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Responsible research and innovation: a systematic review of the literature and its applications to regional studies

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ABSTRACT

While innovation should be about socioeconomic transformation of society, concerns have been raised about its negative externalities including growing disparities within and between regions. Arguably, Responsible Research and Innovation (RRI) offers a potential solution to address these concerns. However, in theory, its conceptualization and operationalization remain ambiguous. Further, in practice, this makes its application to regional development difficult. Accordingly, this study first conducts a systematic literature review of conceptual papers on RRI. It identifies themes and categorizes them into four domains: drivers, tools, outcomes and barriers. Second, these domains are applied to regional innovation studies. The paper contributes to an increased understanding of RRI and its applications to sustainable regional development as well as how RRI and regional innovation studies can benefit from each other.

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Responsible research and innovation; systematic literature review; stakeholders; region; policy; regional development

1. Introduction

The purpose of innovation should be in and around socioeconomic transformation and overall development of society. However, current trends in research and innovation have raised social, ethical and environmental concerns (Owen, Bessant, & Heintz, 2013). While this applies globally, the same can be taken at a regional level. In particular, there are concerns that at the regional level, innovation and related economic activities are leading to growing disparities between and within regions producing winners and losers (Rodríguez-Pose, 2018; Storper, 2018). These issues should be addressed proactively to ensure that society obtains the greatest benefits from science, research and innovation and ensures sustainable development.

Responsible innovation (RI) and responsible research and innovation (RRI)¹ have been gaining in currency as important themes in recent years (Stilgoe & Guston, 2017). The discussion of ethics in science, technology, research and innovation is not new, but the concept of RRI appeared recently to incorporate responsibility into research and

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innovation policies and practices (Flick, 2016; Owen, Macnaghten, & Stilgoe, 2012; Stilgoe, Owen, & Macnaghten, 2013; Von Schomberg, 2011). RRI has emerged at the wake of several grand societal challenges and declining public trust on government, businesses, science and innovation (EBT, 2017). The aim is to restore public confidence in science and innovation (Owen et al., 2012), to achieve inclusive and sustainable future (Stilgoe et al., 2013) through societal desirable innovation (Von Schomberg, 2011).

According to Von Schomberg (2011, p. 9), RRI is defined as ‘a transparent interactive process where societal actors and innovators become mutually responsible to each other, viewing the ethical acceptability, sustainability and societal desirability of the innovation process and its marketable products’. In 2013, Stilgoe and colleagues proposed a broader definition of RRI ‘taking care of the future through collective stewardship of science and innovation in the present’ (Stilgoe et al., 2013, p. 1517). RRI also refers to the democratic governance of the purpose of research and innovation and the orientation of that research and innovation towards the production of the ‘right impact’ (Owen et al., 2012; Weckert, Valdes, & Soltanzadeh, 2016). This implies inclusion of stakeholders and the public at the very beginning of the research and innovation process to collectively direct it to generate the ‘right’ outcomes in favour of people, the planet and profit (Illies & Meijers, 2009; Sutcliffe, 2011).

The above developments and emergence of RRI have implications for regional development. Economic activities and innovation can be viewed in the space context (Boschma & Martin, 2010) and should be targeted towards solving major social and regional problems. The regional innovation system literature (e.g. Asheim, 2000, 2004; Morgan, 2007), as well as open innovation literature (Chesbrough, 2006) and regional entrepreneurial ecosystems literature (e.g. Feldman, 2014) has put an emphasis on the presence of a variety of actors including users in the innovation process. However, these scholars have taken the governance of innovation as given. Thus, the negative externalities of economic activities including innovation are often overlooked in these debates (Martin, 2016). Yet, there is evidence of increasing disparities between and within regions due to unequal distribution of gains within them (Iammarino, Rodríguez-Pose, & Storper, 2019; Rodríguez-Pose, 2018; Storper, 2018). Therefore, RRI brings to the fore the importance of governance of the innovation process, particularly the inclusion of stakeholders to allow both top-down and bottom-up processes as well as the need for inclusive and sustainable development, specifically in the context of regional development.

In the European context, in particular the EU, RRI has emerged as a topical policy issue (Coenen, 2016; European Commission, 2013; Fitjar, Benneworth, & Asheim, 2019; Rip, 2014). At the same time, there has been ongoing discussion and debate on sustainable regional development through different policy instruments such as the Cohesion Policy (Bachtler, Martins, Wostner, & Zuber, 2017). Thus, while the competitiveness of regions (Foray, 2014; McCann, 2008) are essential for economic growth, employment and profitability, their social cohesion (Barca, McCann, & Rodríguez-Pose, 2012) equally matters. It seems, on the one hand, the focus of regional innovation policies is still more on competitiveness and less on cohesion. On the other hand, the emphasis on RRI, particularly looking at Horizon 2020 (European Commission, 2014), a European research programme, has been more on governance broadly but less on its specificities. Both these situations and competing demands on economic competitiveness and social

cohesion put into question the essence of regional development, whether a balance can be found and how.

In this context, RRI could be a viable approach for sustainable regional development, taken into consideration its implications for regional innovation policy and practices. However, how or to what extent can responsibility be conceptualized and operationalized within the field of innovation studies as well as applied to regional development remains ambiguous (Forsberg et al., 2015; Owen et al., 2012). At the same time, in view of the need for engaged pluralism through interdisciplinary studies (Fagerberg, Martin, & Andersen, 2013), there is a lack of studies that have looked at both RRI and regional innovation studies together. As such, little is known about how much RRI can learn from regional innovation studies and vice versa. Therefore, this study seeks to answer the following research questions:

How is RRI conceptualized in literature? And, to what extent can it be applied to the context of regional development and vice versa?

Accordingly, this study has two aims: first, it explores the concept of RRI through systematic literature review and identifies emerging themes. Second, it applies these themes to regional innovation studies as well as reflect on how the latter can also enhance the theory on RRI. The study makes a contribution by bringing RRI and regional innovation studies literature together. The rest of the paper is structured as follows: Section 2 introduces the method used for the systematic literature review. Section 3 presents descriptive analysis and Section 4 presents a thematic analysis of the literature on RRI based on the SRL. Section 5 is the discussion, synthesizing the four domains of the themes on RRI and their application to regional development. Section 6 concludes with a summary discussion including implications for theory, practice and policy, and avenues for future research.

