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Introduction

This report includes the results of the Literature Review conducted under WP1 (Mapping and benchmarking) of the project "Fostering Improved Training Tools for Responsible Research and Innovation" (FIT4RRI), co-funded by the EU DG Research and Innovation under Horizon 2020.

Overall, the project aims at contributing to the diffusion and consolidation of Responsible Research and Innovation (RRI) and Open Science (OS) in the European research funding and performing organisations (RFPOs) by, on the one hand, e**nhancing competences** and **skills** related to RRI and OS through an improvement of the RRI and OS **training offer** (in terms of training tools, actions and strategies) currently available and, on the other hand, promoting the diffusion of more advanced **governance settings** favouring the institutional embedment of RRI and OS in research organisations.

In this context, the WP1, coordinated by Conoscenza e Innovazione (K&I), is specifically aimed at mapping the **drivers** for and **barriers** to the diffusion and embedment of RRI and OS practices and approaches in RFPOs and Benchmarking **RRI** and **OS experiences,** which succeeded in mainstreaming RRI practices in individual RFPOs, groups of them or specific research fields. WP1 is also expected to provide inputs for the RRI-oriented experiments to be carried out under WP3 (Experiments). This component of the project, focused on governance settings, is also expected to interact with the other component of FIT4RRI (WP4), focused on RRI and OS training offer.

This literature review is the output of the Task 1.1. of WP1, the objective of which is **building a map of the critical issues** pertaining to RRI (and OS) for RFPOs, identifying trends, barriers, drivers, interests and values connected to RRI and Open Science.

The document is in four parts.

- **Part One** is devoted to the structure and the methodology of the literature review.
- **Part Two** includes the results of the literature review concerning the changes affecting science in general, so as to provide an overall picture about the context in which RRI/OS is to be placed.
- **Part Three** includes the results of the literature review concerning RRI/OS, as concerns both the theoretical approaches to RRI/OS and experiences and facts connected to it.
- **Part Four** is aimed at connecting the outcomes of parts Two and Three, in order to understand how RRI can actually be used to help scientists and research organisations to meet the challenges related to changes affecting R&I.

The text has been written by Luciano d'Andrea and Federico Luigi Marta (K&I), with the exception of the paragraph "RRI in academic journals: drivers and barriers" (Part Three, Para. 2.2.), drafted by Nina Kahma and Susanna Vase (University of Helsinki), and reviewed by Alfonso Alfonsi (K&I) and Mikko Rask (University of Helsinki).

Part One

Structure and methodology

1. Structure

1.1. Assumptions

The structure of the literature review has been developed on the basis on some assumptions, connected with the same approach adopted by FIT4RRI.

The starting point of the project proposal is provided by the **critical stance** adopted by the **Call**. The Call highlights the presence of gaps in the "the dissemination of RRI practices", which vary "from one discipline to another and from one country to another". In order to match these gaps, the Call indicates, as a key solution, the further development of "specific trainings for researchers and academics (in particular young scientists during under- and post-graduate training)" even though "also policy-makers and staff working in funding bodies, need to be supported".

In the **proposal**, such a critical stance is interpreted in a broader perspective, i.e., as a "serious **gap** between the **potential role** that Responsible Research and Innovation (RRI) and Open Science (OS) could play in helping Research Funding and Performing Organisations (RFPOs) to manage the rapid transformation processes affecting science (especially science-in-society aspects) and the **actual impact** RRI and OS currently have on RFPOs, research sectors and national research systems".

The literature review should therefore start to address the factors which are at the basis of such a gap, starting with the **main assumption of the project proposal**, i.e., that RRI should play a role in managing the rapid changes affecting science and innovation.

1.2. Aims and structure of the literature review

As we said above, the project proposal defines a logical pathway in which the literature review plays an important role, i.e., that of enabling an analysis of RRI trends, barriers and drivers, as well as the interests and values involved in it. Its outputs should be a "map of critical RRI issues for RFPOs".

However, following the assumption that RRI has or should have a role in the management of the main changes affecting science and innovation, it was decided to include in the literature review trends, barriers, drivers, interests and values connected to S&I in general, so as to start analysing the interactions between RRI and changes occurring in science and innovation.

This approach explains the **structure** given to this literature review.

Apart from this one, it includes the following **three parts**.

Part Two is focused on the **changes affecting science**, both internally and in its relations with society. It includes two sections.

- **Theoretical approaches**. This section includes a comparative summary of the main theoretical approaches used to interpret the transformation processes occurring in science and innovation (Mode 1 - Mode 2, Post-academic science, etc.).
- **Change processes**. This section includes a reasoned inventory of change processes occurring in science and innovation. In particular, the focus is on the problematic aspects related to these changes, especially as concerns the professional and living conditions of scientists and the organisational functioning of research institutions.

Obviously, these two sections are strongly intertwined, since the theoretical approaches are based on an analysis of change processes, even though many of them escape the theoretical lens adopted in these approaches.

Part Three is focused on **Responsible Research and Innovation** (RRI). It includes two sections.

- **Theoretical approaches**. This section includes a comparative summary of theories and concepts of RRI, so as to identify its main features and structures.
- **RRI in action**. This section includes an analysis of drivers and barriers to RRI. This section, in particular, contains:
- A literature review of academic journals which can be considered an autonomous product, even though fully embedded in this report
- A literature review based on the practical and empirical literature produced in the framework of EC-funded projects focused on RRI.

Part Four aims to connect the **outputs emerging from the previous parts**, in view also of the next steps of FIT4RRI. It includes three sections.

- **Summary of the main issues**. This section is aimed at briefly summarising the main findings of the literature review.
- **Open questions**. This section is focused on a reflection about the reasons behind the still limited and uneven penetration of RRI in European research systems.
- **A provisional framework for the experimentations**. This section provides some orientations for approaching RRI in a way which can be as fruitful as possible in the context of the experiments to be carried out under WP3.

For its aims and structure, the literature review can be understood as both **comprehensive** and **interpretive**.

It is **comprehensive** since its scope is necessarily wide, including different components developed through different approaches (see Para. 2). It is **interpretive**, since its main output is defining interpretive frameworks about RRI to be usefully applied in the next steps of the project. In order not to confuse the analytical and the interpretive, each section of the report includes a paragraph (titled “Discussion”) where the interpretive dimension is developed.

In the DoA, the Literature Review was described as dealing with “RRI and open science centred on governance settings”. However, it is *de facto* focused on RRI rather than on Open Science, for three main reasons.

1. In its traditional meaning, the concept of "Open Science" largely **overlaps with the concept of** "**Open Access**" (OECD, 2015b), which is fully embedded in the concept of "Responsible Research and Innovation".
2. In the meaning recently adopted by the European Commission (2016c), Open Science acquired a broader meaning, coupling the idea of "Open Access" with that of increasingly intense cooperation among all stakeholders and players (scientists, citizens, publishers, research institutions, research funding organisations, education professionals, etc.) through interaction models made possible by digital technologies. Also in this second sense, however, **Open Science seems to be largely overlapped with the concept of RRI**, although its focus is mainly on the many opportunities made available by information technologies and on university-industry relations.
3. Finally**,** at least in the European context, **RRI has so far been used as a "cultural label"** in scientific or policy literature about the openness of science and innovation to society. For this reason, such a concept can be used to readily access literature. This is not the case for the concept of "Open Access" which is still little used in literature, at least in the meaning proposed by the European Commission.

These considerations, however, cannot solve the **tensions which likely exists between the concept of RRI and that of Open Science**. Broadly speaking, RRI sees the "openness of science" as strongly related to the alignment of science to values, ethical standards and expectations of society by making it more reflexive, anticipatory, responsive and inclusive, while Open Science focuses much more on the transformative role played by ICT tools, networks and media, understood as able to radically modify the way in which science is carried out, disseminated and deployed, thus making it more open, global, collaborative, creative and closer to society. Therefore, if the objectives are similar, the overall approach and the view of science and science-society relations of RRI and Open Science are only partially overlapped with each other.

2. Methodology

This literature review **includes six components**, each one partially or totally autonomous from each other.

