RESPONSIBLE RESEARCH AND INNOVATION – A CONCEPTUAL CONTRIBUTION TO THEORY AND PRACTICE OF TECHNOLOGY MANAGEMENT

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Abstract. The concept of Responsible Research and Innovation (RRI) has become a popular term as a result of making it a cross-cutting theme for the Horizon 2020 Framework Programme of the European Union. RRI may be understood as a process by which societal actors and innovators become mutually responsive to each other with a view to the acceptability, sustainability and societal desirability of the innovation process and its products. The work presents a review of the state-of-art scientific literature on Responsible Research and Innovation (RRI) together with a synthesis of theoretical and practical challenges faced by this new concept. Mapping of RRI dimensions and its theoretical assumptions is performed. Bibliometric analysis of the scientific literature on RRI is carried out. The analysis of RRI-related projects is conducted. The attempt is made to clarify what RRI means for an enterprise in practical terms and what makes an innovation project in an enterprise a responsible one. Finally, a proposal for a closer interchange between RRI and Technology Assessment discourses is made together with an argument for a more extensive use of future-oriented methods that increase epistemic horizons of an innovating organisation.

Keywords: Responsible Research and Innovation (RRI), responsibility, European Union, innovation, technology management, technology assessment.

JEL Classification: O32, O33, O38.

Introduction

Responsible Research and Innovation (RRI) is a term that describes research and innovation (R&I) activity that is ethically acceptable and socially desirable. The idea that technology is not value-neutral (van de Poel 2012) and that R&I should be aligned with societal values, needs and concerns is decades old but the very term RRI has its origin only in 2009 when it appeared in the work by Robinson (2009) in the context of nanotechnology development. It was later adopted in the European Union as a new policy concept (European Commission 2011, European Parliament 2013). Then RRI has earned the status of a cross-cutting priority in EU's Horizon 2020 Framework Programme for Research and Innovation (H2020).

Von Schomberg (2012) proposes that RRI is understood as a *transparent, interactive process by which societal actors and innovators become mutually responsive with a view to* 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).

According to the European Commission, the RRI concept has the following pillars (also called dimensions or policy agendas): 1) Ethics, 2) Gender Equality, 3) Governance, 4) Open Access, 5) Public Engagement, 6) Science Education. All actors engaged directly or indirectly in R&I, i.e. researchers, policy makers, educators, business and industry innovators and civil society organisations, are expected to integrate RRI into their values, policies and actions in order to tackle the so-called Grand Societal Challenges. Particular process features are encouraged: 1) diversity and inclusion, 2) anticipation and reflection, 3) openness and transparency, 4) responsiveness and adaptive change (Owen et al. 2012). Comprehensive mind map

encompassing and linking various dimensions RRI (grand challenges, policy agendas, resources, outcomes, engaged actors, related terms, process dimensions) is presented in Appendix 1.

The overview of available scientific literature and RRI-related activities have allow the author to identify the following scientific problems: (1) Ontological and epistemological underpinnings and assumptions pertaining RRI have not been systematised, (2) Relevance of the concept to the practice of technology management in the market reality has not been sufficiently studied. In this paper, an attempt is made to increase the body of knowledge in the two above aspects. Author applies literature review, bibliometric analysis, mind mapping and logical construction methods to achieve the above stated goals.

1. RRI – revisiting the notion of responsibility

Even if RRI is not about prescribing what scientists and innovators should do, it is about making the entire world of science and innovation more responsible (…) write Kupper et al. (2015) in their report of the "RRI Tools" project. In relation to innovating enterprises, the communication from the same project assures readers that RRI is not about additional regulation but about making companies more profitable and socially responsible. Such statements about RRI make it evident that deconstructing the word "responsibility" is key to deeper analysis of this concept.

If responsibility were to by classified into legal responsibility, ethical (moral) responsibility and social responsibility (Gianni 2016), RRI is, for the most part, linked to the concept of ethical (moral) responsibility. However, paradoxically, the term "responsibility" is absent in the traditional ethical discourse where concepts like virtue, rights, contract, utility, or duty were prominent (Mitcham 2012). More precisely, responsibility may be understood as being accountable for one's action or as an act of attributing an action (and its results) to somebody. Pellé and Reber (2016) note that responsibility may have both positive and negative connotations; it may have both retrospective and prospective orientations (Figure 1).