2. Method

We followed the SLR procedure of Tranfield, Denyer, and Smart (2003). A literature search² in the Web of Science, Science Direct, Springer, Scopus and Emerald databases was conducted in order to cover RRI research across all disciplines.³ In addition, papers from *The Journal of Responsible Innovation*⁴ were also included in the analysis. Papers were extracted from the databases using the following search terms, either alone or in combination, using the logical operators 'AND' and 'OR': 'responsible innovation' and 'responsible research and innovation', from the period 2003–2016. We chose to start our search in 2003 as the concepts of RI and RRI rapidly became the focus of debate and discussion across intellectual and institutional discourses from the mid-2000s onwards (Stilgoe & Guston, 2017). Moreover, the term 'responsible research' first appeared in the European Commission's Sixth Framework Program in 2002 ("The 6th Research Framework Programme (FP6)," 2005) with the notion of creating greater public engagement with science and technology. There has been a growth in publications of academic literature on RRI since then, as signified by the launch of *The Journal of Responsible Innovation* in 2014.

The search results were exported into EndNote and, duplicates papers were removed and the accessibility of the full texts was investigated. Papers for which only abstracts

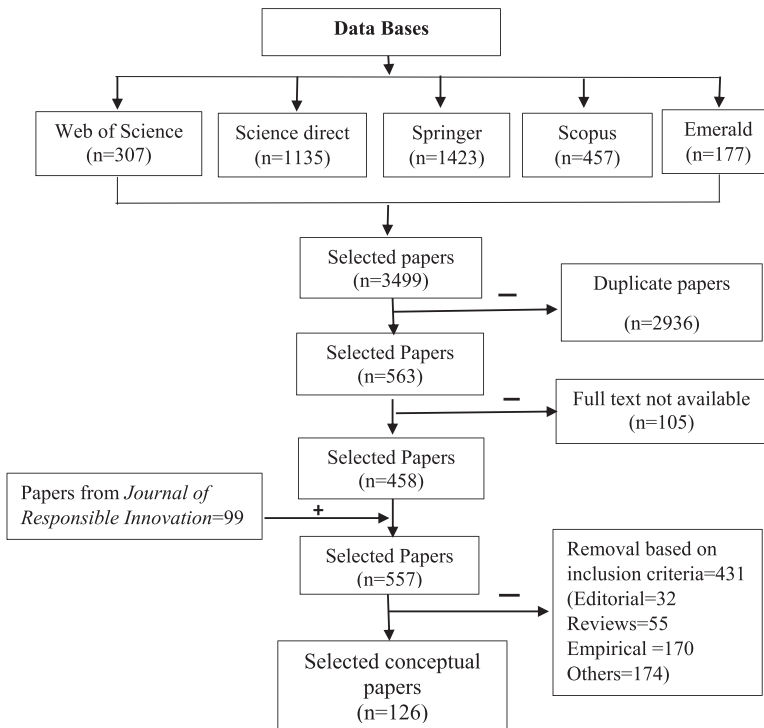


Figure 1. Flow chart of SLR process.

were available were eliminated from the study. The available full texts papers were categorized as either editorials, reviews, conceptual papers or those that were empirical in nature. Only full-text conceptual peer-reviewed academic articles published in English during the period 2003–2016 were included. [Figure 1](#) describes the selection process.

We followed the recommendation of Thorpe, Holt, MacPherson, and Pittaway (2005) to adhere strictly to the principles of transparency, clarity and broad coverage of the discussion of RRI in our study. A total of 126 papers were analysed in this study. Each author reviewed the full text of one-third of the articles and analysed them in accordance with the reading guide developed by the authors (Appendix 1). The reading guide included the review of key themes, theories and contributions towards theory and practice.

After the initial review, we deduced the major themes of the papers from the key concepts, discussion, principles, ideas, etc. presented within them. ‘Themes’ are defined here as fundamental concepts that describe the subject matter, core ideas, concepts, discussion and conceptual linkage of expression represented in the articles (Ryan & Bernard, 2003; Thorpe et al., 2005). We created additional tables, not included in the current paper version due to space limitations, where a description of each ‘theme’ by each article was clearly specified. To illustrate, we saw following definition of engagement in work of Vincent (2014) ‘Public engagement in science and innovation to make a shift from “deficit model” to a “participatory model” to make public presence in scientific enterprise’. In Gudowsky and Peissl (2016), authors talk about ‘Public engagement in future studies to

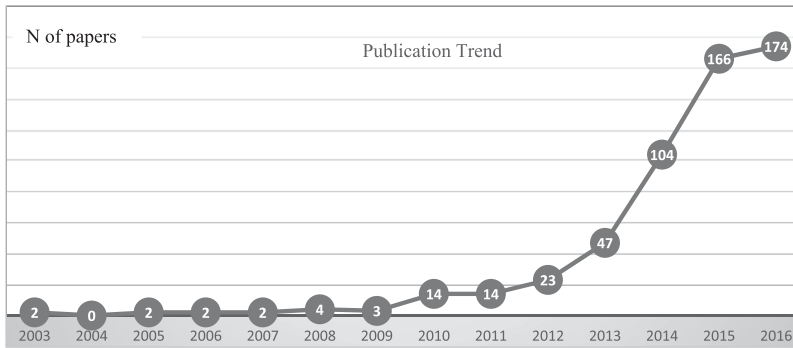


Figure 2. Numbers of paper by year of publication.

Table 1. List of journals publishing most RRI papers.