The **first component** concerns the **shift from modern to post-modern society** (Part Two, Para. 1.1. and Para. 1.2.) which revolves around a set of classics of the contemporary sociological theory, including, e.g., Margareth Archer, Zygmunt Bauman, Ulrich Beck, Daniel Bell, Peter Berger, Manuel Castells, Norbert Elias, Anthony Giddens, and Thomas Luckmann. This component is also enriched with contributions from many other authors providing insights into how this shift is occurring in different spheres of social life.

The **second component** focuses on the **theoretical models developed to account for the many changes affecting science and innovation** in the last decades (Part Two, Para. 1.3. and 1.4.). This component is mainly based on a set of scholars in Science and Technology Studies, including e.g., Henry Etzkowitz, Silvio Funtowicz, Michael Gibbons, Loet Leydesdorff, Helga Nowotny, Jerry Ravetz, Peter Scott, and John Ziman.

These two components largely leverage upon a consolidated corpus of knowledge and theoretical approaches. Their added value is mainly produced by the connections established among

the different issues presented so as to shape an overall background for the next parts and sections of the report.

The **third component** focuses on the **main change processes affecting science** (Part Two, Section 2). In this case, a "scoping review" has been conducted, i.e., a literature review aiming “to map the key concepts underpinning a research area and the main sources and types of evidence available” (Mays, Roberts & Popay, 2001), through a “snowballing method” allowing to put together issues rarely dealt with comprehensively.

The **fourth component** pertains to the **theoretical approaches to RRI** (Part Three, Section 1). The component is a **conceptual review** primarily based on a second-tier analysis of existing literature reviews on RRI concepts and approaches.

Finally, two other components are included in this literature review, both **dealing with RRI in action**.

The **fifth component** is based on an analysis of the deliverables produced under EC-funded projects dealing with RRI (Part Three, Para. 2.1.). This analysis entailed a scanning of all deliverables produced under projects carried out in FP7 and Horizon 2020 Framework Programme and the selection of the most relevant among them.

The **sixth component** is a literature review of scientific articles on drivers and barriers related to RRI (Part Three, Para. 2.2.). The methodology applied is presented in the introduction of the text.

Part Two

Science and innovation

This part explores the social transformations affecting science and innovation, adopting two different approaches detailed in two different sections.

The first section analyses the different theoretical approaches developed in the last few decades to account for the major changes which have occurred in the way in which scientific knowledge is produced and used. In this paragraph, specific attention is focused on the proper framing of these changes within the broader transition from modernity to post-modernity.

The second section will provide a reasoned **inventory of change processes** occurring in science, assuming a "**grass-roots perspective**", i.e., one expressing, as far as possible, the point of view of the "average Principal Investigator" working in an "average" research institution or university.

A number of conclusive reflections will follow.

1. Theoretical approaches

1.1. The shift from modernity to post-modernity

In this section the changes occurring in science and innovation are framed within the broader changes which, as of the 1960s, have profoundly modified contemporary society as a whole.

As a whole, these changes have been described as a shift from modern society to another kind of society, variably termed as "post-industrial society" (Bell, 1976), "late modernity" (Giddens, 1991), "risk society" (Beck, 1992), "liquid society" (Bauman, 2000), "network society" (Castells, 2000) or "high-speed society" (Rosa, 2013).

For the sake of simplicity, we will refer to this "new society" as a "**post-modern society**", even though this concept is highly controversial (Beck, 1992).

While the modernity/post-modernity debate lasted for more than two decades (and, to a certain extent, is still continuing), a relatively broad convergence about the key trends characterising this shift can be observed. The following seem to be particularly relevant here, i.e.:

- Globalisation
- Weakening of social structures
- Individualisation
- Risk and uncertainty
- Diversification and fragmentation
- Blurred cognitive and social boundaries.

Globalisation. Post-modern times are characterised by the emergence of a single interconnected world (made possible by the huge development of ICTs) producing complex and extended social configurations of mutual interdependences (De Swaan, 1988) of different natures (economic, social, cultural, but also cognitive and emotional). One of the main well-known effects of globalisation has been the rapid growth of economic competition at global level, affect-

ing both national economies and individual companies. Globalisation has led to a systematic dis-embedding of social relations (Giddens, 1990), i.e., lifted out from their local embeddedness, based on specific space-time relations.

Weakening of social structures. Globalisation has produced a rapid weakening of social structures, i.e., the dominant patterns of action and social relationships (Berger & Luckmann, 1996; North, 1990; Nadel, 1951), legitimated by cognitive structures, such as socially supported views, representations, beliefs and stereotypes. In fact, any social structure, until then, was necessarily based on specific space-time frames and fully incorporated into the local dimension. Dis-embedding processes led to an overall weakening of culture (i.e., traditional worldviews and social norms) and its capacity to produce patterns and cognitive schemes orienting individual behaviours and led to an increased role of "self-reflexive" behaviours in personal and institutional life (Archer, 2007; Giddens, 1991; Beck, Giddens & Lash, 1994).

Individualisation. Connected to the weakening of social structures, a parallel acceleration of the process of individualisation (Elias, 1991) can be observed, deriving from and driving an increase in people's subjectivity (Quaranta, 1986; d'Andrea, Declich & Feudo, 2014), i.e. their capacity and power to think and act more freely, as well as to "build up" their own lives, projects, and identities (Berger, Berger & Kellner, 1974; Giddens, 1991; Beck & Beck-Gernsheim, 2002). Individualisation produced a set of general trends, including:

- The tendency of individuals to **bypass intermediated entities** (associations, trade unions, political parties, etc.)
- The tendency of individuals towards **self-disclosure** (in terms of opinions, ideas, personal attitudes, private feelings, intimate aspects of life, body, etc.) in public or semi-public environments (both physical and virtual)
- The radical change in the usual **mechanisms of social control** (for example, the tendency of people towards self-steering, rejecting established values and beliefs and instead becoming sensitive to the opinions of their friends).

Risk and uncertainty. Risk profiles have changed too. Because of the weakening of social structures and of the institutions of modern society (see below), people have become more directly exposed to risks of different kinds (Beck, 1992; Giddens, 2001; Renn, 2008; Zinn, 2008), such as environmental risks, unemployment, lack of access to social protection and pension schemes, or health risks. Moreover, individuals are increasingly asked to manage their own lives by themselves, with no institutions or dominant social patterns to guide them. Finally, also technology, while used to control risks, produces in turn new risks (Beck, 1999; Giddens, 1990). Therefore, the sense of uncertainty appears to be a dominant characteristic both in social life and in the biographical dimension.

Diversification and fragmentation. The modified balance between individuals and social structures has produced great social and cultural diversification within society. It is more and more difficult to identify homogeneous social groups and classes or dominant behavioural patterns. Even the identity of individuals is more unstable, fragmented and inconsistent (Giddens, 2001; Bauman, 2005; Barglow, 1994). At the same time, diversification feeds a multitude of ideas, initiatives, behaviours and forms of knowledge, accelerating social changes (Rosa, 2013).

Blurred cognitive and social boundaries. Another consequence of the mix of weakening of social structure and individualisation is the blurring, if not the collapse, of social boundaries on

which modernity was built (Beck, Bonss & Lau, 2003), including the most fundamental distinctions (nature/culture or past/present/future) (d'Andrea, Declich & Feudo, 2014), as well as distinctions among life domains and social spheres (for example, private/public or professional life/leisure). Even personal identity does not have stable boundaries. The effect is that new boundaries have to be constantly negotiated among actors so that common problems or public issues can be addressed.

1.2. The critical turn of the social institutions of modernity

One of the major outcomes of this set of intertwined processes is that the social institutions on which modernity was grounded (such as family, politics, institutionalised religions, economics, state and, obviously, science) are facing deep critical transformations, the long-term outcomes of which are uncertain.

It is quite difficult to define common trajectories for these transformations. Although, four main cross-cutting critical issues can be identified among those most relevant to this literature review, i.e.:

- Diminishing authority
- Distrust and disaffection
- De-standardization
- Declining capacity to provide services and to ensure social equality.
-

Diminishing authority. All the institutions of modernity are to different extents exposed to an erosion of authority and prestige, so that they are less and less able to provide orientation and guidance, while compliance with the rules set by them decreases. This process may include the authority of politicians and political parties (see, for example, Dalton, 2004), of parents (see, for example, Galiani, Staiger & Torrens, 2017) or of religious leaders (Bruce, 2006), even though it does not imply a decline in religion itself (see, for example, Kaufman, 2008). This process reduces the power of institutions, which means they increasingly need to negotiate more with internal and external actors.

