RRI's and RI's differences and similarities when funding, performing, and steering future research to avoid confusion and provide guidance. In conclusion, RRI and RI form a fast growing research area with abundant research and collaborative opportunities. However, reaching its full potential requires coordination, leadership, clarity, and the further creation of specific theories and concrete frameworks dedicated to either RRI, RI or joint research.

CRediT authorship contribution statement

Martijn Wiarda: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Visualization, Supervision. **Geerten van de Kaa:** Conceptualization, Resources, Writing – review & editing, Supervision, Funding acquisition. **Emad Yaghmaei:** Conceptualization, Validation, Resources, Writing – review & editing, Supervision, Funding acquisition. **Neelke Doorn:** Conceptualization, Validation, Resources, Writing – review & editing, Supervision, Funding

[4] e.g., STIR, scenario planning, and CTA

acquisition.

Acknowledgement

This work was supported by the European Union's Horizon 2020 research and innovation programme Co-Change [grant number 873112] and Pro-Ethics [grant number 872441]. The opinions expressed in this article reflect only the authors' view and in no way reflect the European Commission's opinions.

Appendix

RRI/RI keyword frequency analysis

Title word	N.	Abstract words	N.	Author keywords	N.
INNOVATION	287	INNOVATION	1048	RESPONSIBLE RESEARCH AND INNOVATION	143
RESPONSIBLE	241	RESPONSIBLE	619	RESPONSIBLE INNOVATION	119
SCIENCE	36	RRI	591	ETHICS	37
RRI	34	TECHNOLOGY	285	GOVERNANCE	32
RESPONSIBILITY	33	SCIENCE	281	INNOVATION	27
CASE	31	SOCIAL	281	NANOTECHNOLOGY	25
GOVERNANCE	31	PAPER	272	RESPONSIBLE RESEARCH AND INNOVATION (RRI)	22
TECHNOLOGY	30	ETHICAL	230	EMERGING TECHNOLOGIES	21
DEVELOPMENT	25	DEVELOPMENT	224	PUBLIC ENGAGEMENT	21
ETHICS	25	TECHNOLOGIES	204	TECHNOLOGY ASSESSMENT	21
ASSESSMENT	20	GOVERNANCE	190	RESPONSIBILITY	20
PUBLIC	20	POLICY	186	RRI	17
SOCIAL	19	SOCIETAL	178	SYNTHETIC BIOLOGY	17
TECHNOLOGIES	19	PUBLIC	173	SUSTAINABILITY	14
EMERGING	17	APPROACH	164	STAKEHOLDER ENGAGEMENT	12
ENGAGEMENT	17	STUDY	153	ANTICIPATION	8
ETHICAL	17	FRAMEWORK	152	CORPORATE SOCIAL RESPONSIBILITY	8
POLICY	17	RESPONSIBILITY	148	PARTICIPATION AND SCIENCE GOVERNANCE	8
SOCIETY	17	SOCIETY	146	SOCIOTECHNICAL INTEGRATION	8
SYNTHETIC	17	PROCESS	145	BIG DATA	7
BIOLOGY	16	EMERGING	140	FORESIGHT	7
PROJECT	16	STAKEHOLDERS	139	ICT	7
EDUCATION	15	CHALLENGES	132	SCIENCE POLICY	7
EUROPEAN	15	ARTICLE	130	SOCIAL INNOVATION	7
PERSPECTIVE	15	DATA	128	SUSTAINABLE DEVELOPMENT	7
STUDY	15	WILL	128	ANTICIPATORY GOVERNANCE	6
APPROACH	14	EUROPEAN	125	INDUSTRY	6
HEALTH	14	ISSUES	125	ARTIFICIAL INTELLIGENCE	5
HUMAN	14	ENGAGEMENT	119	CORPORATE SOCIAL RESPONSIBILITY (CSR)	5
MANAGEMENT	14	FUTURE	117	ENGAGEMENT	5