There is a considerable number of issues related to RRI that pose difficulties and require further in-depth reflection. García et al. (2016) point at the following obstacles to good understanding and broad implementation of RRI:

- Lack of shared, consistent understanding of what it means to each of the actors' groups;
- Vagueness and very broad perspective that hampers the application of the concept in practical terms;
- Need to explain RRI in a different manner to different groups of actors and stakeholders;
- Absence of generally established norms;
- Scarcity of examples of good practice;
- Lack of understanding – especially in business context – of how and when implement it.

Furthermore, it is worth noting that the RRI pillars were named arbitrarily, probably as a result of internal bureaucratic processes in European Commission. No substantial justification for inclusion of those criteria has been offered. One may wonder why key issues such as sustainability, social justice or human rights are omitted. As Pellé and Reber (2016) mention, the pillars are not of the same order and some of them could be incorporated into each other. There is a level of redundancy, possible tensions and even contradictions among them.

2. Bibliometric analysis of RRI

Analysis of key bibliometric indicators sheds some light on the development process of RRI concept, most important contributors to the RRI discourse and the geographic dimension of that discourse. There have been up to date 360 documents registered in Scopus database (scientific articles, conference papers, book chapters, reviews, notes, editorials, books, letters) with the term "responsible research and innovation" included in the title, keywords or abstract. Significant rise in the popularity of the term may be observed since 2009, however year 2018 is the first one in eight years when the growing trend halted (Figure 2). In this light, it will be interesting to observe how the publication activity on RRI develops in the next years.

Figure 1. Retrospective and prospective orientation of responsibility (source: own elaboration based on Pellé and Reber 2016)
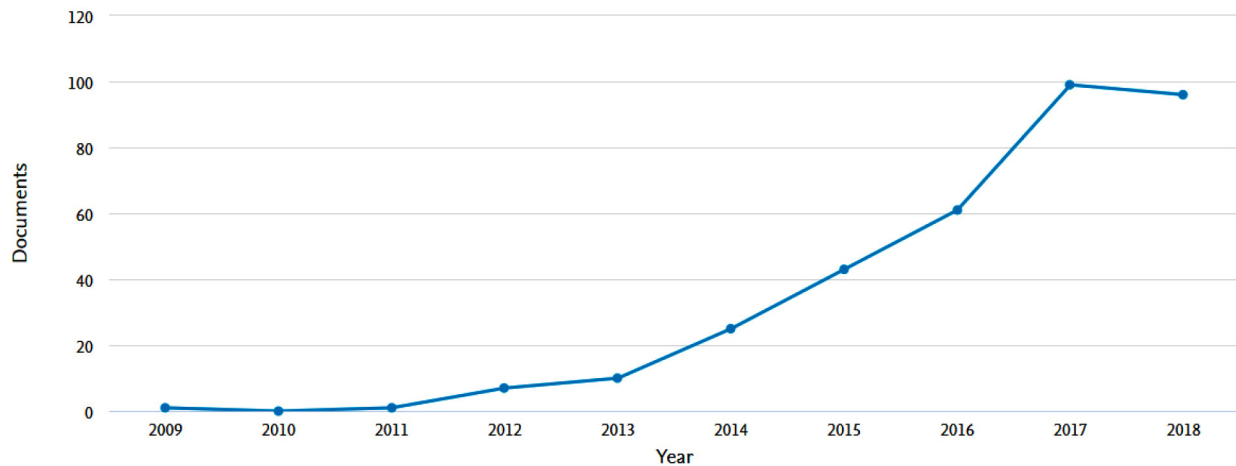
Figure 2. Number of publications on the topic of "responsible research and innovation" indexed in Scopus database (source: Scopus)

The RRI discourse is dominated by the European authors with United Kingdom, Netherlands and Germany occupying the first three places with the respect to the country of origin of the indexed documents. The first non-European country (United States) comes only in the 10th place. Especially symptomatic is the lack of Asian authors (who are increasingly prominent in terms of general scientific output) that deal with the topic. It may suggest that RRI is still a niche Europocentric concept that has not gained global recognition. 49 out of 360 indexed documents (ca. 14%) report financial support from the European Union.