Distrust and disaffection. A decline in people's trust and an increase in their disaffection towards the institutions of modernity can usually also be observed. This is particularly evident in the case of politics, where the spread of anti-political attitudes (i.e., negative feelings towards politicians, parties, parliaments, and governments) is increasingly being reported (see, for example, Blokker, 2013; Mair, 2013; Clarke, 2015). However, a decreasing level of trust is also observed towards financial institutions (see Springford, 2011) and medical institutions (see, for example, Zheng, 2015).

De-standardization. Another factor characterising the social institutions of modernity is de-standardization, i.e., the lack of dominant standards and behavioural patterns regulating social institutions, leading to the desynchronization of social life (Rosa, 2003). Well known examples include the de-standardization of family (see, for example, Vono de Vilhena & Oláh, 2017), transitions to adulthood (Furlong, 2013), life course (Beck, 1992; Heinz, 2001), or employment (Koch & Frits, 2013). De-standardization can be observed also in the increasing cognitive and ethical relativism characterising society (Schantz & Seidel, 2011). More in general, de-

standardization is also a manifestation of the weakening of established boundaries between social spheres, social identities or social conditions. For example, boundaries between youth and adulthood are uncertain and youth cultures are increasingly shared by both children and adults (Buckingham, Bragg & Kehily, 2014).

Declining public resources. The factors described above have led to a shrinking availability of public resources to meet an often increasing demand for services. This is not an even process and the situation largely varies according to national contexts and sectors. However, the weakening of States and the globalisation of financial markets are pushing governments and public authorities to impose greater controls over available resources and to reduce public expenditures. This does not mean that the welfare state is disappearing (Fahey, 2010), but that it is becoming much more difficult than in the past to combine competitiveness with social cohesion, as testified, in Europe, by the uncertain development of the European Social Model (Hermann & Mahnkopf, 2010; Hacker, 2013; Vaughan-Whitehead, 2015).

1.3. The critical turn of science: interpretive models

Different interpretive models have been developed in the last few decades to account for the many changes affecting science and innovation. Undoubtedly, the most well-known are the Mode 1 - Mode 2 model (Gibbons et al., 1994, Nowotny, Scott & Gibbons, 2001, 2003), Post-academic Science (Ziman, 2000), the Triple (or Quadruple) Helix Approach (Etzkowitz & Leydesdorff, 1998, 2000; Carayannis, Barth & Campbell, 2012) and Post-Normal Science (Funtowicz & Ravetz, 1993).

A. The Mode 1 - Mode 2 Model

The most influential and comprehensive interpretive scheme is undoubtedly the Mode 1 - Mode 2 model, which can be viewed as half-descriptive and half-prescriptive, so that Mode 2 can be understood as both "the way science is going and the way it should go" (Stilgoe, 2016). Moreover, the Mode 1 - Mode 2 model is probably the one that recognizes most the relationships between new modes of scientific knowledge production and the overall shift from modernity to post-modernity, even though the latter is referred to as "knowledge society" (Nowotny, Scott & Gibbons, 2001).

The main attributes distinguishing Mode 2 from Mode 1 have been summarised by the authors themselves (Nowotny, Scott & Gibbons, 2003) and can be schematised as follows.

Mode 1	Mode 2
Academic context	Context of application
Disciplinarity	Transdisciplinarity
Homogeneity	Heterogeneity
Autonomy	Reflexivity/Social accountability
Traditional quality control (peer review)	Novel quality control

(From: Hassels & Van Lente, 2008)

These main trends can be summarised as follows.

Research context. Under Mode 2, knowledge is generated within a context of application, which influences all research steps (definition of the problems to address, methodologies to apply, outcomes to disseminate and results to be used). Under Mode 1, all these elements are generated in the academic context and transferred, if need be, to the context of application.

Disciplinary dynamics. Under Mode 2, research is used to solve problems and, therefore, it needs different theoretical perspectives and methodologies not necessarily derived from pre-existing disciplines (hence the concept of transdisciplinarity). Under Mode 1, research is generated under the internal impulse of specific disciplinary research dynamics.

Research community. Under Mode 2, research is conducted by communities (mainly virtual communities) which are different in nature and connected to each other in open ways, thanks to the huge development of ICTs. Thus, research is also carried out by new kinds of knowledge organisations, including think-thanks, NGOs, management consultants or activist groups, with the effect that science is becoming a heterogeneous practice. Under Mode 1, research is done almost exclusively by academic research institutions.

Actors involved. Under Mode 2, the research process becomes much more reflexive, i.e., it includes dialogue or "conversations" among many different actors so as to incorporate different views. In this way, "problem- solving environments influence topic-choice and research-design as well as end-users" (Nowotny, Scott & Gibbons, 2003). Under Mode 1, the topics, research design and end-users are autonomously identified in the academic realm.

Quality control. Under Mode 2 conditions, new criteria come into play (not necessarily consistent with each other) of different kinds of quality (economic, social, political, etc.), strongly influencing prioritization processes. Under Mode 1, peer review, the use of disciplinary-based quality criteria was practically the only approach for quality assessment of scientific products.

B. Post-Academic Science

Post-academic science is an expression coined by John Ziman (1994, 2000) to describe the emerging transformations of the ways in which scientific knowledge is produced. According to Ziman, the shift from academic to post-academic science is marked by a set of general trends (Kellogg, 2006; Hassels & Van Lente, 2008). In contrast to the Mode 1 - Mode 2 model, the approach developed by Ziman is not intended to be at all prescriptive or normative, since the author himself finds fault with many of the trends underlying post-academic science, but a purely descriptive and interpretive model. The main attributes distinguishing post-academic from academic science can be summarised as follows.

Academic science	Post-academic science
Academic sites	Multiple-site networks
Internal scrutiny	Public scrutiny
Scientific value of knowledge	Utility of scientific knowledge
Separation between scientific research and industrial research	Industrialisation of scientific research
Disciplinarity	Transdisciplinarity and specialisation
Autonomy, separation between research work and administrative work, institutional access to research funds	Political steering, bureaucratisation of the research work and competitive access to research funds

Multiplication of knowledge production sites. In post-academic science, research is a collective enterprise, involving large trans-disciplinary networks of scientific actors collaborating in multiple sites. Different kinds of institutions are involved and relations between them can be short-term and superficial. This "virtual lab" is made up of permanent employees and an increasing number of scientists working under fixed-term contracts. In academic science, research was carried out in single labs while the scope of cooperation with other institutions was smaller and based on long-term relations.

Openness to public scrutiny. This "virtual lab" is mainly web-based and research results are increasingly accessible to anyone on the web, even though there is still tension between the tendency to allow Open Access to scientific publications and data and the tendency to privatize this access. In any case, science, in post-academic conditions, is much more open (both potentially and concretely) to public scrutiny than it was in the academic era, where the same access to publications and data was extremely limited if not technically impossible for laypeople or non-scientific institutions.

Utility of scientific knowledge. Another trend is that science is increasingly under pressure to produce "useful knowledge", i.e., knowledge which could have an economic value, could be used by governments or could be applied to address social needs. One of the effects of this tendency is the decreasing role of fundamental curiosity-driven research in the scientific landscape and the increasing support given to applied research.

Industrialisation of scientific research. The stress placed on the utility of research products has fostered increased adoption of industrial standards and organisational procedures in the scientific process. Paradoxically, while scientific publications and data are increasingly accessible to anyone, data and knowledge susceptible to economic exploitation are more and more privatised. In academic science, industrial research and scientific research are clearly separated.

Transdisciplinarity and specialisation. In the context of post-academic science, transdisciplinarity and specialisation are both expanding. This is not a paradox (Kellogg, 2006). In fact, the increasing complexity of research activities is leading to a fragmentation of research tasks and, consequently, to increased specialisation. Thus, while a few have a truly interdisciplinary frame of inquiry, most researchers perform small and repetitive tasks without contacts with other researchers.

Political steering, bureaucratisation and competitive access to research funds. According to Ziman (1996), «*science is becoming a too large and expensive enterprise. Governments are putting strict financial ceilings on their patronage and are trying to get better value for their money*». Consequently, governments are taking a political steering stance over science, devising policies favouring the development of marketable technologies, leveraging also upon an increasingly competitive access to research funds. This also entails a progressive bureaucratisation of research activities and an increasing impact of administrative work on research processes. Academic science is characterised by greater autonomy for researchers and scientific institutions, separation of research work and administrative work, and by the delivery of institutional funds to research institutions.