RI keyword frequency analysis

Title words	N.	Abstract words	N.	Author keywords	N.
INNOVATION	180	INNOVATION	671	RESPONSIBLE INNOVATION	113
RESPONSIBLE	142	RESPONSIBILITY	383	INNOVATION	31
CASE	20	SOCIAL	188	RESPONSIBLE RESEARCH AND INNOVATION	31
DEVELOPMENT	18	TECHNOLOGY	163	ETHICS	19
TECHNOLGY	18	PAPER	134	GOVERNANCE	18
GOVERNANCE	16	ETHICAL	122	NANOTECHNOLOGY	14
RESPONSIBILITY	15	DEVELOPMENT	121	RESPONSIBLITY	12
PUBLIC	14	TECHNOLOGIES	118	SUSTAINAIBLITY	10
ETHICS	13	GOVERNANCE	114	TECHNOLOGY ASSESSMENT	10
SOCIAL	13	RRI	114	PUBLIC ENGAGEMENT	9
SOCIETY	13	RI	106	TECHNOLOGY	9
STUDY	13	PUBLIC	104	EMERGING TECHNOLOGIES	8
MANAGEMENT	12	SCIENCE	101	STAKEHOLDERS ENGAGEMENT	8
SCIENCE	12	STUDY	100	RESEARCH	7
TECHNOLOGIES	11	SOCIETAL	98	SOCIO-TECHNICAL INTEGRATION	7
ASSESSMENT	10	FRAMEWORK	87	SOCIAL INNOVATION	6
CHALLENGES	10	POLICY	87	SYNTHETIC BIOLOGY	6
FRAMEWORK	10	APPROACH	82	AGRICULTURE	5
APPROACH	9	SOCIETY	73	ANTICIPATORY GOVERNANCE	5
DESIGN	9	CHALLENGES	72	INDUSTRY AND INNOVATION	5
ETHICAL	9	EMERGING	70	NEUROIMAGING	5
HEALTH	9	ETHICS	69	RESPONSIBLE	5
PERSPECTIVE	9	ARTICLE	68	RRI IN INDUSTRY	5
BIOLOGY	8	PRACTICES	68	RRI KPI'S	5

(*continued on next page*)

(*continued*)

Title words	N.	Abstract words	N.	Author keywords	N.
CARE	8	RESPONSIBLE	68	RRI METRICS	5
HUMAN	8	WILL	67	TECHNOLOGIES	5
INDUSTRY	8	DATA	65	ANTICIPATION	4
PRACTICE	8	POTENTIAL	65	BIG DATA	4
TECHNOLOGICAL	8	VALUES	65	DESIGN	4
AGRICULTURE	7	INDUSTRY	64	ENGAGEMENT	4

RRI keyword frequency analysis

Title words	N.	Abstract words	N.	Author keywords	N.
INNOVATION	136	RRI	586	RESPONSIBLE RESEARCH AND INNOVATION	92
RESPONSIBLE	120	INNOVAITON	469	INNOVATION	23
RRI	34	RESPONSIBLE	282	ETHICS	21
SCIENCE	22	SCIENCE	152	RESPONSIBLE INNOVATION	18
RESPONSIBLITY	21	PAPER	131	RESPONSIBLITY	14
CASE	14	TECHNOLOGY	118	RRI	14
GOVERANNCE	11	SOCIAL	107	GOVERNANCE	13
TECHNOLOGY	11	SOCIETAL	102	RESPONSIBLE RESEARCH AND	12
ASSESSMENT	10	ETHICAL	101	RESPONSIBLE RESEARCH AND INNOVATION (RRI)	12
EDUCATION	9	DEVELOPMENT	99	NANOTECHNOLOGY	8
EMERGING	9	POLICY	91	STAKEHOLDER ENGAGEMENT	8
ETHICS	9	APPROACH	89	TECHNOLOGY ASSESSMENT	8
PRACTICE	9	RESPONSIBILITY	81	ENGAGEMENT	7
DEVELOPMENT	8	PROCESS	80	PARTICIPATION AND SCIENCE GOVERANCE	7
ENGAGMENT	8	FRAMEWORK	79	RESPONISBLE	7
EUROPEAN	8	TECHNOLOGIES	79	TECHNOLOGY	7
POLICY	8	EUROPEAN	78	EMERGING TECHNOLOGIES	6
TECHNOLOGIES	8	GOVERNANCE	71	SYNTHETIC BIOLOGY	6
FUTURE	7	SOCIETY	68	ASSESSMENT	5
LEARNING	7	STAKEHOLDERS	67	ICT	5
PROJECT	7	CHALLENGES	66	INDUSTRY	5
ICT	6	EMERGING	65	INDUSTRY AND INNOVAITON	5
INDUSTRY	6	PROJECT	64	PUBLIC ENGAGMENT	5
PERSPECTIVE	6	PROCESSES	63	RESEARCH	5
SCHOOL	6	ISSUES	62	RRI IN INDUSTRY	5
SOCIAL	6	CONCEPT	61	RRI KPIS	5
SYNTHETIC	6	PUBLIC	58	RRI METRICS	5
APPROACH	5	ARTICLE	57	INNOVATION (RRI)	4
BIOLOGY	5	RESEARCHER	56	IRRESISTIBLE PROJECT	4
BRAIN	5	WILL	56	RESEARCH AND INNOVATION	4