Journal	Number of papers	%
<i>Nanoethics</i>	15	11.9
<i>Journal of Responsible Innovation</i>	15	11.9
<i>Science Engineering and Ethics</i>	11	8.73
<i>Life Sciences, Society and Policy</i>	5	3.96
<i>Futures</i>	5	3.96
<i>Technology in Society</i>	5	3.96
<i>Technology Forecasting and Social Change</i>	4	3.17
<i>Journal of Information, Communication and Ethics in Society</i>	4	3.17

reflect public values as per societal needs', and Malsch (2015) mentions the need to 'Strengthen democratic right of individuals including government officials, members of civil society organizations, and employees of companies'. These articles were then seen as addressing the themes of 'public engagement', 'stakeholder engagement'. During our analysis, we identified also other themes, like upstream engagement, transdisciplinary approach, that together with pre-engagement, stakeholder and public engagement were labelled 'RRI-drivers' domain. Such an approach to categorization and labelling is suggested by (Braun & Clarke, 2006; Jones, Coviello, & Tang, 2011).

3. Descriptive analysis

A total of 557 papers were identified on the topic of RRI, including theoretical contributions, editorials, reviews, empirical studies and other types of paper. These papers are published in 208 different journals,⁵ which illustrates that the topic of responsible innovation has spread across different domains and disciplines. Until 2009, only a limited number of publications existed but this tripled between 2013 and 2015. Figure 2 gives an overview of the evolution of the field based on the distribution of the 557 papers between 2003 and 2016.

The 126 conceptual papers subjected to analysis in this paper are spread across 57 journals (Appendix 2). Table 1 presents an overview of the major journals that publish the majority of conceptual RRI papers.

As evident from Table 1, discussion about RRI is widely spread across disciplines. The majority of RRI research is concentrated in and around sensitive areas of technological

Table 2. Thematic areas and domain categorisation of papers with corresponding authors.

Domains	Thematic area	Authors
RRI-drivers (28 articles)	Pre-engagement	te Kulve & Rip, 2011
	Stakeholder engagement	Schwarz, 2009; Rose, 2012; Malsch, 2015; Nathan, 2015; Pols, 2016; Allon et al., 2016; Gudowsky & Peissl, 2016; Schroeder et al. 2016
	Upstream engagement	Lee, 2012; Torgersen and Schmidt, 2013; Bronson, 2015; Patrignani & Whitehouse, 2015b
	Public engagement	Hilstrom, 2003; Rose et al., 2011; Stilgoe, 2012; Pierce, 2013; Vincent, 2013c; Guston, 2014; Hester et al., 2015; Gudowsky & Peissl, 2016; van der Burg, 2016
	Civil society engagement Transdisciplinary	Allon et al., 2016; Paredes-Frigelett, 2016 Prónay and Buzas, 2015; Siemieniuch et al., 2015; Clarke and Kitney, 2016; Turcanu et al. 2016
RRI-tools (57 articles)	Walkshop approach	Wickson et al., 2015
	Engagement workshop	te Kulve & Rip, 2011; Blok, 2014; Selin, 2015; Stahl & Coeckelbergh, 2016; Rerimassie, 2016
	Online platform/Online knowledge sharing opening up Comprehensive and acceptability analysis	Selin, 2015; van Oost et al., 2016 Jakobson and Cakula, 2014; Vogel, 2014; Rose, 2012; Gupta et al., 2016 Patenaude et al., 2015; Meissne et al., 2016
	Social experimentation	Stilgoe, 2012; Stilgoe, 2016
	Foresight	Stahl, 2013b; Vincent, 2013d; Guston, 2014; Gudowsky & Peissl, 2016; Rhiariart et al., 2016;
	Hermeneutic	Grunwald, 2014
	Anticipation (of risk)	Hilstrom, 2003; Som et al., 2010; Owen et al., 2012; Vincent, 2013a; Guston, 2014; Wender, 2014; Hester et al., 2015
	Technology assessment	Rip, and van Lente, 2013; Schaper-Rinkel, 2013; van Oudheusden, 2014; Fuchs and Gazso, 2015; Kiran et al., 2015; Le Feuvre et al., 2016; Ingelbrecht, et al. 2016
	Informed consent	van Veen, 2013; Kelin, 2015; Flick, 2015; Spruit et al. 2016; van de Poel, (2016)
	Governance (by experimentation)	Asveld, 2016; Laird, and Wynberg, 2016
	Participatory appraisal	Jahnel, 2015
	Socio-technical integration	Fisher et al., 2015; Stahl et al., 2014; Carayannis et al., 2016; Saez-Martínez et al., 2016; Turcanu et al., 2016
	Design strategy	Wildman, 2007; Timmermans et al., 2011; Kiran, 2012; Stahl, 2014; Marie et al., 2015; Pesch, 2015; Woo et al., 2015
RRI-outcomes (54 articles)	Action research	Goorden et al., 2008
	Lifecycle thinking	Kohler, 2013; Wender et al., 2014; Patrignani and Whitehouse, 2015b; Thorstensen, and Forsberg, 2016
	Attitude of prudence	Vincent, 2013b
	Responsible attitude	Voegtlin & Scherer, 2015; Vincent, 2013a; Stahl, 2013a; Blok, 2016; Peterson and Wickson, 2016
	Goal oriented responsibility	Patrignani, and Whitehouse, 2015a
	Responsiveness	Owen et al., 2012; Blol, 2014; Mampuys, and Brom, 2015; Clarke and Kitney, 2016; Gupta et al., 2016
	Alignment and harmony	van der Burg, 2010
	Mutual understanding and respect	Blok, 2014; van der Meij, 2015; Gupta et al., 2016
	Trust	van Veen, 2013; Haen, D. 2014; Asveld, 2016; Turcanu et al., 2016
	Sustainability impact	Owen et al., 2012; Davis and Laas, 2014; Voegtlin & Scherer, 2015; Schroeder, and Ladikas, 2015; de Saille & Medvecky, 2016
	Shared responsibility	Malsch, 2015
	Glocal sustainability	Deblonde, 2015, Pelle' and Reber, 2015
	Consensus	Stahl, 2014; Struik et al., 2014; Fuchs and Gazso, 2015; Marie et al., 2015; Hagen, 2016; Stahl & Coeckelbergh, 2016
Co-creation	Wickson et al., 2015; Selin, 2015; Mavroeidid and Tarnawska, 2016	
Quality of life	Peine et al., 2015	
Social progress Sharing economy	Roco et al., 2011; Stahl & Coeckelbergh, 2016; Venot, J.P (2016), van den Hove et al., 2012; Rip, 2014; Ziegler, 2015; Moraglio and Diemel, 2015	

(Continued)

Table 2. Continued.