C. TRIPLE HELIX APPROACH

Another renowned model describing the changes occurring in the ways in which scientific knowledge is produced is the Triple Helix Approach (Etzkowitz & Leydesdorff, 2000), which, more recently, has also been proposed as the Quadruple Helix Approach (Carayannis, Barth & Campbell, 2012). As in the case of the Mode 1 - Mode 2 model, this approach is also partly descriptive and partly prescriptive, in the sense that it considers it necessary, for the sake of science and society as a whole, to sustain the trends depicted in the model.

Rather than just knowledge production, the model focuses on innovation. In particular, the model observes the prominent role acquired by universities in the innovation process, which has transformed the previously dyadic industry/government relations into closer triadic interactions and coordination involving State, Academia and Industry (hence the image of the "Triple Helix").

For the sake of simplicity, we shall focus only on some of the main trends identified under the Triple Helix model.

The main attributes distinguishing Triple Helix from dyadic industry/government relations are as follows.

Dyadic industry-government relations	Triple Helix
Academia not involved in innovation	Academia involved in innovation
Separation of institutional spheres	Co-evolution and hybridisation of institutional spheres
Two university missions: teaching and research	Third mission and entrepreneurial research
Disciplinarity	Transdisciplinarity

Involvement of Academia with innovation. In the Triple Helix approach, academia is increasingly involved in innovation dynamics, leading to ever closer cooperation and coordination with Industry and State.

Relations among institutional spheres. The involvement of academic institutions in innovation is happening in a context of increasing levels of interdependency among the three institutional spheres, creating the premises for co-evolution. Interdependency and co-evolution are producing, at the interface between State, Academia and Industry, the spread and differentiation of an increasing number of "hybrid" organisations (spin-off firms, tri-lateral initiatives, strategic alliances, etc.), facilitating higher cooperation levels. This is also supported through internal differentiation at the institution level (for example, the creation of the liaison offices in universities).

University missions. At the level of academia, the triple helix approach emphasises the changes directly affecting universities, which are assuming new characteristics linked to their new role of proactive promoters of innovation**,** epitomised in the concept of "entrepreneurial university[1]. The key concept that universities are being asked to pursue is a "third mission", i.e., promoting socio-economic development, together with the traditional missions of teaching and research (Etzkowitz, Ranga, Benner, Guaranys, Maculan, & Kneller, 2008). Obviously, the

[1] The Entrepreneurial university can be also legitimately considered as a model distinguished from the Triple Helix approach. See, in this regard, Kwiek, 2015.

definition of a third mission has structurally modified the ways in which the other two missions are pursued. For example, students should also be trained and encouraged to become entrepreneurs or to create new companies so they can contribute directly to the economic development of society.

Disciplinary dynamics. Finally, the Triple Helix approach emphasizes the increasing relevance of trans-disciplinary research, especially considering that the most advanced research sectors, such as nanotechnology, are to a great extent based on contributions, methodologies and interests emanating from different disciplinary fields.

D. POST-NORMAL SCIENCE

Post-normal science is another model for interpreting changes affecting scientific knowledge production. This model is more limited in scope compared to those presented above. In fact, developed by Silvio Funtowicz and Jerome Ravetz (1993), rather than describing a general turn in scientific production, it highlights the increasing need to investigate issues where «*facts are uncertain, values in dispute, stakes high and decisions urgent*". Thus, the concept of "post-normal science» refers to the kind of research which goes beyond the boundaries of usual applied research, since it entails higher decision stakes and a higher level of uncertainty of the facts under investigation.

Post-normal science necessarily requires new institutional arrangements, including:

- The use of an extended peer community, involving all those who, for different reasons, are affected by the issues under investigation
- The use of a language which is more comprehensible to all actors in the public arena
- The development of new channels and ways to communicate science to facilitate political debate
- Greater involvement of policy actors in all phases of the research process
- The coexistence of competing interpretive proposals, from which competing solutions may derive.

E. OTHER MODELS

In a review of the literature on new knowledge production, Hessels & Van Lente (2008) identify other interpretive models of changes affecting science and innovation.

Academic capitalism. The model (Slaughter & Leslie, 1997; Slaughter & Rohades, 2000) is mainly oriented towards accounting for the increasing weight of market dynamics in the life of university institutions under the pressure of globalisation processes. The model emphasizes the increasing importance of university market activities and growing competition in the academic environment (access to funds, patenting, activating university-industry partnerships, etc.).

Strategic research. The term "strategic research" was coined by Irvine & Martin (1984) to refer to basic research which, from the beginning, is conducted with the expectation that usable

knowledge will be produced to address practical needs. Later, Arie Rip (2004) used the same concept to refer to a broader regime aiming to combine the economic and societal relevance of research and excellence. The European Commission also uses the concept of "strategic research" in the Europe 2020 strategy to refer to research focused on the big challenges for Europe, such as energy security, transport, climate change and ageing.

Innovation systems. Another approach is that of innovation systems. The concept was introduced by Lundvall (1985, 1992) and developed by the same author (Lundvall, 2016) and many others (for example, Pavell & Pavitt, 1994; Metcalfe, 1995) including international agencies (such as OECD, 1997). The model sees innovation as a nonlinear process based on interaction among many actors of different types (including research institutions), where knowledge-related dynamics play a prominent role in terms of not only developing new ideas and solutions but also activating learning processes involving the organisations concerned.

Finalisation theory. Hessels & Van Lente (2008) also mention, among the many approaches to scientific knowledge production, the finalisation theory, mainly developed by Bohme, van den Daele and Krohn (1976). On the basis of empirical research, they distinguish between different cognitive phases of the development of research fields, including the first ones (pre-paradigmatic and paradigmatic phases) where scientific research is not influenced by factors external to science, while in the last case (the finalisation phase), these external factors play a role. In this phase, according to the finalization theory, scientists need external demand in order to identify and select from among alternative research paths, equivalent from a scientific perspective but different in terms of potential economic and societal impacts.

1.4. Key trends in science and innovation

The eight different models, although differing from each other in terms of focus and interpretive scheme, revolve around a single set of trends affecting science and innovation. An attempt to cluster these trends is provided in the following table.

Cluster of trends	Models
Multi-actor process	Mode1-Mode2, Post-academic Science, Triple Helix, Post-normal science, Academic Capitalism, Strategic Research, Innovation Systems, Finalisation Theory
Utility of scientific knowledge	Mode1-Mode2, Post-academic Science, Triple Helix, Post-normal science, Academic Capitalism, Strategic Research, Innovation Systems, Finalisation Theory
Macro-transdisciplinarity and micro-specialisation	Mode1-Mode2, Post-academic Science, Triple Helix, Post-normal science
Accountability and public scrutiny	Mode1-Mode2, Post-academic Science, Post-normal science
Political steering	Mode1-Mode2, Post-academic Science, Post-normal science, Strategic Research

A. MULTI-ACTOR PROCESS

All models converge on the idea that scientific knowledge is now produced through **widening networks** of researchers and research institutions, with the direct involvement, also, of **many**

other kinds of actors, including governmental entities, local authorities, industrial partners, civil society organisations or the public at large.

The models focusing on innovation (e.g., Triple Helix, Academic Capitalism, Innovation Systems) emphasize the interactions of universities and research institutions with industrial partners and governments, while other models (e.g., Mode 1 - Mode 2 or Post-Academic Science) also clarify the relations with societal actors. All in all, science and innovation are becoming a truly "**social enterprise**" (d'Andrea & Montefalcone, 2009), involving multiple actors with different roles, the boundaries of which are blurred and variable. The development of so-called "citizen science" is an expression of this.

Some of the interpretive models emphasize how the increasing interactions among scientific, industrial, governmental and societal actors are activating forms of hybridization, i.e., the spread of institutions which cannot be fully identified as belonging to the industrial sector, the scientific sector, or the civic sector (e.g., new institutions, like science parks or spin-off firms, sharing features from the industrial sector and the research sector or NGOs, developing research scientific capacities).