References

Aicardi, C., Reinsborough, M., Rose, N., 2018. The integrated ethics and society programme of the Human Brain Project: reflecting on an ongoing experience. J. Responsible Innov. 5 (1), 13–37. https://doi.org/10.1080/23299460.2017.1331101.

Albort-morant, G., Henseler, J., Leal-mill, A., and Cepeda-carri, G. (2017). Mapping the Field : A Bibliometric Analysis of Green Innovation. 1–15. 10.3390/su9061011.

Aria, M., Cuccurullo, C., 2017. bibliometrix: an R-tool for comprehensive science mapping analysis. J. Informetrics 11 (4), 959–975. https://doi.org/10.1016/j.joi.2017.08.007.

Balmer, A.S., Calvert, J., Marris, C., Molyneux-Hodgson, S., Frow, E., Kearnes, M., Bulpin, K., Schyfter, P., Mackenzie, A., Martin, P., 2016. Five rules of thumb for post-ELSI interdisciplinary collaborations. J. Responsible Innov. 3 (1), 73–80. https://doi.org/10.1080/23299460.2016.1177867.

Barben, D., Fisher, E., Selin, C., and Guston, D. H. (2007). Anticipatory governance of nanotechnology: foresight, engagement, and integration. In Handbook of science and technology studies (Vol. 24, Issue 6, pp. 979–1000). 10.2307/2076663.

Beck, U., 1992. Towards a New Modernity. Risk society. SAGE Publications. https://doi.org/10.2307/143601.

Bentham, J., 1781. An Introduction To The Principles Of Morals And Legislation.

Bernal, J.D., 1939. The Social Function Of Science. George Routledge and Sons.

Blok, V., Hoffmans, L., Wubben, E.F.M., 2015. Stakeholder engagement for responsible innovation in the private sector: Critical issues and management practices. J. Chain Network Sci. 15 (2), 147–164. https://doi.org/10.3920/JCNS2015.x003.

Blok, V., and Lemmens, P. (2015). The emerging concept of responsible innovation. Three reasons why it is questionable and calls for a radical transformation of the concept of innovation. In Responsible innovation 2: Concepts, approaches, and applications (pp. 19–35). 10.1007/978-3-319-17308-5.

Bock, B., 2012. Social innovation and sustainability; how to disentangle the buzzword and its application in the field of agriculture and rural development. Stud. Agricult. Econ. 114 (2), 57–63. https://doi.org/10.7896/j.1209.

Boucher, P., 2015. Domesticating the drone: the demilitarisation of unmanned aircraft for civil markets. Sci. Eng. Ethics 21 (6), 1393–1412. https://doi.org/10.1007/s11948-014-9603-3.

Brand, T., Blok, V., 2019. Responsible innovation in business: a critical reflection on deliberative engagement as a central governance mechanism. J. Responsible Innov. 6 (1), 4–24. https://doi.org/10.1080/23299460.2019.1575681.

Brundage, M., Guston, D.H., 2019. Understanding the movement(s) for responsible innovation *. In: Von Schomberg, R., Hankins, J. (Eds.), International Handbook on Responsible Innovation. Edward Elgar Publishing, pp. 102–121.

Burget, M., Bardone, E., Pedaste, M., 2016. Definitions and conceptual dimensions of responsible research and innovation: a literature review. Sci. Eng. Ethics 23 (1), 1–19. https://doi.org/10.1007/s11948-016-9782-1.

Bush, V. (1945). Science, the endless frontier. 10.1016/j.jconrel.2019.07.034.

Callon, M., Courtial, J.P., Turner, W.A., Bauin, S., 1983. From translations to problematic networks: An introduction to co-word analysis. Social Sci. Inf. 22 (2), 191–235.

Chesbrough, H., 2003. Open Innovation. Harvard business school press.