Domains	Thematic area	Authors
RRI-barriers (20 articles)	Integrity	Gardner and Williams, 2015; Horn, 2016; Lacour et al., 2015
	Care	Pavie, 2014; Preston and Wickson, 2016
	Principle-based decision-making	Holbrook & Briggie, 2014; Wiesing and Clausen, 2014; Pols, 2015
	Asymmetrical power distribution	Tyfield, 2012; Saravanamuthu et al., 2013; Forsberg, 2014; van Oudheusden, 2014
	Moral pluralism	Pelle', 2016; Wong, 2016
	Conflicting interests	Fouilleux and Loconto, 2016; Taddeo, 2016; Weckert et al., 2016
	Over inclusiveness	Spinello, 2003
Multiple values		Racine et al., 2014; Zwart et al., 2014; Arnaldi & Gorgoni, 2015; Mampuys and Brom, 2015; Ruggiu, 2015
	Level of perceived responsibility	Grinbaum, 2013
	Volitional evolution	Miller, 2015

innovation such as nanotechnology, biotechnology, gene-drive technology, digital technology, etc.

4. Thematic analysis

This section addresses the first research question: How is RRI conceptualized in literature? Accordingly, we endeavour to understand the conceptualization of RRI within regional innovation studies and other related fields as well as extend its potential applications to regional development. We therefore, subjected the included papers in the study to thematic analysis and identified themes, which we categorized into four RRI-domains as: drivers, tools, outcomes and barriers.

The thematic areas and domain categorization of the papers included in this study, together with their authors, are presented in Table 2. Some articles address two or more domains, and are therefore included in each of them.

In general, RRI is conceptualized as collective stewardship of science and innovation in order to meet the needs and expectation of society and to ensure inclusive, responsible and sustainable development. Specifically and evident in Table 2, the most debated domains of

Table 3. Major themes on RRI-drivers and description.

Thematic area	Description
Public engagement	Public engagement in science and innovation to make a shift from 'deficit model' to a 'participatory model' to make public presence in scientific enterprise. Public engagement in future studies to reflect public values as per societal needs.
Stakeholder engagement	Societal actors (researchers, citizens, policy-makers, third sector organizations and businesses) work together during the whole research and innovation process to better align both the process and its outcomes with the values, needs and expectation of society. Stakeholder engagement for communitarian and subsidiarity perspectives. Strengthen democratic right of individuals including government officials, members of civil society organizations and employees of companies.
Upstream engagement	No guarantee that the responsibility will eliminate risk in condition of uncertainties. By the process of upstream engagement, the purpose is to create an environment of shared responsibility. During public debate, agenda should be kept open even if this result in a conflict, such conflict in fact would be best stimulus for further debate. Means of including wide variety of voices and values that could help in shaping research and innovation attuned with the values of wider community.
Transdisciplinary	Means for dealing with prospective limitation of scientific knowledge and technological know-how.

RRI are tools, followed by outcomes, drivers and RRI-barriers but the last has received limited attention. Below we discuss each domain in more detail.

4.1. RRI-drivers

The key themes within this domain focus on the antecedents or elements that lead to RRI. These elements mainly reflect the way in which RRI can be approached and represent the basic conditions necessary for RRI. What drives RRI is engagement, in particular the engagement of users, customers, relevant stakeholders, experts, policymakers, politicians and the public in the early stage of the research and innovation process by way of active and deliberate participation. Although different themes appear within this domain, the bottom line is the inclusion of different actors in research and innovation activities. This adds a diversity of knowledge and better anticipation of consequences of the result of basic or applied research (Owen et al., 2012). This is important in view of the argument that in general knowledge production and in particular the innovation process has shifted from mode 1 driven by the scientist in a linear innovation process to mode 2 involving an interactive process of learning with other users and stakeholders (Nowtmy, Scott, & Gibbons, 2003). Even in the context of basic research where some elements of mode 1 knowledge production remain dominant, the need to be anticipatory, inclusive and reflexive as well as responsive on other stakeholder remains important.

Table 3 presents examples of some of the most frequently mentioned drivers of RRI.

However, inclusion, participation or engagement should not be exploited as a means of securing specific outcomes, but rather to forge broader societal impact (Pellé, 2016; Sthal, 2014). The purpose of engagement activities is to set things in motion or solidify ongoing development effects; however, the questions of who, why, when to include or even how and to what extent to include seem problematic. One possible alternative could be pre-engagement, which could be a crucial platform to gain intuition about further engagement of the relevant actors in research and innovation (te Kulve & Rip, 2011). As such, pre-engagement could mean mapping of engagement for the research and innovation process, with the aim of achieving responsible outcomes.

4.2. RRI-tools

The RRI-tools domain includes methods or approaches intended for the effective engagement, anticipation and mitigation of potential risks that research and innovation might bear, to ensure that the particular research and innovation is aligned with the norms, values and expectations of society (Som et al., 2010). Table 4 presents some of the most frequently cited themes of RRI-tools.

Knowledge, in this context, plays a crucial role. Innovators, entrepreneurs and societal actors need to acknowledge the fact that individual knowledge would still be limited to address overall socioeconomic, environmental and ethical issues in society.

How to orchestrate and manage knowledge from multiple perspectives is the major topic of the articles under this domain. The themes within the RRI-tools domain are therefore highly concentrated on possible ways of accumulating knowledge and successfully deploying it to overcome societal and environmental challenges. RRI-tools promote the notion of shared responsibility in order to take care of the future (Blok, 2014; Stahl &

Table 4. Major themes on RRI-tools and description.