Citation data was extracted from the Scopus database (Figure 3). Works on RRI have been cited 2241 times since 2009. Two works take a clear lead: by Owen et al. 2012 (cited 346 times) and von Schomberg 2013 (cited 284 times). The graph shows a strong upward tendency in citing works related to RRI. This may be seen as an indicative of the importance of the topic as well as of the gradual accumulation of the body of knowledge on RRI.

In Figure 4 the most frequently used terms in relation to RRI are presented in clusters. The clusters reflect the co-occurrence of terms in the analysed publications but they don't form qualitatively coherent groups. Further analysis

of the most frequent terms present in the literature on RRI resulted in the identification of the following aspects of RRI:
– Institutions (European Union)
– Actors (university, company, practitioner)
– Challenges (complexity, dilemma, legitimacy, technology development, transition, emergence)
– Sectoral relevance (synthetic biology, ICT)
– Desired features (anticipation, inclusion, responsiveness)
– Conceptual matters (definition, scope, framing)
Analysis of the occurrence frequency leads to some expected and unexpected conclusions. The expected conclusions are related to the institutional and conceptual matters as well as the desired features of RRI. They allow to infer that RRI is a European concept that still lacks the common understanding of its definition, scope and underlying assumptions. It is not surprising either that RRI aims both at universities and companies with the goal of making their research projects more anticipatory, inclusive and responsive to the needs, values and concerns of the society. What is surprising is the results of the analysis of the dominant thematic scope. Domination of synthetic biology and ICT over, for example, nanotechnology, health technologies, genetical engineering is not at all obvious.
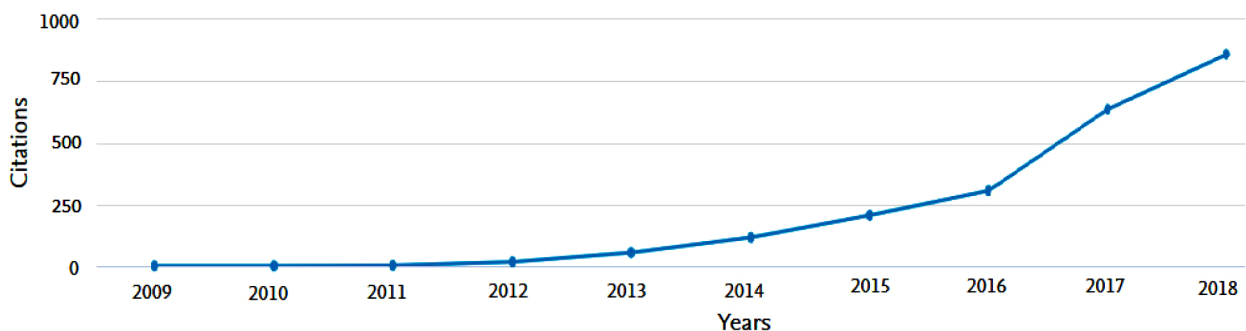