B. Utility of Scientific Knowledge

Unlike in the past, **science has to justify itself** and **scientists have to justify their research** by producing knowledge which has or is likely to have an economic and a societal value. This tendency is emphasized in all the approaches considered above and produces a shift in the context in which scientific knowledge is produced, from the internal dynamics of science to the context of application.

This tendency has different consequences, including:

- The decreasing role of "pure" curiosity-driven research (Ziman, 2000) accompanied with increasing difficulties in discriminating between basic research, applied research and product development (Gibbons, 1999)
- The adoption of research policies directly connecting research to societal challenges and economic growth (Jacob et al., 2013)
- The adoption of new criteria (of an economic, social or political nature) for the allocation of research funds and resources (see, for example, European Commission, 2013)
- The development of new languages more comprehensible to all actors in the public arena to deal with scientific issues (Faulkner, 2011)
- The development of new communication channels and social configurations around the production of scientific knowledge (Bultitude, 2011)

Thus, there is "a shift from the search for knowledge to the search for relevance" (Davenport, Leitch & Arie Rip, 2003) as also the criteria related to the "**relevance**" of scientific research are changing (Hessels, Van Lente & Smits, 2009) so as to encompass societal needs and economic advantages, with multiplying effects on all the single components of the research process. Examples of this include the adoption of industry-inspired working models and criteria (the "entrepreneurial university" model epitomizes such a trend) and increasing competition among researchers and research institutions on a global scale to produce usable discoveries.

C. TRANSDISCIPLINARITY

The progressive dominance of problem-solving research is fostering an ever greater tendency towards **transdisciplinarity**. It should also be noted that transdisciplinarity is coupled with an increasing segmentation of the research process into extremely specialised sectors, with their own culture, communication circuits and publications. Thus, transdisciplinarity goes hand in hand with **hyper-specialisation**.

Transdisciplinarity may have various consequences, including:

- Radical changes in the institutional organisation of research and higher education institutions
- The creation of new scientific communities and networks, with their own culture, language, symbols, interests and approaches
- The reshaping of the structure of scientific publishing
- Tensions between disciplinary communities
- The modification of research methodologies
- The increasing role of knowledge brokerage.

D. ACCOUNTABILITY, TRANSPARENCY AND PUBLIC SCRUTINY

Another evident change in science as a social institution is an **increasing demand for accountability and transparency** of science and scientists and the enlarged **openness of scientific knowledge to public scrutiny**.

All this may have different implications, including:

- The increased weight of ethical issues related to both scientific processes and outputs
- Modifications in the organisational charts and procedures adopted by research organisations (for example, establishment of public engagement offices, the adoption of ethical protocols, the establishment of ethical committees, etc.)
- Multiplication of monitoring and evaluation mechanisms on research and research outputs based on the involvement of citizens and stakeholders (see, for example, Jackson Barbagallo & Haste, 2005; Center for Advancement of Informal Science Education, 2009; Canadian Institute of Health Research, 2010).

Demands for accountability, transparency and public scrutiny are directly connected to the public's changing attitude towards science. According to Innerarity (2013), statistical data show that more trust is placed in science than other social institutions, but confidence in the objectivity of scientific experts is declining drastically. Thus, "in a knowledge society, the significance of knowledge increases, but the relevance of science decreases".

E. POLITICAL STEERING

One of the main features of science in a post-modern era is undoubtedly the strengthening role played directly by governments and governmental agencies in the research process. The autonomy of science and scientists is relatively limited, while governments are more engaged in defining priorities and criteria for accessing research funds, evaluating research results and orienting innovation processes.

Political steering, however, also implies profound changes in governmental structure, in terms of capacities, skills, and strategic orientations. Political steering carried out through inadequate personnel and leaderships may be an obstacle for research. Moreover, as stressed by Ziman (2000), political steering is also connected to the bureaucratisation of research activities, with an increasing burden of administrative work falling on scientists and research personnel.

1.5. Connecting science to the shift from modern to post-modern society

The aim of this summary of the main approaches developed for interpreting the changes affecting science and innovation was to provide a clearer framing of Responsible Research and Innovation within a broader picture.

Simplifying somewhat, **five clusters of trends** have been isolated, more or less summarising the many trends highlighted by the approaches examined above, i.e.:

- Multi-actor process
- Utility of scientific knowledge
- Transdisciplinarity
- Accountability, transparency and public scrutiny
- Political steering.

It could be useful now to link these science and innovation trend clusters to the overall change processes marking the shift from modernity to post-modernity, as they were detailed above, i.e.:

- Globalisation
- Weakening of social structures
- Individualisation
- Risk and uncertainty
- Diversification and fragmentation
- Blurring cognitive and social boundaries.

The results of this exercise are summarised in the following table.

Clusters of trends in science	Overall trends in post-modern age	Description
Science as a multi-actor process	Globalisation	Dis-embedding of traditional social relations underpinning scientific knowledge production, which is no longer carried out in specific local space-time frameworks, but through open and extended social configurations involving both expert and lay actors (OECD, 2016).
	Weakening of social structures	Science increasingly unable to manage the multiplying levels of relations connecting it with the other social spheres or keep control over internal processes (Ziman, 2000)
	Blurring cognitive and social boundaries	Decreasing solidity of traditional categorisations cognitively and socially underpinning modernity. In the case of science, weakening of the demarcation criteria distinguishing science and non-science (see, for example, Gieryn, 1983, 1995), scientists and laypeople (see, for example, Wynne, 1996; Collins, 2014; Grundmann, 2017) or science and technology (Gibbons, Limoges, Nowotny, Schwartzman, Scott, & Trow, 1994). Hence the increasing need for boundary work supporting science (Gieryn, 1983; Hellström & Merle; 2003; Evans, 2005; Koskinen, 2016)
Utility of scientific knowledge	Globalisation	Science as part of the global competition (OECD, 2016), albeit with limited development of the institutions of the knowledge economy (Pagano & Rossi, 2009). Science increasingly involved in national and international policies to address global challenges strategies (see, in this regard, Schwachula, Vila Seoane & Hornidge, 2014; OECD, 2015a)
	Weakening of social structures	Because of their diminishing authority and credibility, science and scientists are increasingly questioned and asked to demonstrate their usefulness (Gibbons, Limoges, Nowotny, Schwartzman, Scott, & Trow, 1994; Ziman, 2000; Chilvers & Macnaghten, 2014).
	Individualisation	Growing capacity and power of ordinary (lay) people to develop their own, autonomous, view of science and science-related issues (including anti-science orientations) and to sustain them in the public arena (Bultitude, 2011; Engdahl & Lidskog, 2014)
Transdisciplinarity	Blurred cognitive and social boundaries	Decreasing weight of the categories that organise the world into stable separate sectors (disciplines in science, ministries in the government sector, professional spheres in the job market, etc.) despite strong resistance towards this process (for resistance and problems related to the weakening of disciplinary boundaries, see Bourdieu, 1984; Jahn, Bergmann & Keil, 2012)
	Risk and uncertainty	Increasing sensitiveness towards global risks, calling for science to be reorganised according to

Clusters of trends in science	Overall trends in post-modern age	Description
		problems rather than to disciplinary fields, requiring an inclusive approach encompassing both disciplinary and cross-disciplinary research (European Commission, 2010)
Accountability, transparency and public scrutiny	Weakening of social structures	Decreasing authority of social institutions leading them to "justify" the money spent for the activities carried out in terms of efficiency and impacts (see Guthrie, Wamae, Diepeveen, Steven & Grant, 2013; OECD, 2016)
	Individualisation	Extreme individualisation in contemporary society, increasing the capacity of ordinary people as individuals to have a say in public affairs (Beck & Beck-Gernsheim, 2002). In science, this is leading to an increasing demand for individualised views of science.
	Risk and uncertainty	People's increasing sensitiveness to risk, including those produced by science, feeding the demand for scientific institutions to be transparent and fully accountable (Pardo & Calvo, 2002; European Commission, 2009)
	Diversification and fragmentation	Social institutions and service providers reacting to an increasingly diversified demand by multiplying and reinforcing evaluation mechanisms in order to be more accountable and open to public scrutiny
Political steering	Globalisation	Governments increasingly assuming a leadership role in supporting national economics in global markets, thus including science in this effort (Porter, 1990; Dinnie, 2008)
	Risk and uncertainty	Governments increasingly expected to gain control of the sources of risks, including those related to science and innovation, through regulatory policies (Irwin, Rothstein, Yearley & McCarthy, 1997; Jasanoff, 2012; Demortain, 2017)