Thematic area	Theme description
Engagement workshop	Multiple level of analysis and socio-technical scenarios are the complementary approaches for constructive engagement.
Comprehensive and acceptability analysis	The core value judgement in risk analysis is monetary while social acceptance is measured by how much people are willing to pay. This approach actually can be used as reflective and acceptability analysis.
Collective experimentation/social experimentation	Renegotiating between known and unknown. Social experimental nature of emerging technologies.
Anticipation of risk	Anticipating risks and making efforts to prevent is considered as the ultimate responsible attitude.
Technology assessment	A proactive approach, which could provide safe and responsible innovation and avoid controversies.
Foresight	Future studies human-centered science and technology transdisciplinary foresight could be a starting point to elicit public values and societal needs. Robustness of credibility of foresight outputs are essential to achieve policy related impact. Important factors in generating the attributed impact: key design choices and processes, the quality and variety of outputs for different stakeholders, the engagement of stakeholders during and after the project, innovative media campaigns. Knowledge of effective mechanisms and foresight impact pathways will help to guide in achieving those impact.
Informed consent	Technologies with great promise could pose ethical issues and these could be avoided considering these issues at the early development of the technology. Informed consent reflects moral responsibility of the innovators, which could resolve ethical issues associated with the implementation of the technology.
Governance by experimentation	Experimental approach build on the insight from the approach of strategic niche management and resilience through diversity add the notion of moral learning thus by making it possible to be responsive if the results are socially unacceptable.
Participatory appraisal	Opening up analytic and participatory appraisal in order to consider ignored uncertainties, scrutinize different possibilities and emphasize new options. Participatory appraisal for concrete procedure for the enactment of 'participation' and 'responsibility' in action and not just in empty words.
Collaborative socio-technical integration	Frame work for collaborative integration which is participatory research approach that includes scholarly engagement, ethical, legal and social implication/aspects (ELSI/ELSA) research, laboratory studies, team science, technology assessment, inter- and transdisciplinarity, and public engagement.
Online platform	Online platform for sharing and tracking the activities on emerging technologies.
Online knowledge sharing	Automated learning support system to improve the efficiency and quality of further knowledge flow for sustainable knowledge cooperation among educational institutions and entrepreneurs/innovators.

Coeckelbergh, 2016). This implies transforming the notion of responsibility from liability to care (Owen et al., 2012; Pellé, 2016).

4.3. RRI-outcomes

'Responsible process towards responsible outcomes' is the main aspect of RRI-(Owen et al., 2013). The RRI-outcomes domain thus comprises the themes associated with outcomes as a result of the implementation of RRI-tools in the research and innovation process. Therefore, the themes within this category comprise attitudes, behaviours and impacts of RRI practices in research and innovation activities. For instance, RRI practices can help establish a culture of lifecycle thinking involving critical assessment of environmental sustainability in new product development (Deblonde, 2015; Köhler, 2013; Vincent, 2013). Similarly, responsible attitudes and behaviours would build individual and collective capability to direct research and innovation towards the socioeconomic

Table 5. Major themes on RRI-Outcomes and description.

Thematic area	Description
Life cycle thinking	Modern technologies have led to a substantial increase in resource productivity due to miniaturization of products, however natural resource consumption has not fallen. Even clean technologies use rare earth metals for their efficiency. This led to the question about their sustainability. RRI practices develop life cycle thinking culture among the technology designers and consumers.
Attitude of prudence	Anticipation of the potential environmental, health, security impacts and the ethical, legal and societal impacts of the application of the emerging technology
Responsible attitude	Anticipating risks and making efforts to prevent them. Good intentions always do not ascertain responsible behaviour. Hence, the intentions are to be evaluated from an ethical and political perspective.
Co-creation	Creative ideas are seldom produced in social isolation. Engagement of stakeholders and public in innovation activities could enable in co-creating new knowledge and innovations.
Sustainability impact	Sustainability refers to continuously necessary long-term process. Adaptation of responsible approaches in innovation mean sustainability impact.
Social Progress	Innovation focused on the concerns of society as per societal needs, values and expectations mean overall social progress.
Consensus	More transparent debate and inclusiveness in decision-making process among scientific community and society at large creates win-win and acceptable outcomes.

transformation of society (Voegtlin & Scherer, 2015). Table 5 outlines some of the major RRI-outcomes debated in the literature.

4.4. RRI-barriers

The major themes within this category mainly focus on the potential hindrances that RRI practice may face. In the RRI literature, society is viewed as a unit of multiple values comprised of individuals and societal actors such as the state, firms and civil society with conflicting interests (Taddeo, 2016). Directing research and innovation towards ‘societal desirability’ could be challenging. Consequently, the themes within this domain are the possible obstacles that may arise while implementing RRI aspects in research and innovation policy. For example, RRI promotes open access to research and innovation results (Gupta et al., 2016; Rose, 2012). However, RRI and its successful transition could be challenged as the debate on the relevance of protecting intellectual property rights in research and innovation is an ongoing one (Spinello, 2003). Another example, businesses invest in research and development with the aim of introducing goods and services to the market quickly to gain a competitive advantage over their competitors. For instance, in some multinational corporations, research and innovation are oriented towards outcomes to produce a quick turnover. Researchers, innovators and even managers within such corporations are evaluated as per research and innovation outcomes (Grinbaum, 2013). In such a corporate culture, there is a danger that RRI and its aspiration will be considered as barriers to research and innovation. In the process, it appears that they demonstrate ignorance of ethical and environmental issues, either intentionally or unintentionally (Blok, 2016).

By contrast, societal and environmental activists oppose such practices and force businesses to abandon them (te Kulve & Rip, 2011). Thus, heterogeneous societal norms and values, moral pluralism, power asymmetry, conflicting political ideologies, demands for democratization and governance of research and innovation make RRI, a daunting task (Forsberg, 2014; van Oudheusden, 2014). Nevertheless, bringing all these

Table 6. Major themes on RRI-barriers and description.