Figure 3. Citations of works on the topic of Responsible Research and Innovation indexed in Scopus database (source: Scopus)
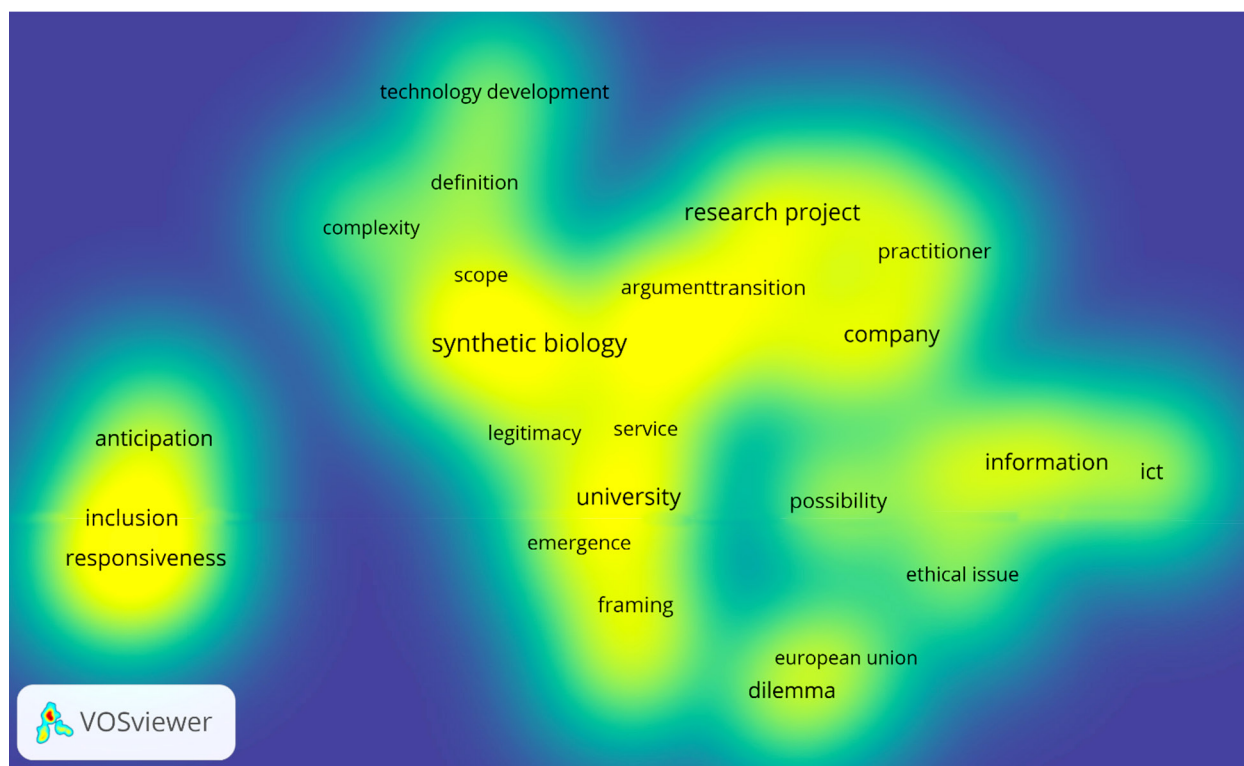
Figure 4. Clustering and density of key terms occurring in the literature on RRI on the basis of Scopus data (source: own elaboration with use of VOSviewer)

3. Responsible Research and Innovation in the EU Programmes

As indicated in the previous section, RRI is essentially a European concept promoted by the European Union. There have been at least 40 approved projects (with total funding of ca. € 105 million) in the framework of Horizon 2020 Programme that deal with RRI from different perspectives and address different stakeholders. The exact number of RRI- related projects is difficult to determine since the aspects of responsibility feature in many initiatives sponsored under H2020, however in this paper only 40 projects directly relating to RRI are analysed. Most of them (34) may be found under the thematic priority of "Developing governance for the advancement of Responsible Research and Innovation". Remaining projects are funded under priorities "Integrate society in science and innovation" (four projects) and "Make scientific and technological careers attractive for young people" (two projects). Details of RRI-related topics addressed by the analysed projects are presented in Table 1. They give a good overview of the directions and foci of the activities addressing RRI.

Table 1. Topic addressed by the RRI-related projects funded in the framework of Horizon 2020 Programme (source: own elaboration on the basis of Horizon Dashboard, https://webgate.ec.europa.eu/dashboard)

Topic Description	H2020 Signed Grants	H2020 EU Contribution
European Ethics and Research Integrity Network	1	€ 1 499 000
Fostering RRI uptake in current research and innovations systems	2	€ 3 089 313
Responsible Research and Innovation in industrial context	3	€ 4 723 677
Scientific Information in the Digital Age: Text and Data Mining (TDM)	1	€ 1 492 370
Innovative approach to release and disseminate research results and measure their impact	1	€ 1 951 933
Ethics in Research: Promoting Integrity	1	€ 1 987 780
Reducing the risk of exporting non ethical practices to third countries	1	€ 2 141 173
Science with and for Society National Contact Points (NCPs) in H2020	1	€ 1 999 594
National Contact Points for quality standards and horizontal issues	1	€ 1 967 828
Estimating the costs of research misconduct and the socio-economic benefit of research integrity	1	€ 999 713