Colizzi, V., Mezzana, D., Ovseiko, P.V, Caiati, G., Colonnello, C., Declich, A., Buchan, A. M., Edmunds, L., Buzan, E., Zerbini, L., Djilianov, D., Kalpazidou Schmidt, E., Bielawski, K., Elster, D., Salvato, M., Alcantara, L., Minutolo, A., Potesta, M., Bachiddu, E., Montesano, C., 2019. Structural Transformation to Attain Responsible BIOSciences (STARBIOS2): Protocol for a Horizon 2020 Funded European Multicenter Project to Promote Responsible Research and Innovation Corresponding Author: J. Med. Internet Res. Res. Protocols 8 (3). https://doi.org/10.2196/11745.

Collingridge, D., 1980. The social control of technology. St. Martin's Press.

Crane, D., 1972. Invisible college: diffusion of knowledge in scientific communities. University of Chicago press. https://doi.org/10.25250/thescbr.brk352.

de Hoop, E., Pols, A., Romijn, H., 2016. Limits to responsible innovation. J. Responsible Innovation 3 (2), 110–134. https://doi.org/10.1080/23299460.2016.1231396.

de Saille, S., 2015. Innovating innovation policy: the emergence of 'Responsible Research and Innovation. J. Responsible Innovation 2 (2), 152–168. https://doi.org/10.1080/23299460.2015.1045280.
Evans, J.H., 2007. Consensus Knowledge Prod. Academic Field 35, 1–21. https://doi.org/10.1016/j.poetic.2007.01.001.
Felt, U., Wynne, B., Gonçalves, M. E., Jasanoff, S., Callon, M., Jepsen, M., Joly, P.-B., Konopasek, Z., May, S., Neubauer, C., Rip, A., Siune, K., Stirling, A., and Tallacchini, M. (2007). Taking European knowledge society seriously. In Office for Official Publications of the European …. http://ec.europa.eu/research/science-society/document_library/pdf_06/european-knowledge-society_en.pdf%5Cnhttp://www.synbioproject.org/process/assets/files/6452/_draft/european-knowledge-society_en.pdf.
Ferramosca, S., 2019. Framing the evolution of corporate social responsibility as a discipline (1973 –2018): A large - scale scientometric analysis. Corporate Social Responsibility and Environmental Management, pp. 178–203. https://doi.org/10.1002/csr.1792. April.
Fisher, E., 2007. Ethnographic invention: Probing the capacity of laboratory decisions. NanoEthics 1 (2), 155–165. https://doi.org/10.1007/s11569-007-0016-5.
Fisher, E., Rip, A., 2013. Responsible Innovation: Multi-Level Dynamics and Soft Intervention Practices. Responsible Innovation: Managing the Responsible Emergence of Science and Innovation in Society, pp. 165–183. https://doi.org/10.1002/9781118551424.ch9.
Fisher, E., Rourke, O., John, R., Eric, B., Michael, E., Mapping, T. P., Rourke, M. O., Evans, R., Kennedy, E. B., and Gorman, M. E. (2015). Mapping the integrative field : Taking stock of socio-technical collaborations.
Fraaije, A., Flipse, S.M., 2020. Synthesizing an implementation framework for responsible research and innovation. Journal of Responsible Innovation 7 (1). https://doi.org/10.1080/23299460.2019.1676685.
Genus, A., Iskandarova, M., 2018. Responsible innovation: its institutionalisation and a critique. Technol. Forecast. Soc. Change 128, 1–9. https://doi.org/10.1016/j.techfore.2017.09.029. October 2017.
Genus, A., Stirling, A., 2018. Collingridge and the dilemma of control: Towards responsible and accountable innovation. Research Policy 47 (1), 61–69. https://doi.org/10.1016/j.respol.2017.09.012.
Grinbaum, A., Groves, C., 2013. What Is "Responsible" about Responsible Innovation? Understanding the Ethical Issues. Responsible Innovation: Managing the Responsible Emergence of Science and Innovation in Society, pp. 119–142. https://doi.org/10.1002/9781118551424.ch7. April.
Guston, D.H., 2014. Understanding "anticipatory governance.". Social Stud. Science 44 (2), 218–242. https://doi.org/10.1177/0306312713508669.
Guston, D.H., Fisher, E., Grunwald, A., Owen, R., Swierstra, T., van der Burg, S., 2014. Responsible innovation: motivations for a new journal. J. Responsible Innovation 1 (1), 1–8. https://doi.org/10.1080/23299460.2014.885175.
Guston, D.H., Sarewitz, D., 2002. Real-time technology assessment. Technol. Soc. 24 (1–2), 93–109. https://doi.org/10.1016/S0160-791X(01)00047-1.
Hackett, E.J., Conz, D., Parker, J., Bashford, J., Delay, S., 2004. Tokamaks and turbulence: research ensembles, policy and technoscientific work. Research Policy 33 (5), 747–767.
Hume, D., 1777. An Enquiry Concerning The Principles Of Morals.