Thematic area	Description
Principle-based policy-making	Innovation policy design are guided by principles (either proactionary or precautionary). These principles should not be treated as decision procedures. If done so, values are predetermined, intelligence is gathered, and the results are fed into the principles and ultimately spit out prescription.
Asymmetrical distribution of power	Power distribution among the participants in research, innovation and decision-making could result in status quo hindering the entire process.
Moral pluralism	What is considered morally desirable often stems from conflicting values.
Over inclusiveness	The challenge of navigating between tolerating free riders and stimulating innovations.
Level of perceived responsibility	The perception of individual or shared responsibility might create obstacles in deciding whether to innovate or not.
Conflicting interest	Conflicting interest could mislead the purpose of innovation. This could obstruct in quick and agreed decision.

competing demands and conflicting interests together to achieve ‘societal desirability’ should remain the aim of RRI (Taddeo, 2016). Table 6 presents the most frequently cited thematic areas of the RRI-barrier domain.

Today’s research policies are mainly based on a principle-based decision-making process in the form of rational risk taking or the precautionary principle (Holbrook & Briggie, 2014). The dominant influence of such a principle-based decision-making culture in research policy restricts a responsive attitude by abandoning innovations that might bear further negative consequences for society (Holbrook & Briggie, 2014). Creating harmonious or standardized RRI on a global scale could encounter obstacles due to multiple values, interests and perceptions of what is ‘responsible’ or ‘irresponsible’ research and innovation (Arnaldi & Gorgoni, 2015; Ruggiu, 2015).

Inclusion is the main aspect that drives RRI. However, inclusion by itself seems ambiguous. To ensure a smooth transition to the RRI process, appropriate inclusion is essential and defining and determining ‘appropriate inclusion’ could be a challenge for RRI. Serious consideration of appropriate inclusion must be defined, otherwise there is a danger of over-inclusivity. This could result in the imperil of the integrity of commons (Spinello, 2003), information and power asymmetry (Blok et al., 2015), and unintended consequences of RRI itself.

5. Discussion: application of four RRI domains to regional innovation studies

The descriptive analysis of SLR shows that none of the RRI studies focusing on regional dimensions. The studies on RRI are mainly based on the debate around sensitive technology innovation such as nanotechnology, biotech and digitalization and in and around negative consequences associated with these innovations for the society and the environment. So far, the discussion about RRI has taken limited attention within regional innovation studies. However, the authors argue that RRI debate is highly compatible with regional innovation studies discourse. In facts, RRI studies contribute to debate on regional innovation studies by adding governance dimension, providing guidance on drivers and tools for more responsible regional policies. Regional innovation studies discourse and RRI discourse combined together might provide a synchronized effect on responsible and sustainable outcomes of innovation and entrepreneurial activities for regional development.

The widening grand challenges (Lund Declaration, 2009) and growing disparity at spatial levels resulting in winner and losers (Rodríguez-Pose, 2018; Storper, 2018) are increasingly raising public concerns (Owen et al., 2013) about the unintended consequences of research and innovation. These issues should be addressed proactively on the level of national and regional policies, to ensure that society gains the greatest benefits from science, research and innovation. Therefore, the purpose of innovation should be in and around socioeconomic transformation and overall development of society. RRI address this need by emphasizing the need for a shift in the predominant notion of science and innovation “in” society to science and innovation “for and with” society (Owen et al., 2012).

Engagement of broader stakeholders from the design phase of decision on innovation policy or innovation and entrepreneurial activities becomes the major driver of RRI. However, whether stakeholders are local, national, regional or global, are not specified in RRI studies. Here regional innovation studies might enrich the debate on RRI since stakeholder engagement is an extensively discussed topic within innovation and regional innovation studies. As for instance, innovation is considered an interactive process of learning among different actors (Lundvall, 2010) and recently the implications of networking (Ter Wal, Alexy, Block, & Sandner, 2016), open innovation (Chesbrough, 2006), social innovation (Phillips, Lee, Ghobadian, O'Regan, & James, 2015) and user innovation (Von Hippel, 2005) are ongoing discussion within innovation and regional innovation studies. Regional innovation studies consider engagement as a source of knowledge diversity for innovativeness, co-creation and collaboration for innovativeness (Solheim, 2016). RRI considers stakeholder engagement for co-creation and collaboration to ensure responsible outcomes for societal need based innovation (Guston, 2014; Vincent, 2014). Thus RRI adds value to regional innovation studies by enlightening effects beyond and above economic value realization.

In order to stimulate innovation and development, policy plays a vital role. With growing societal and environmental challenges, it is widely acknowledged that there is a need for policy intervention capable to respond to present and future challenges. Therefore, it is urgent to find effective and efficient innovation and development policy intervention, which should be designed with interaction with broader stakeholder (Barca et al., 2012). However, interaction should not be limited within certain stakeholders or experts and policy-makers. Adapting RRI-drivers in regional innovation and development policies and innovation and entrepreneurial activities would facilitate regional development, which are based on societal needs (Barca et al., 2012).

For responsible and sustainable research and innovation outcomes, it is necessary to know how, what and where to innovate (Bessant, 2013). This requires a diversity of knowledge from broader stakeholders to identify the right innovative idea and anticipate both positive and negative externalities of such innovation and to target it for a sustainable future (Owen et al., 2012). RRI-tools could be instrumental in planning, deciding and executing innovations and innovation policies for regional development. This is mainly because RRI-tools allow in expanding anticipatory horizons beyond positive externalities or economic benefit to consider negative externalities and consequences in society and environment.