End of Table 1

Topic Description	H2020 Signed Grants	H2020 EU Contribution
Innovative methods for teaching ethics and research integrity	2	€ 4 994 673
Developing research integrity standard operating procedures	1	€ 3 999 860
Opening Research Organisations in the European Research Area	2	€ 6 405 535
New constellations of Changing Institutions and Actors	2	€ 6 947 633
Grounding RRI practices in research and innovation funding and performing organisations	2	€ 2 996 434
Engaging industry – Champions for RRI in Industrial Sectors	1	€ 3 549 475
Moving from constraints to openings, from red lines to new frames in Horizon 2020	1	€ 6 799 943
Webs of Innovation Value Chains and Openings for RRI	1	€ 2 995 565
A Linked-up Global World of RRI	1	€ 2 999 545
Mapping the Ethics and Research Integrity Normative Framework	1	€ 3 770 000
The Ethics of informed consent in novel treatment including a gender perspective	1	€ 3 077 198
The Ethics of technologies with high socio-economic impact and Human Rights relevance	1	€ 3 996 788
Promoting integrity in the use of research results in evidence based policy: a focus on non-medical research	1	€ 2 800 000
The ethical dimensions of IT technologies: a European perspective focusing on security and human rights aspects	2	€ 5 663 979
RRI in support of sustainability and governance, taking account of the international context	1	€ 3 158 613
Implementing a European Train-the-trainers initiative with regard to Ethics and Research Integrity	1	€ 2 800 000
Supporting structural change in research organisations to promote Responsible Research and Innovation	1	€ 3 993 633
Supporting structural change in research organisations to promote Responsible Research and Innovation	3	€ 9 498 335
Responsible Research and Innovation in Higher Education Curricula	2	€ 2 998 172
TOTAL	40	€ 105 297 756

Consortia formed to implement the RRI projects consisted of 475 participants from 48 countries (the same entity was counted multiple times if it participated in several consortia – some of them in as many as seven). There are only 27 participations (5,5%) of entities from continents other than Europe: South Africa, China, Brazil, United States, India, Australia, Japan, Kenya, Chile, Colombia, Israel, Egypt, Jamaica. That fact provides another proof for the thesis about the Eurocentrism of the RRI concept. Three top countries in terms of number of participants and awarded funding are Germany, Netherlands and United Kingdom. Participants from these three countries constitute 29% of all participants of the RRI-related projects and consume 35% of the total funding (Figure 5).

RRI assumes engagement of all actors involved in research and innovation activities. The composition of participants of the RRI-related projects indicates that the interest in RRI is currently expressed mostly by higher education institutions (200 participations) and public research organisations (105 participations). Engagement of enterprises in the RRI project consortia is far below the level that would reflect business' role in R&I processes. There are 60 participations of the for-profit organisation in the RRI projects, including 48 small and medium enterprises (Figure 6).

The conducted analysis reveals that RRI adoption is concerns mostly public entities (universities, research institutions and funding agencies) in Western Europe. For-profit organisations constitute merely 13% of all participations in RRI-related projects. There are few cross-continental partnerships in the implementation of the projects. This has to change since R&I activity is increasingly global in its nature. RRI cannot become a globally recognised concept if only Western European actors are involved in shaping and promoting it (van de Poel et al. 2017).

4. RRI and Technology Management (rationale, requirements, benefits)

RRI is sometimes considered to be a proposition that applies more to publicly funded research institutions rather than to market driven technology management processes and corporate research and innovation (Ceicyte and Petraite 2018). The challenge of getting industry on board

of the RRI discourse has been recognised in the academia and in the EU policy community. Various resources and initiatives have been addressing this issue (Iatridis and Schroeder 2016, Martinuzzi et al. 2012, Scholten and Blok 2015, Stahl 2018). One of the reports lists the potential benefits of adopting RRI (Responsible Industry 2017):

– enhancing company's reputation,
– decreasing business risk and unintended consequences,
– strengthening public trust in the safety of products,

– adopting an environmentally friendly profile,
– increasing company's competitiveness.