Hutcheson, F., 1725. An Inquiry Into The Original Of Our Ideas Of Beauty And Virtue.
Iatridis, K., Schroeder, D., 2015. Responsible Research and Innovation in Industry: The Case for Corporate Responsibility Tools. In Responsible Research and Innovation in Industry: The Case for Corporate Responsibility Tools. Springer International Publishing AG Switzerland. https://doi.org/10.1007/978-3-319-21693-5.
Jonas, H., 1984. The imperative of responsibility: In search of an ethics for the technological age. University of Chicago Press.
Kant, I. (1785). Groundwork of the metaphysics of morals.
Kant, I. (1787). Critique of pure reason.
Katz, J.S., Martin, B.R., 1997. What is research collaboration? Research Policy 26 (1), 1–18. https://doi.org/10.1016/S0048-7333(96)00917-1.
Kaya Ozbag, G., Esen, M., Esen, D., 2019. Bibliometric analysis of studies on social innovation. Int. J. Contemporary Econ. Admin. Sci. 9 (1), 25–45. https://doi.org/10.5281/zenodo.3262221.
Khasseh, A.A., Mokhtarpour, R., 2016. Tracing the historical origins of knowledge management issues through referenced publication years spectroscopy (RPYS). J. Knowledge Manag. 20 (6), 1393–1404. https://doi.org/10.1108/JKM-01-2016-0019.
Kuhn, T., 1962. The Structure of Scientific Revolutions. The University Chicago Press.
Lindblom, C.E., 1959. The science of "muddling through. Public Adm. Rev. 19 (2), 79–88. https://doi.org/10.4324/9781315255101-29.
Long, T.B., Blok, V., Dorrestijn, S., Macnaghten, P., 2020. The Design and Testing of a Tool for Developing Responsible Innovation in Start-Up Enterprises, p. 9460. https://doi.org/10.1080/23299460.2019.1608785. May 2019.
Loureiro, P.M., Conceição, C.P., 2019. Emerging patterns in the academic literature on responsible research and innovation. Technol. Soc. 58, 101148 https://doi.org/10.1016/j.techsoc.2019.101148. May.
Lubberink, R., Blok, V., van Ophem, J., Omta, O., 2017a. A Framework for responsible innovation in the business context: lessons from responsible-, social- and sustainable innovation. Responsible Innovation 3: A European Agenda?, pp. 181–207. https://doi.org/10.1007/978-3-319-64834-7.
Lubberink, R., Blok, V., van Ophem, J., Omta, O., 2017b. Lessons for responsible innovation in the business context: A systematic literature review of responsible, social and sustainable innovation practices. Sustain. (Switzerland) 9 (5). https://doi.org/10.3390/su9050721.
Macnaghten, P., Owen, R., Stilgoe, J., Wynne, B., Azevedo, A., de Campos, A., Chilvers, J., Dagnino, R., di Giulio, G., Frow, E., Garvey, B., Groves, C., Hartley, S., Knobel, M., Kobayashi, E., Lehtonen, M., Lezaun, J., Mello, L., Monteiro, M., Velho, L., 2014. Responsible innovation across borders: tensions, paradoxes and possibilities. J. Respons. Innov. 1 (2), 191–199. https://doi.org/10.1080/23299460.2014.922249.
Martinuzzi, A., Blok, V., Brem, A., Stahl, B., Schönherr, N., 2018. Responsible Research and Innovation in industry-challenges, insights and perspectives. Sustainability (Switzerland) 10 (3), 1–9. https://doi.org/10.3390/su10030702.
Marx, W., Bornmann, L., Barth, A., Leydesdorff, L., 2014. Detecting the historical roots of research fields by Reference Publication Year Spectroscopy (RPYS). J. Ass. Inf. Sci. Technol. 64, 751–764. https://doi.org/10.1002/asi. July.
Moral-Muñoz, J.A., Herrera-Viedma, E., Santisteban-Espejo, A., Cobo, M.J., 2020. Software tools for conducting bibliometric analysis in science: An up-to-date review. Profesional de La Informacion 29 (1), 1–20. https://doi.org/10.3145/epi.2020.ene.03.
Newman, M.E.J., 2004. Coauthorship networks and patterns of scientific collaboration. PNAS 101 (SUPPL. 1), 5200–5205. https://doi.org/10.1073/pnas.0307545100.
Nordmann, A., 2014. Responsible innovation, the art and craft of anticipation. J. Responsible Innov. 1 (1), 87–98. https://doi.org/10.1080/23299460.2014.882064.
Oftedal, E.M., Foss, L., Iakovleva, T., 2019. Responsible for responsibility ? A study of digital E-health Startups. Sustainability 11 (5433), 1–21.
Owen, R. (2014). Responsible research and innovation: options for research and innovation policy in the EU. https://ec.europa.eu/research/innovation-union/pdf/expert-groups/Responsible_Research_and_Innovation.pdf.