In general, scholars in the fields of regional innovation studies and economic geography have made substantial contributions to explaining the role of innovation, innovation

networks and innovation policies in regional development in the context of globalization (see, e.g. Asheim, Boschma, & Cooke, 2011; Fløysand & Sjøholt, 2007; Isaksen & Onsager, 2010; Jakobsen & Lorentzen, 2015; McCann, 2008; McCann & Acs, 2011). However, following pressure from spatial competitiveness to catch up with the current trend of globalization, regional innovation policies have mostly focused on the innovativeness of space (local, national and regional) (Asheim, Grillitsch, & Trippel, 2016; Boschma & Frenken, 2011; Boschma, Minondo, & Navarro, 2012; Martin & Sunley, 2011; Trippel, Grillitsch, Isaksen, & Sinozic, 2015) rather than responsible innovation outcomes and innovation impacts. Until recently, both cohesion (Bachtler et al., 2017; Barca et al., 2012) and smart specialization (Foray, 2014; McCann & Ortega-Argilés, 2015) policies has emerged within EU with the purpose of promoting both competitiveness and cohesion in and between EU regions. However, it seems the emphasis, so far is more on competitiveness than cohesion. This raises the question of how new mission-oriented innovation policies can be applied to align these competing goals – achieving competitiveness and economic growth while focusing on the social transformation and environmental sustainability (de Saille & Medvecky, 2016). Therefore, adapting RRI-tools such as foresight could facilitate detailed anticipation of risk and opportunities, alternatives to address present and future societal challenges. Although RRI-tools present different risk assessment approaches, RRI studies have not clearly articulated engagement strategies. However, these are discussed within innovation and regional innovation studies. Action research, social lab and living lab, engaged pluralism are getting attention within regional innovation and regional studies (e.g. Clark, Gertler, Feldman, & Williams, 2003; Fagerberg et al., 2013). RRI can benefit by adapting such engagement strategies to extract necessary knowledge for responsible outcomes. However, within regional innovation studies such engagement strategies are not visibly positioned as a shift towards responsible outcomes.

In light of the above, first, responsible and sustainable innovation outcomes result from collective stewardship where the steering role of government and public policy are crucial (Mazzucato & Semieniuk, 2017). Second, policies should focus on creating and shaping demands that satisfy sustainable societal development (Barca et al., 2012). This can be, for example, cultivated through RRI-tools such as design strategy, opening up, foresight, knowledge sharing among stakeholders in the decision about innovation (Owen et al., 2012). The co-creation of values and shared responsibility are predominant factors that shape responsible innovation policy development (Coeckelbergh, 2016). Such orchestration requires investment by both private and public actors, and a long-term perspective. Furthermore, the eventual significance of policies and strategies for sustainable regional development depend on the effectiveness of the implementation across regions.

Although regions differ in the availability of resources, institutions, knowledge, infrastructure and their needs and capabilities for innovativeness and viable development, the systemic nature of innovation, in particular regional innovation systems (Asheim et al., 2016; Asheim & Gertler, 2005; Morgan, 2007), creates room for responsible development. Further, a recent special issue of European Planning Studies debated this thematic area, focusing on new path development as fostered by policies that incorporate both actor and system-based elements (Isaksen & Jakobsen, 2017). These are certain attempts associated with growing regional challenges. However, desired outcomes of policy interventions, innovation or entrepreneurial activities cannot be ascertained a priori. In light of this, RRI advocates on achieving RRI-outcomes as societal desirable through RRI-drivers and RRI-

tools. As for instance, engaging broader stakeholders can contribute in the diversity of knowledge to focus on need based innovative solutions enhanced by anticipation of risk and opportunities of such innovation in society and environment (Guston, 2014).

Overall, the strategic innovation and development policy, innovation and entrepreneurial activities should follow an iterative, continuous and flexible process of adaptive learning (Stilgoe et al., 2013), which could be advanced by the collective efforts of stakeholders and the public. We believe that the integration of RRI practices within regional innovation policies and practices as well as the adoption of RRI practices in research and innovation activities would make a significant contribution towards sustainable regional development. However, the RRI-barriers point to the challenges of implementing RRI in regional innovation policies. Difficulties in the operationalization of RRI, potential power and information asymmetry among stakeholders, difficulties in obtaining a consensus on 'societal desirability' and resource constraints can lead to the perception of RRI as an obstacle to, rather than a facilitator of, research and innovation (Zwart, Landeweerd, & van Rooij, 2014) consequently affecting regional development. These issues should not be overlooked; rather, the focus should be on overcoming these barriers through reflexive and responsive dialogue, cooperation and collaboration.

6. Conclusion

This paper has endeavoured in understanding the conceptualization of RRI and extent its application to sustainable regional development. In theory, despite its increasing interest, the concept of RRI remains ambiguous. In practice, this makes it difficult to implement, particularly when it comes to regional development. Accordingly, undertaking an SRL, this paper explores the concept of RRI by identifying and categorizing those themes into RRI domains as drivers, tools, outcomes and barriers. It then applies these themes to regional development. Therefore, this study makes a contribution by bringing RRI and regional innovation studies together exploring their effect on one another and combined effect on responsible and sustainable regional development.

Following the ongoing discussions around RRI and regional innovation studies, especially on cohesion and smart specialization, there is an opportunity for engaged pluralism (Clark et al., 2003; Fagerberg et al., 2013) between academic disciplines, innovation studies and regional studies. It seems the conversation about RRI has not gained attention in regional innovation studies and vice versa. Yet, the two discourses are highly compatible and can gain by new insights by shared discussion. For instance, discussion about engagement strategies is present in regional innovation studies as living labs, social labs, action research and community engagement. In fact, there is a way to learn from both discourses and elements from RRI studies can be applied into regional innovation studies and vice versa. Although it is not explicit, a lot of concepts that are used in RRI are also debated in regional innovation studies. This confirms a potential opportunity for both RRI and regional innovation studies to collectively contribute to combined advancement of theory and practice. In the context of regional development, RRI practices could be crucial in planning, deciding and executing innovation policy strategies for a sustainable future. This means adapting RRI into policy formulation and innovation activities could ensure and maintain a balance between cohesion and

competitiveness (Fitjar et al., 2019) resulting in smart, inclusive and sustainable development in and between regions.

This study has implications both for theory, practice and policy. At a theoretical level, our paper contributes by introducing RRI domains as drivers, tools, outcomes and barriers. At the practical level, the findings of this study are crucial for informing policies and practices to align the purpose, process and outcomes of innovation in order to achieve sustainable development. More specifically, focused on the role of RRI-drivers, tools and barriers to achieve responsible outcomes. At the same time, we recommend the inclusion of broader stakeholders and societal actors while deciding and designing innovation policies and critically analysing the consequences of decision through anticipation.