It is noticeable that very similar set of arguments is used to encourage business towards more corporate social responsibility (Nazarko 2019). It must be admitted that there is little or no evidence that following RRI principles increases company's competitiveness and profitability in the long run. The promise of increased profits from RRI should rather be seen as an ideal model in which more responsibility is translated into more robust strategic choices,
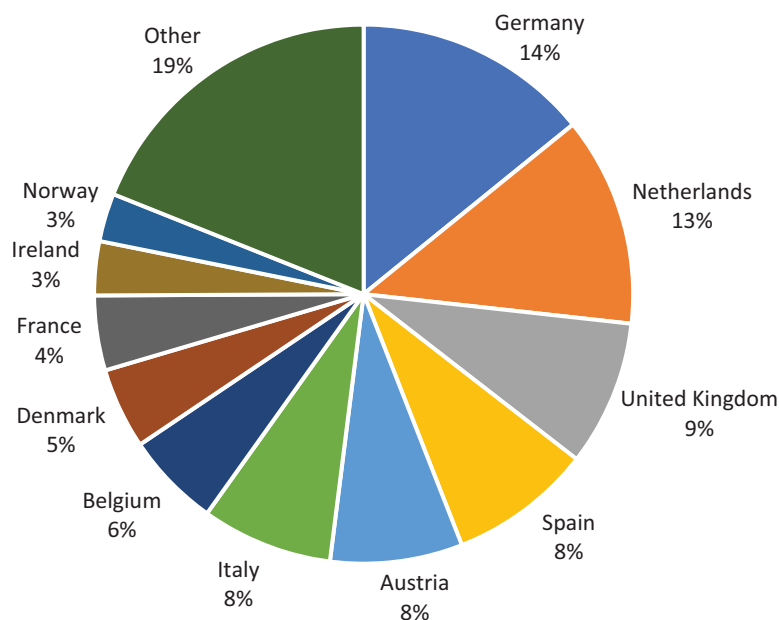

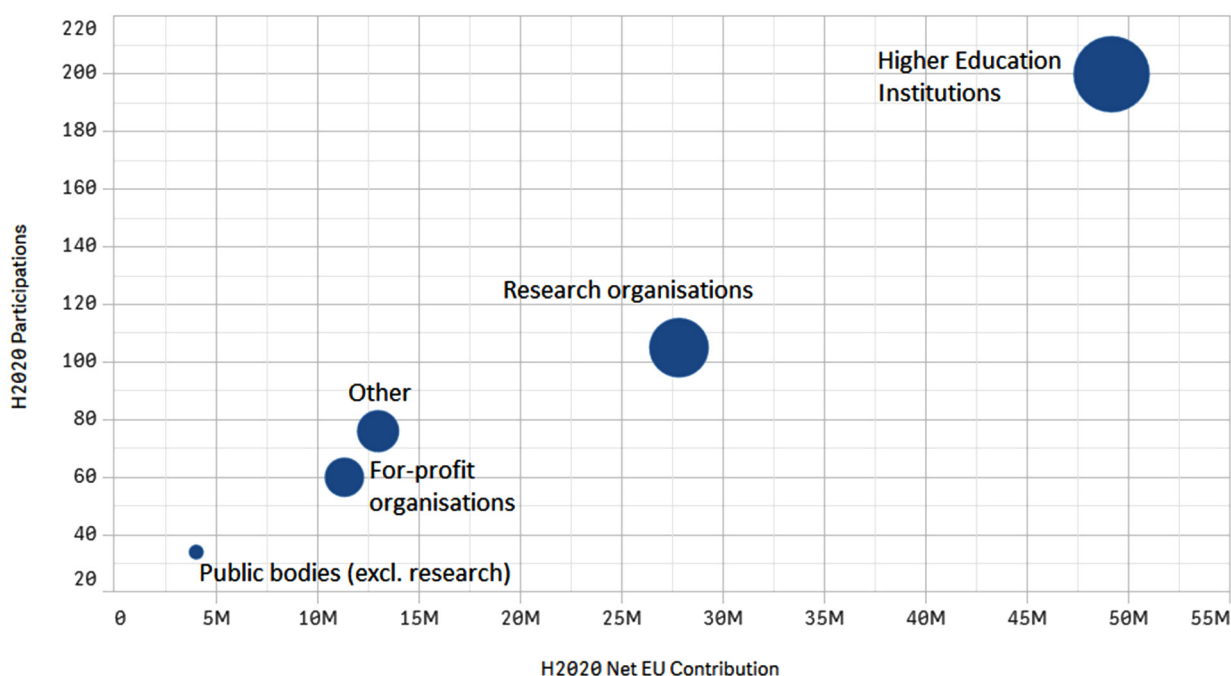Figure 5. Funding of the RRI-related project participants by country (source: own elaboration on the basis of Horizon Dashboard, https://webgate.ec.europa.eu/dashboard)