Owen, R., Goldberg, N., 2010. Responsible Innovation: A Pilot Study with the U.K. Engineering and Physical Sciences Research Council. Risk Anal. 30 (11), 1699–1707. https://doi.org/10.1111/j.1539-6924.2010.01517.x.
Owen, R., Macnaghten, P., Stilgoe, J., 2012. Responsible research and innovation: From science in society to science for society, with society. Science and Public Policy 39 (6), 751–760. https://doi.org/10.1093/scipol/scs093.
Owen, R., Pansera, M., 2019. Chapter 2. Responsible Innovation and Responsible Research and Innovation. Handbook on science and public policy.
Owen, R., Stilgoe, J., Macnaghten, P., Gorman, M., Fisher, E., Guston, D., 2013. A Framework for Responsible Innovation. Responsible Innovation 27–50. https://doi.org/10.1002/9781118551424.ch2.
Phelps, C., Heidl, R., 2012. Knowledge, Networks, and Knowledge Networks : A Review and Research Agenda 38 (4). https://doi.org/10.1177/0149206311432640.
Poel, I. Van De, Asveld, L., Flipse, S., Klaassen, P., Kwee, Z., Maia, M., Mantovani, E., Nathan, C., Porcari, A., Poel, I. Van De, Asveld, L., Flipse, S., Klaassen, P., Kwee, Z., Maia, M., Mantovani, E., Nathan, C., Porcari, A., Yaghmaei, E., and Nathan, C. (2020). Learning to do responsible innovation in industry : six lessons. 10.1080/23299460.2020.1791506.
Polanyi, M., 1962. The republic of science - Its political and economic theory. Minerva 1, 54–74. https://doi.org/10.1007/BF01101453.
Polanyi, M., 1966. The tacit dimension. Doubleday and Co.
Raman, S., Mohr, A., Helliwell, R., Ribeiro, B., Shortall, O., Smith, R., Millar, K., 2014. Integrating social and value dimensions into sustainability assessment of lignocellulosic biofuels. Biomass Bioenergy 82, 49–62. https://doi.org/10.1016/j.biombioe.2015.04.022.
Randles, S., Edler, J., Gough, C., Joly, P.-B., Mejlgaard, N., Bryndum, N., Lang, A., Lindner, R., Kuhlmann, S., 2015. Lessons from RRI in the Making 321427, 1–9.
Ravetz, J.R., 1997. The science of "what-if?". Futures 29 (6), 533–539. https://doi.org/10.1016/s0016-3287(97)00026-8.
Ribeiro, B.E., Smith, R.D.J., Millar, K., 2017. A Mobilising Concept? Unpacking Academic Representations of Responsible Research and Innovation. Sci. Eng. Ethics 23 (1), 81–103. https://doi.org/10.1007/s11948-016-9761-6.
Rip, A. (2016). The clothes of the emperor . An essay on RRI in and around Brussels. 9460. 10.1080/23299460.2016.1255701.
Robinson, D.K.R., 2009. Co-evolutionary scenarios: An application to prospecting futures of the responsible development of nanotechnology. Technological Forecasting and Social Change 76 (9), 1222–1239. https://doi.org/10.1016/j.techfore.2009.07.015.
Rogers, E., 1962. Diffusion of innovation. Free Press of Glencoe.
Rowe, G., Frewer, L.J., 2000. Public participation methods: A framework for evaluation. Science Technology and Human Values 25 (1), 3–29. https://doi.org/10.1177/016224390002500101.
Schot, J., Rip, A., 1997. The Past and Future of Constructive Technology Assessment. Technological Forecasting and Social Change 54 (2–3), 251–268. https://doi.org/10.1016/s0040-1625(96)00180-1.
Schot, J., Rip, A., and Misa, T. (1995). Managing technology in society: The approach of constructive technology assessment.
Schuijff, M., and Dijkstra, A. M. (2020). Practices of Responsible Research and Innovation: A Review. In Science and Engineering Ethics (Vol. 26, Issue 2). Springer Netherlands. 10.1007/s11948-019-00167-3.
Schumpeter, J., 1934. The theory of economic development. Springer.
Schuurbiers, D., 2011. What happens in the Lab: Applying Midstream Modulation to Enhance Critical Reflection in the Laboratory. Sci. Eng. Ethics 17 (4), 769–788. https://doi.org/10.1007/s11948-011-9317-8.
Shanley, D., 2021. Imagining the future through revisiting the past : the value of history in thinking about R (R) I ' s possible future (s) history in thinking about R (R) I ' s possible future (s). Journal of Responsible Innovation 0 (0), 1–20. https://doi.org/10.1080/23299460.2021.1882748.
Smith, A., 1759. The theory of moral sentiments. Penguin.
Smith, A. (1776). An inquiry into the nature and causes of the wealth of nations.
Smolka, M., 2020. Generative Critique in Interdisciplinary Collaborations : From Critique in and of the Neurosciences to Socio-Technical Integration Research as a Practice of Critique in R (R) I. NanoEthics, 14, 1–19.