There are moreover also recurrent schemes shaping policy reactions to the critical shift from modernity to post-modernity, including the following:

- Increasing effort to **reduce costs**, to deliver more with less (Institute of Leadership & Management, 2010) or to deliver less with less (Rivera, Roman & Simmonds, 2012; Hyman, 2015)
- Increasing efforts to **improve efficiency** and to demonstrate their own social usefulness (European Commission, 2013)
- Establishing **accountability regimes** (Bovens, 2006)
- Introducing **collaborative mechanisms** (Boyle & Harris, 2009; Ae Chun, Luna-Reyes & Sandoval-Almazan, 2012) and fostering the **participation of citizens and stakeholders** (Peters & Pierre, 1995; Jordan, Wurzel & Zito, 2005)

- Introducing **deliberative approaches in decision making** (Bohman & Rehg, 1997; Dryzek & List, 2003; Goodin, 2008)
- Establishing **regulatory framework** for risk prevention (see, in this regard, the debate on the regulatory state: Majone, 1994, 2010; Bartle & Vass, 2008; Lodge, 2008)
- Developing **ethical procedures**, in terms of the so-called "applied ethics" (Frey, 2004; Cohen & Wellman, 2014; Koven, 2016), driving the spread of specialised ethical codes for the pragmatic regulation of specific sectors, preventing risks and ensuring integrity.

As may easily be observed, most, if not all, of these orientations are included – sometimes in descriptive, sometimes in prescriptive terms – in the models of scientific knowledge production (post-academic science, Mode 1 - Mode 2 model, etc.) examined above and – as we shall see in Part Three – they are also largely incorporated in the concept and tools of RRI.

1.6. Discussion

In this Section, a short analysis has been conducted with the final aim of framing RRI within the overall changes affecting science. With this aim in mind, an attempt was made to frame the latter within the main trends of change affecting societies in their shift from the modern to the so-called post-modern age. Therefore, this first section detailed three main operations:

- A summative analysis of the main trends affecting societies and social institutions
- A comparative analysis of the main interpretive approaches developed to account for the main changes affecting science and innovation
- An attempt to find connections between the latter and the former.

Three short considerations about the outputs of this process can be made.

A. Changing Society and Changing Science

Needless to say, changes affecting science and innovation reflect the major transformations occurring in society as a whole. In modern society, social institutions, science included, were solid, highly structured, authoritative, standardised and self-contained, while in the post-modern context they appear to be weak, with uncertain boundaries and internal procedures, and destandardised.

While they were legitimated by the power of the state, now their legitimacy, credibility and reputation are continuously questioned, activating negotiation processes at different levels (symbolic, institutional, interpretive, etc.).

B. Science as a Socially Weak Institution

Since science is experiencing the same critical turn affecting all the institutions of modernity, we should then recognise it as an institution which is socially at risk, even though, quite paradoxically, it is now technically stronger than it was in the past (in terms of both scientific advancements and technological impacts). It is quite strange that we are usually reluctant to con-

sider science as an institution socially at risk, given the crisis of other institutions (such as politics, trade unions, marriage or family), where factors and trends are very similar.

This crisis could be defined in terms of **under-socialisation of science**, i.e. as an inadequate or even decreasing capacity of science and innovation systems to adapt to a changing society and to manage and steer the transformations affecting them (d'Andrea & Montefalcone, 2009).

What is at stake with science socialisation is not only the management of the growingly complex relations between science and society but also the functioning of the internal mechanisms of science, pertaining to the way in which scientific knowledge is produced, assessed, and used and ultimately the way in which the scientific method is actually applied and protected.

C. Science from Models to Facts

So far, our reasoning has been based on general models. However, the distance between models and facts can be extremely wide. In fact, different situations and hybrids can co-exist and recurrent patterns of change may assume multiple forms, depending on the institutional, national, or social context, producing, also, variable impacts. Thus, the question we wish to examine now is the extent to which these trends actually manifest themselves in the lives of researchers and research institutions.

This is the issue which we will address in the next section.

2. Change processes

This section focuses on creating a **reasoned inventory of change processes** occurring in science (with a special focus on STEMs[2]), going also beyond or, rather, beneath the general models briefly presented above. Some preliminary remarks are to be made.

- The **inventory is necessarily selective**, focusing on the changes which may be of most relevance to science-in-society issues and RRI. In particular, an effort will be made to assume the point of view, so to speak, of an "average Principal Investigator" working in an average research institution or university, so as to understand as far as possible how s(he) may "decode" the concepts and messages connected to RRI. In fact – as we highlighted above – the assumption of FIT4RRI is that the acceptance and spread of RRI depends on its relevance and capacity to address the problems scientists and research institutions have to manage, deriving mostly from changes affecting science and innovation.

- The **inventory deliberately does not consider the many variables** which come into the picture. Changes in science and innovation are obviously different according, e.g., to national research systems and policies, disciplinary fields, kinds of research, kinds of involved institutions, economic environment and social context.

[2] STEMs refers to Science, Technology, Engineering and Mathematics.

2.1. Hypercompetition

There could be many possible starting points for an analysis of changes affecting science. However, adopting a grass-roots perspective, so to speak, the factor producing the most impact on the lives or research institution and researcher is probably the skyrocketing increase in the competition to access funds and resources. This competition is so tough, especially in high-growth sectors such as biosciences, that some authors refer to it as "**hypercompetition**" (Alberts, Kirschner, Tilghman & Varmus, 2014; Schatz, 2014; Fochler, Felt & Müller, 2016).

The concept of "hypercompetition" is taken from economics and business management (D'Aveni, 1994) to refer to a competitive environment characterised by new traits which drastically distinguish it from "traditional" competitive environments. In the hypercompetitive environment, **time has collapsed the traditional process cycle** (launch of new product, exploitation and counter attack) and **equilibrium is impossible to sustain**. Therefore, competitive advantages can only be temporary and changes are continuous, since the only advantage is to keep replacing an advantage, including your own advantage.

2.2. Acceleration of the research process

One major effect of a hypercompetitive environment is undoubtedly the **acceleration of the research process** (Pels, 2003; Garforth & Cervinková, 2009; Müller, 2014; Vostal, 2016). In general, fast work is considered a requirement for high quality research and the rapid exploitation of scientific knowledge. This process is not necessarily bad or good (Vostal, 2016; Felt, 2017), even though a movement promoting "slow science" is also emerging (slow science.org, 2013).

Acceleration means an «*increase of countable academic output per predefined unit of time*», e.g. per year, such as data produced, articles written, volumes edited, grant proposals submitted, lectures given, students passed, etc. (Müller, 2014). This necessarily requires a **reorganisation of the academic life** and **changes in the researcher's lifestyle** as well. If this does not happen, accelerating the research process may be problematic for the proper management of the reduction of the time needed for conducting experiments, verifying data, interacting with other researchers, writing papers, peer-reviewing, publishing, etc.

More in general, as Müller (2014) emphasizes, «*many of the problematic trends in current academia become tangible on the experiential level as questions of pace*», producing, e.g., tensions between different duties and tasks, a feeling of constant time pressures or problems in organising research work. For these reasons, in many research sectors, researchers experience **a condition of stress and pressure** which may greatly affect their professional and even personal lives (Bianchetti & Quartiero, 2010).

2.3. Shrinking of public research funds

Another factor feeding competition is the **shrinking of public research funds**, also affecting high-growth research fields, such as biosciences (Alberts, Kirschner, Tilghman & Varmus, 2014).

In 2014, for the first time since 1981 (when data were first collected), OECD recorded a decrease in overall government spending on research and development (R&D) and higher education (OECD, 2016).

In the **European Research Area**, the government budget allocation on research and development (GBARD) **has declined in relative terms from 2008** to reach 0.67% of the Gross Domestic Product (GDP) in 2016, with a -0.5% compounded average growth rate (CAGR). A great variability across the countries is however to be noted. For example, increases are reported in countries like Austria, Czech Republic, Denmark, Finland, Germany, Poland, and Switzerland and decreases in countries like France, Hungary, Italy, Latvia, Spain, and United Kingdom (European Commission, 2016d).