Figure 6. RRI-related project participants by type (source: Horizon Dashboard, https://webgate.ec.europa.eu/dashboard)
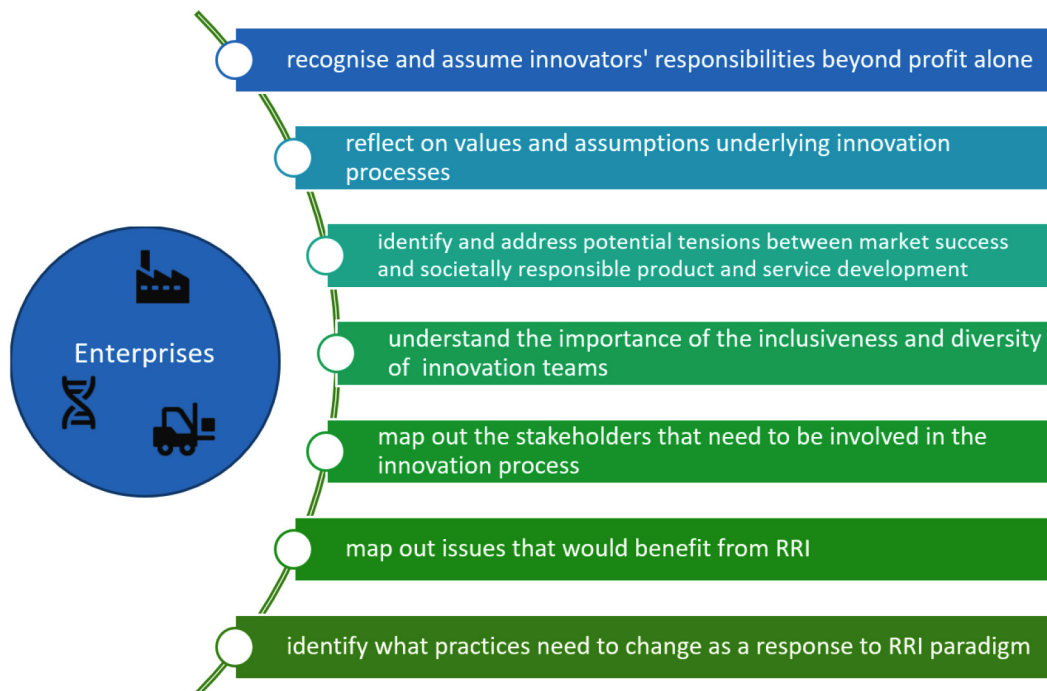
Figure 7. Competences, skills and actions needed in industry to foster the RRI agenda (source: own elaboration on the basis of Smallman et al. 2016)

increased productivity (Chodakowska and Nazarko 2017) and "future-proof" product portfolios.

Smallman et al. (2016) try to give a practical answer to the question "What to do if you want your business to follow RRI principles?" (Figure 7).

Following the line of thought of Ceicyte and Petraite (2018) it is argued in this paper that decomposing RRI into *Responsible Research (relating more to the publicly funded scientific endeavours) and Responsible Innovation (more relevant to industrial context) may bring more clarity to the reflection on responsibility in R&I. The proposed distinction helps understand better how the notion of responsibility may be measured in both public and private (corporate) context.*

Only few metrics and indicators of responsibility (Ravn et al. 2015) are relevant to businesses – the ones that relate to market and marketing, social and environmental impact of products, company's stakeholders or technology management. The metrics found in the literature clearly focus on policy-makers and public research performing and funding organizations. Study by Flipse and Yaghmaei (2018) confirms that there is a clear need to develop frameworks and key performance indicators that would connect better to the R&I activities in industry.