Stahl, B.C., Obach, M., Yaghmaei, E., Ikonen, V., Chatfield, K., Brem, A., 2017. The responsible research and innovation (RRI) maturity model: Linking theory and practice. Sustainability (Switzerland) 9 (6), 1–19. https://doi.org/10.3390/su9061036.

Stilgoe, J., Lock, S.J., Wilsdon, J., 2014. Why should we promote public engagement with science? Public Understand. Sci. 23 (1), 4–15. https://doi.org/10.1177/0963662513518154.

Stilgoe, J., Owen, R., Macnaghten, P., 2013. Developing a framework for responsible innovation. Research Policy 42 (9), 1568–1580. https://doi.org/10.1016/j.respol.2013.05.008.

Stirling, A., 2008. Opening up" and "closing down": Power, participation, and pluralism in the social appraisal of technology. Science Technology and Human Values 33 (2), 262–294. https://doi.org/10.1177/0162243907311265.

Subramanyam, K., 1983. Bibliometric studies of research collaboration: A review. Journal of Information Science 6 (1), 33–38. https://doi.org/10.1177/016555158300600105.

Sutcliffe, H. (2011). A report on responsible research and innovation. … Research and Innovation of the European …, 1–77. http://www.matterforall.org/pdf/RRI-Report2.pdf.

Swierstra, T., Rip, A., 2007. Nano-ethics as NEST-ethics: Patterns of moral argumentation about new and emerging science and technology. NanoEthics 1 (1), 3–20. https://doi.org/10.1007/s11569-007-0005-8.

Taebi, B., Correljé, A., Cuppen, E., Dignum, M., Pesch, U., 2014. Responsible innovation as an endorsement of public values: the need for interdisciplinary research. Journal of Responsible Innovation 1 (1), 118–124. https://doi.org/10.1080/23299460.2014.882072.

Thapa, R.K., Iakovleva, T., Foss, L., 2019. Responsible research and innovation: a systematic review of the literature and its applications to regional studies. European Planning Studies 27 (12), 2470–2490. https://doi.org/10.1080/09654313.2019.1625871.

Thor, A., Marx, W., Leydesdorff, L., Bornmann, L., 2016. Introducing CitedReferencesExplorer (CRExplorer): A program for reference publication year spectroscopy with cited references standardization. Journal of Informetrics 10 (2), 503–515. https://doi.org/10.1016/j.joi.2016.02.005.

Timmermans, J. (2017). Mapping the RRI Landscape: An Overview of Organisations, Projects, Persons, Areas and Topics. In Responsible innovation 3 (pp. 21–47). 10.1007/978-3-319-64834-7.

Van de Poel, I., Asveld, L., Flipse, S., Klaassen, P., Scholten, V., Yaghmaei, E., 2017. Company strategies for responsible research and innovation (RRI): A conceptual model. Sustainability (Switzerland) 9 (11), 1–18. https://doi.org/10.3390/su9112045.