This process is mainly interpreted as **structural**, in the sense that it is not due to contingent economic and financial crises but to the increasing costs of research (Ziman, 1996; Alberts, Kirschner, Tilghman & Varmus, 2014), including those for equipment, researchers' time, laboratory animals (Stephan, 2012) and access to scientific publications (Rose-Wiles, 2011), producing a growing impact on research organisations (Ehrenberg, Rizzo & Jakubson, 2003). This is making access to research funds much more selective and competition to access private funds much tougher.

This process also involves **an impact on time**. Indeed, the shrinking of funds is producing a decline in the success rate of grant applicants, with scientists having less time to devote to their research work (Alberts, Kirschner, Tilghman & Varmus, 2014).

2.4. Diversification of tasks

Managing competition and the acceleration of scientific work in a context of diminishing resources means that a **market-oriented organisation** of the research process is becoming increasingly necessary.

One of the main consequence of such a process is a broad **diversification of tasks** (Kogan, Moses & El Khawas, 1994; Musselin, 2007), i.e., researchers are engaged in a **wider range of activities requiring, a wider range of skills and capacities**. For example:

- **Participation in extended research networks** obliges researches to spend time and resources to develop and maintain interactions with other research institutions, researchers and other stakeholders, in a context of diminishing time availability and resources (Bakken, Lantigua, Busacca & Bigger, 2009)
- The tendency to stress the **utility of scientific knowledge** pushes them to write research proposals to access research funds, to be engaged with technology transfer, to adapt their activities to performance-based and efficiency-oriented new management orientations (Fredman & Doughney, 2012) or to deal with the many economic aspects related to the research process, so as to address the decreasing availability of research funds
- The emphasis on **accountability, transparency and public scrutiny** obliges researchers to deal with many aspects related to science communication, ethical issues, administrative work and management of research funds.

Diversification of tasks both derives from and feeds an increase in the **bureaucratization of research work** (Schneider, 2013; Bozeman, 2015) which has a wide range of consequences on the lives of researchers and research institutions (see the box below).

THE ADMINISTRATIVE BURDEN OF RESEARCHERS

The Federation of American Societies for Experimental Biology (FASEB) carried out in 2013 a survey on the administrative burden of researchers, involving 1,324 biological and biomedical researchers. The following items summarised the administrative burden deriving from grant preparation, submission, management, and funding.

Grant Preparation

• Extremely time consuming, taking anywhere from 25 to 100 percent of a PI's time for several months each year. • Each agency has unique formatting and informational requirements, even for basic information such as CVs and conflict of interest reporting. • Requirement for institutional regulatory body review and/or pre-approval prior to grant submission. • Lack of financial support for a PI's or Postdoc's salary during the grant proposal drafting and submission process. • Grant proposals require many details that are difficult to accurately predict, such as calculation and justification detailed research budgets.

Effort Reporting

• Difficult to accurately determine how much time was spent each week on overlapping projects by technical personnel supported by multiple grants. • Data from effort reporting may be flawed due to rigid reporting and formatting requirements (i.e., approximations are not allowed and the assumption of a 40-hour workweek is not always applicable to research), creating misinformation that is used to develop policies. • Lack of Institutional Administrative Support, Pre- and Post-Award • Lack of administrative support made grant submission and management the highest burden for many responders. • Concerns regarding indirect costs and the extent to which they are used to provide pre- and post-award management support. • Lack of scientific expertise among support staff results in researchers performing most of the administrative work themselves.

Personnel Management

• Delays and inefficiencies in the creation of new positions funded by a grant and in transfer of employees from one position to another as grants or research projects change. (It is unclear to what extent this is the result of agency policies versus institution policies, or whether this is primarily due to federal, state, or local labor laws.) • Having to lay-off trained research assistants and then re-hire and train new research assistants due to short gaps between one grant ending and the next being awarded. • Lack of sufficient flexibility for PIs to create desired personnel positions due to funding mechanism-specific rules.

Time-to-Award

• The time between submission of a grant proposal and receipt of an award makes short- and intermediate-term planning for research projects very difficult. • Delays in funding decisions cause PIs to continue submitting more and more "backup" grants.

Financial Tracking and Reporting

• Issues related to error-prone, overly complex, and difficult-to-navigate billing and financial tracking systems. • Lack of institutional expertise with smaller grants or less common funding mechanisms leads to conflicting institutional management and reporting. • Difficulty in assigning expenses to individual grants in multi-grant funded laboratories and similar issues with managing segregated funding. • Use of different financial categories by Institutions and agencies.

Grant Funding Regulations
• Inability to charge computers or required hardware and software updates to relevant grants. • Expansion of funding mechanism-specific rules for how awards can be spent, creating confusion.

Subcontracts, Multi-Institution, and Multi-Agency Funding
• Communication issues among researchers and administration across different study sites. • Difficulty with project management and oversight creates disincentives to participate in future large-scale collaborations. • Monthly invoicing and reimbursements for subcontracts do not always occur in a timely manner. • Lengthy finalization process for subcontracts due to institutional and agency requirements as well as state and federal laws.

Electronic Submission and Tracking Systems
• Institutional and agency systems "opaque" and "confusing." • Deploying software prior to full testing and validation is burdensome. • Utilization of user-unfriendly electronic forms by both agencies and institutions.

Source: FASEB, 2013

2.5. Increased staffing

Task diversification is producing labour diversification, due to **increased staffing of research personnel** so as to ensure that all the necessary tasks involved in the research process are done properly and in due time.

However, the diminishing availability of research funds and resources is making it more difficult to enlarge research staff through the usual hiring and promotion schemes science institutions used in the past.

This has brought an **increase in contingent staff**, i.e., doctoral students and Postdocs, involved in research processes. This increase grew significantly in the last decades, to the extent that research systems in general, and especially in some specific sectors such as the bio-sciences, can be referred to as a "**PhD factory**" (Dijstelbloem, Huisman, Miedema & Mijnhardt, 2013).

This tendency is primarily due to **costs**. For example, in the USA, in 2010, a Postdoc salary was about $15.00 an hour, a graduate student about $20.00 (excluding fringe benefits and indirect payments), and a staff scientist about $32.00 per hour (Stephan, 2012). Moreover, in contrast to tenure-track researchers, contingent staff are increasingly paid with **soft-money**, i.e., money from research grants (Alberts, Kirschner, Tilghman & Varmus, 2014), thus working on the basis of a specific project. Reducing costs and increasing the labour force allow research organisations to be more competitive in the global research and innovation market.

This system is **disadvantageous for PhD students and Postdocs**, since «*they enjoy the thrill and challenge of scientific research*» and are engaged in a "rat race" (Alberts, Kirschner, Tilghman & Varmus, 2014) to access permanent positions while opportunities to get a permanent contract are drastically diminishing and the time needed to reach a permanent position are becoming longer (Stephan, 2012). Ravetz (2016), in turn, highlights the presence of a question of right involved in such mechanisms, since the science system is increasingly training people «*with the prospect of a lifetime sequence of short-terms jobs on contracts, lacking any rights of security and whose renewal depends on the four of the principal investigators*». In this way, many researchers, mostly after more than 10 years of temporary contracts, are forced to look for a ca-

reer outside research, even though their experience of work is one-sided and they are not fit (or feel unfit) for other kinds of work.

This system is also a **frail system**, since it functions as a sort of **pyramid scheme or Ponzi system**, which works only if demand for faculty positions keeps on growing (Stephan, 2005). It is based on an "**implicit contract**", according to which PhD students and Postdocs provide a "surplus" of work, getting some benefits from their supervisors (for example, support in looking for new positions, co-signature of a publication, etc.) (Stephan & Levin, 1997). Again, the problem is that supervisors find it increasingly difficult to fulfil their promises due to the increasing competition.

Lack of information is another factor feeding this process. When deciding on their future career, students and PhD students seldom receive appropriate information about career options, opportunities and especially risks (Stephan, 2013). For this reason they see their **careers as highly linear** (Garforth & Cervinková, 2009), including a period devoted to doctoral studies, one or two Postdoctoral periods and then an attempt to become junior group leader somewhere. All breaks and periods working for non-academic tasks are seen as deviations from the career path. There is a sort of a **gap** between the linear perception of one's own career and the increasingly uncertain and non-linear career perspectives actually offered to young scientists.

A secondary impact of this process is the generation of a **new category of researchers**, i.e., those selling their labour temporarily by joining a research institution only for the time needed to work on a specific project (Ylijoki, 2014a), no longer aspiring to reach a permanent position.