Conclusions

Mitcham (2012) suggests that the development of the notion of responsibility and its application of in legal, religious, engineering, scientific, and philosophical contexts is inherently connected with the technological progress of humanity. RRI, and its rapid evolution, may be therefore seen as an expected (and needed) consequence of the advancement and the growing complexity of the techno-social systems. Despite its dilemmas and inconsistencies, RRI offers potential to integrate the concepts of technology management, Technology Assessment and engineering ethics. In this respect, Technology Assessment may serve an anchor concept (Grunwald 2009, Grunwald 2011, Grunwald 2014, Nazarko 2016).

Reflections on responsibility in technology management have revealed an important difficulty for entities involved in RRI, namely: a particular action can be seen and assessed differently before (*ex ante*) and after (*ex post*) it is taken. In consequence, it is often impossible to reliably state if a certain R&I activity is responsible or not. Partial remedy to that challenge consists in the recommendation to make an extensive use of future-oriented methods and techniques that increase one's epistemic horizons and systematise the knowledge of what is possible, plausible and/or probable (Ejdys et al. 2015, Halicka 2016, Radziszewski et al. 2016, Nazarko 2017).

Ultimately, one may conclude that the full realisation of RRI principles and priorities can only be possible if fundamental changes are introduced not only in the R&I activities of different actors but also in the way the contemporary economic system assigns value to products and services.

Competences of Scientists, other Researchers and Students through Practical Research Activities" measure.

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APPENDIX 1. RESPONSIBLE RESEARCH AND INNOVATION MIND MAP

RESPONSIBLE RESEARCH AND INNOVATION

Related Terms
- Corporate Social Responsibility
- Responsible Innovation
- Technology Assessment
- Future-Oriented Technology Analysis
- Engineering Ethics
- Life-cycle assessment
- Foresight
- Technology Management

Process Dimensions
- Diversity and Inclusion
- Anticipation and Reflection
- Openess and Transparency
- Responsiveness and Adaptive Change

Grand Societal Challenges
- Health, demographic change and wellbeing
- Food security, sustainable agriculture and forestry
- Secure, clean and efficient energy
- Smart, green and integrated transport
- Climate action, environment, resource efficiency and raw materials
- Europe in a changing world - inclusive, innovative and reflective societies
- Secure societies - protecting freedom and security of Europe and its citizens

Policy Dimensions (Agendas)
- Ethics
  - research integrity
  - ethical acceptability of scientific and technological developments
- Gender Equality
  - gender balanced teams
  - ender balance in decision-making bodies
  - gender dimension in R&I
- Governance
  - robust and adaptable
  - easy to align with existing practices in R&I
  - share responsibility and accountability among all actors
  - instruments to foster shared responsibility
- Open Access
  - accessibility to scientific information
  - ownership of scientific information
- Public Engagement
  - all societal actors work together
  - aligning outcomes to the values, needs and expectations
- Science Education
  - promote scientific vocations
  - equipping citizens with skills to participate in R&I debates

Engaged actors
- Researchers
  - embed RRI in citizen science
  - co-create community-based participatory research
  - design a RRI-oriented project proposal
- Civil Society Organisations
  - advocate RRI ideas and set up project proposals
- Media
- Business and Industry Innovations
  - embed the RRI principles in a business plan
  - RRI criteria for investors
  - Corporate responsibility tools
- Policy-makers
  - initiate RRI at a national level
  - incorporate RRI principles in funding calls
  - incorporate RRI in policy/funding institutions
  - set up a participatory research agenda
  - incorporate RRI in higher education institutions
- Educators
  - integrate RRI in secondary education
  - incorporate RRI in science engagement organisations
  - project- and inquiry-based learning in STEM

Outcomes
- Learning Outcomes
  - Engaged publics
  - Responsible actors
  - Responsible institutions
- R&I Outcomes
  - Ethically acceptable
  - Sustainable
  - Socially desirable
- Solutions to Societal Challenges

Resources
- Scientific papers
- Tools
- Inspiring Practices
- Reports
- Training