Van Oudheusden, M., 2014. Where are the politics in responsible innovation? European governance, technology assessments, and beyond. Journal of Responsible Innovation 1 (1), 67–86. https://doi.org/10.1080/23299460.2014.882097.

Voegtlin, C., Scherer, A.G., 2017. Responsible Innovation and the Innovation of Responsibility: Governing Sustainable Development in a Globalized World. J. Bus. Ethics 143 (2), 227–243. https://doi.org/10.1007/s10551-015-2769-z.

Von Schomberg, R. (2011). Towards research and innovation in the information and communication technologies and security technologies fields. In Science in Society.

Von Schomberg, R. (2013). A Vision of Responsible Research and Innovation. In Responsible Innovation: Managing the Responsible Emergence of Science and Innovation in Society (Issue June 2013). 10.1002/9781118551424.ch3.

von Hippel, E., 1988. The sources of Innovation. Oxford University Press Inc.

Von Schomberg, R., 2014. Prospects for Technology Assessment in a Framework of Responsible Research and Innovation. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.2439112. May.

White, H.D., McCain, K.W., 1998. Visualizing a discipline: An author co-citation analysis of information science, 1972-1995. J. Am. Soc. Inf. Sci. 49 (4), 327–355 https://doi.org/10.1002/(SICI)1097-4571(19980401)49:4<327::AID-ASI4>3.0.CO;2-W.

Wiener, N., 1954. The human use of human beings. Houghton Mifflin.

Winner, L., 1980. Do artifacts have politics? Daedalus 109 (1), 121–136.

Wong, P.H., 2016. Responsible innovation for decent nonliberal peoples: a dilemma? Journal of Responsible Innovation 3 (2), 154–168. https://doi.org/10.1080/23299460.2016.1216709.

Zwart, H., Landeweerd, L., van Rooij, A., 2014. Adapt or perish? Assessing the recent shift in the European research funding arena from 'ELSA' to 'RRI.' Life Sciences. Society and Policy 10 (1), 1–19. https://doi.org/10.1186/s40504-014-0011-x.

Martijn Wiarda is a PhD candidate in the section of Economics of Technology and Innovation at the Delft University of Technology where his research is dedicated to the topic of Responsible Research and Innovation (RRI). Martijn is involved in the European Union Horizon2020 Projects, 'Co-Create Change in Research Funding and Performing' and 'Participatory Real Life Experiments in Research and Innovation Funding Organisations on Ethics'. In these projects, he closely works together with Dr. Geerten van de Kaa, Prof. dr. mr. ir. Neelke Doorn, and Dr. Emad Yaghmaei.

Geerten van de Kaa is Associate Professor of Standardization and Business Strategy at Delft University of Technology. He holds a PhD from Rotterdam School of Management, Erasmus University. His research focuses on a better understanding of the standardization process in order to enable complex innovations and solve societal and business challenges. He has published in high ranking international journals including Organization Studies, IEEE Transactions on Engineering Management, Technovation, and Technological Forecasting and Social Change. He teaches courses in 'strategic management', 'technology and strategy', and 'standards battles'. He is visiting scholar at Technische Universität Berlin.

Emad Yaghmaei is Senior Researcher at the Delft University of Technology. His research interests cover governance of organisations and processes with a focus on their ethical, social, and governmental impacts. He is especially interested in designing and developing necessary policies and methods for implementation and evaluation of Responsible Innovation within industrial context. His publications lie in the intersection of science, innovation, technology, and society. His current work takes the outset in Responsible Research and Innovation and its institutionalisation within stakeholders across Innovation Ecosystems. He is a member of the IEEE Standard committee on Governance of Artificial Intelligence.

Neelke Doorn is distinguished Antoni van Leeuwenhoek professor 'Ethics of Water Engineering' at Delft University of Technology and Director of Education of the Faculty of Technology, Policy and Management. Neelke holds master degrees in Civil Engineering (TU Delft 1997, cum laude), Philosophy (Leiden 2005, cum laude), and Law (Open University 2016, cum laude). She obtained her PhD degree for her thesis on Moral Responsibility in RandD Networks. Professor Doorn is involved in several projects on Responsible Research and Innovation, including the European PRO-Ethics project. She is co-editor of the Routledge Handbook of the Philosophy of Engineering..