RRI is still an emerging phenomenon; other potential areas for future research could be explored. As for instance, our study revealed that the major driving factor behind RRI is engagement or inclusion. However, as pointed out in our analysis, engagement or inclusion is not a straightforward or easy task. Poorly designed inclusion approaches would result in a situation of ‘unresolved decision’, which in turn might result in a situation of ‘no decision at all’ (te Kulve & Rip, 2011). Such a situation would be ‘irresponsible’ at a time when society is urgently in need of decisions and solutions. Future research should focus on active and productive engagement strategies to design engagement techniques in local, regional, national and global contexts. Whereas regional development strategies have a lot of instruments that entail elements of RRI thinking, the question remains how to change institutions in a way that will provide incentives for all actors involved to follow the ideas of RRI, which is a subject for future research.

Notes

1. The papers in our analysis have used the terms ‘Responsible Innovation (RI)’ and ‘Responsible Research and Innovation’ (RRI). This study has considered ‘RI’ and ‘RRI’ as the same following a similar approach as Stilgoe and Guston (2017).
2. The literature search was performed in October 2016.
3. The databases used for the literature search cover research across the fields of natural sciences, engineering, management, economics, psychology, health, epidemiology and medicine.
4. *The Journal of Responsible Innovation* was not indexed in major databases at the time of our literature search.
5. The list of selected papers will be made available on Research Gate.
6. References presented here exclude 126 articles that are subject of the analysis. (The full list of 126 articles with references available at Research Gate link to be provided.)

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⁶References presented here exclude 126 articles that are subject of the analysis. (The full list of 126 articles with references available at Research Gate link to be provided.)

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Appendices

Appendix 1: Sample reading guide

SLR reading guide	
1. Article title	Informed consent in asymmetrical relationships: an investigation into relational factors that influence room for reflection
2. Author(s)	Shannon Lydia Spruit, Ibo van de Poel and Neelke Doorn
3. Year of publication	2016
4. Journal	<i>Nanoethics</i>
5. Research question	How can informed consent be applied in a nanomaterial context?
6. Key concepts	Informed consent, nanomaterial risks, relational autonomy, room for reflection, interpersonal relationships, dependency, personal proximity, shared interests
7. Main area	Ethics
8. Key findings	This paper discusses three features that make valid informed consent obtainable – dependency, personal proximity and the existence of shared interests. It discusses informed consent in a new setting. Normally, informed consent is used between patients and doctors, or between researchers and research participants. Informed consent allows individuals to make their own decisions concerning their exposure to potential dangers, emphasizing the importance of individual autonomy and responsibility for balancing risks and benefits. However, consent cannot be informed if it has no solid knowledge base, which is the case for nanotechnologies. The paper looks at situations where informed consent could potentially be obtained – between producers and consumers, or between employers and employees in the case of engineered nanomaterials
8a. Practical implications /tools	Not clearly specified but, generally speaking, informed consent might lead to the anticipation of risks and more responsible decision-making
8b. Theoretical implications	In some senses, this article discusses anticipation of risk and, in that way, enhances responsible innovation in nanotechnologies. It develops a relational approach to informed consent

Appendix 2: List of 126 conceptual papers divided by journals

Name of journals	Number of papers
<i>Medical health Care and Philosophy</i>	2
<i>Technology in Society</i>	5
<i>Science Engineering and Ethics</i>	11
<i>Philosophy of Management</i>	2
<i>Technology Forecasting and Social Change</i>	4
<i>Journal of Information, Communication and Ethics in Society</i>	4
<i>Economy and Society</i>	1
<i>Research Ethics</i>	1
<i>International Journal of Performability Engineering</i>	1
<i>Clinical Ethics</i>	1
<i>Nanoethics</i>	15
<i>Europa Journal of Future Research</i>	2
<i>Journal of Agricultural and Environmental Ethics</i>	2
<i>Journal of Academic Ethics</i>	2
<i>Agriculture and Human Values</i>	1
<i>Procedia Computer Science</i>	2
<i>Seminars in Ultrasound CT and MRI</i>	1
<i>Theoretical Foundations of Chemical Engineering</i>	1
<i>Transnational Environmental Law</i>	1
<i>Journal of Knowledge Economy</i>	2
<i>Journal of Technology Transfer</i>	1
<i>Life Sciences, Society and Policy</i>	5
<i>Journal on Chain and Network Science</i>	2
<i>Annals of Physical and Rehabilitation Medicine</i>	1
<i>Science and Public Policy</i>	2
<i>Futures</i>	5
<i>Ethics and Information Technology</i>	1
<i>Information and Management</i>	1
<i>Minds and Machines</i>	1
<i>Innovation-The European Journal of Social Science Research</i>	1
<i>Foresight</i>	1
<i>Diagnostic Histopathology</i>	1
<i>Public Understanding of Science</i>	1
<i>Biological Theory</i>	1
<i>Ethics and Politics</i>	2
<i>Seminars in Pediatric Surgery</i>	1
<i>Journal of Business Ethics</i>	1
<i>Synthetic and Systems Biotechnology</i>	2
<i>Journal of Open Innovation: Technology, Market and Complexity</i>	1
<i>Social Studies of Science</i>	1
<i>Biotechnology Journal</i>	1
<i>Journal of Nanoparticle Research</i>	1
<i>BioSocieties</i>	2
<i>Neuron</i>	1
<i>Journal of Cleaner Production</i>	1
<i>Applied Ergonomics</i>	1
<i>Toxicology</i>	1
<i>Robotics and Autonomous Systems</i>	1
<i>Minerva</i>	2
<i>Current Opinion in Environmental Sustainability</i>	1
<i>Surgical Endoscopy</i>	1
<i>Science & Education</i>	1
<i>Journal of Environmental Radioactivity</i>	1
<i>Environmental Science & Policy</i>	1
<i>Journal of Science Communication</i>	1
<i>Environmental Science and Technology</i>	1
<i>Journal of Responsible Innovation</i>	15
Total	126