It should also be considered that PhD students and Postdocs are the ones who **suffer most from the acceleration of the research process** (Vostal, 2014), being more vulnerable to the "imperatives" of producing, for example, rapid results, publishing one paper at least per year or demonstrating their skills and capacities in view of developing their career. Their aim is not simply to acquire academic capital, but to **acquire academic capital in a short time** (Müller, 2014) so as to gain advantage over competitors.

This also partially explains the presence of **gender inequality dynamics in science** as regards career advancement and access to leadership positions (European Commission, 2012a, 2016a). In fact, increased staffing and acceleration of the research process further heighten competition, disadvantaging those – typically women – who have more difficulty to fully concentrate on work because of the amount of caring activities they perform in family life (Goulden, Frasch & Mason, 2009; Archie, Kogan & Laursen, 2015) as well as for psychological dynamics (Shapiro & Sax, 2011; Dayton, 2013). It is to say that gender inequality is undoubtedly related to many persistent and deep rooted social processes going far beyond the domain of science (Valian, 1998). However, in the case of science, it is also fostered by specific forms of social stereotyping (Shapiro & Williams, 2012) and a masculine image of science (Keller & Kirkup, 1992) which structurally permeates research institutions (European Commission, 2012a).

2.6. Segmentation

Task diversification and acceleration have also led to an increase in the **segmentation** (Musselin, 2007) of academic and research work. Segmentation is mainly based on age and contractual status.

- As regards **age**, tasks are shared out according to career position, so that experiments are prevalently done by PhD students and Postdocs, while seniors researchers are more involved with other tasks of an administrative and organisational nature.
- As for **contractual status**, contingent staff now performs a widening range of tasks previously performed by tenure-track personnel.

Thus, and quite paradoxically, permanent research staff is less in contact with actual scientific work and increasingly tend to transfer research and teaching responsibilities to temporary personnel.

This segmentation process may have many consequences.

- **Decreasing productivity of young researchers**. The segmentation process pushes contingent staff to work for long periods as staff scientists under temporary contracts. The lack of certain job prospects has negative effects on their autonomy and motivations, reducing their productivity (Stephan, 2005).
- **Increased control over academic tasks**. The segmentation of research work is favouring increased control over academic tasks. Control over single-task workers is easier than that over multiple-task workers (Musselin, 2007).
- **Overtraining**. The system tends to retain PhD students and Postdocs longer than necessary, with the double effect of damaging their career opportunities and diverting them from research tasks by increasingly getting them to do non-research (and often low-skilled) tasks (Stephan, 2005).
- **Decreasing quality of teaching**. Segmentation is leading to a decrease in the quality of teaching. This task is increasingly performed by ever cheaper teaching staff (especially temporary staff), while student numbers are rising (Dijstelbloem, Huisman, Miedema & Mijnhardt, 2013).
- **Changes in internal labour relationships**. Segmentation is also leading to a "late industrialisation" of the internal organisation of academic work, thus also modifying labour relationships. In the past, research organisations were perceived as a welcoming environment for researchers and a sort of community of peers. Now they are increasingly functioning as employers who use incentives and other mechanisms to activate internal competition, while researchers increasingly perform the role of labourers. Affiliation to an institution is thus turning into an ordinary labour relationship (Musselin, 2005, 2007).
- **Individualisation**. Researchers (especially Postdocs) are more and more inclined to act as individual professionals, since success is linked to their capacity to get through their research work as fast as possible, devising their own strategies and activating personal relationships. Single projects and collaborations are seen as useful only as long as they allow them to produce high impact publications, and are merely treated as launching points for the next step in a career that is to be advanced elsewhere (Müller, 2014).
- **Self-promotion attitudes**. Individualisation is also fostering self-promotion attitudes among scientists, especially in terms of publicising themselves and their own research activities via the Web (leveraging on the increasing use of blogging, micro-blogging and nanopublications) and public conferences (Dijstelbloem, Huisman, Miedema & Mijnhardt, 2013).
- **Stratification and polarisation in academic staff**. Finally, these changes are also producing stratification and polarisation in academic staff (Slaughter & Leslie, 1997; Slaughter &

Rhoades, 2000; Ylijoki, 2014b), which, in turn, is profoundly modifying and splitting the academic identities of research staff (Ylijoki & Ursin, 2015). In fact, those who benefit from changes (for example, those who exploit the cheap labour provided by contingent staff) and those who are damaged by them (for example, researchers who accept lower-grade positions of a technical or administrative nature in order to access permanent positions) do not share the same identity as scientists, since their interests and perceptions no longer overlap or clearly diverge.

2.7. Increasing mobility

Another key feature of scientific careers is increasing **geographical mobility**. In general, many studies that measure academic performance mainly through publication data highlight that mobility is a **factor favouring an increase in scientists' performance** (see for example: Dubois, Rochet & Schlenker, 2014; Franzoni, Scellato & Stephan, 2014; Halevi, Moed & Bar-Ilan, 2016), allowing scientists to enlarge their personal networks (Franzoni, Scellato, & Stephan, 2014; Weert, 2013), facilitating their career progression (see, for example, Watson et al., 2010) and their access to new skills and capacities (Franzoni, Scellato & Stephan, 2014).

In any case, for scientists, the extent and importance of benefits deriving from mobility largely vary, depending on different factors, including career stage, length of stay, personal choices and specific circumstances (Guthrie, Lichten, Corbett & Wooding, 2017)

In **organisational terms**, and as regards **personal and professional living conditions**, extreme mobility may have important impacts on scientists.

First of all, extreme mobility involving many countries may have **negative impacts on access to permanent positions** (Marinelli, Pérez & Fernández-Zubieta, 2013). A **permanent position is also more difficult to find** for scientists returning home from abroad than "domestic scientists" (Fernández-Zubieta, Marinelli & Peréz, 2013).

Moreover, mobility may have a **strong impact on family life**. There is a **gender component** which comes into play in that, since having care responsibilities (children, partner, etc.) is a barrier to mobility (Cox, 2008; Børing, Flanagan, Gagliardi, Kaloudis & Karakasidou, 2015). Therefore, women are at a disadvantage compared to men (Weert, 2013) and, in fact, they are less likely to be internationally mobile than men (Guthrie, Lichten, Corbett & Wooding, 2017).

There are also problems related to the **loss of social ties** (Heining, Jerger & Lingens, 2007) and those deriving from the **time required for adjustment and familiarization** with the new working and cultural environment, which can even lead to a delay in the publication of new studies (Halevi, Moed & Bar-Ilan, 2016). **Other factors problematising stays abroad** may also include quality of life issues, unsatisfactory arrangements and practices concerning social security, immigration rules, health care insurances, and costs of living (European Commission, 2008)

2.8. Increasing pressure on research assessment systems

Research quality assessment criteria and tools are also affected by rapid changes. This issue is too complex to be deepened here. We will limit ourselves to only a few aspects which overall suggest an **increasing pressure** on research assessment systems.

The core of the problem is that the rapid increase in the number of researchers (Guthrie, Lichten, Corbett & Wooding, 2017), producing an increasing number of papers (European Commission, 2016b), is creating a **hyperproduction of scientific knowledge** (Dijstelbloem, Huisman, Miedema & Mijnhardt, 2013) to the extent that usual research quality assessment procedures (mainly based on peer reviewing and bibliometrics) seem no longer to be able to cope.

Many authors (for example, Young, Ioannidis & Al-Ubaydli, 2008; Osterloh & Frey, 2015; Hicks & Wouters, 2015) emphasize the **expanding and even distorting use of scientific publications**, which, once intended to communicate scientific results and validate them, are now serving different objectives, related to personal careers, resource allocation, visibility, reputation and completion among scientists and among research organisations.

The huge number of scientific products is **making it more difficult to ensure good quality peer review**. For example, the pressure of time, which increasingly characterises the lives of researchers, is a factor which affects peer review quality. Principal investigators have no time to review manuscripts and often leave this task to less experienced colleagues. The increasing number of manuscripts proposed for publication often obliges the editorial boards of journals to enlarge the pool of peer reviewers to include less experienced scholars. Time constraints also affect the peer review of applications for research grants, due also to the increasing number of applications submitted for funding (Alberts, Kirschner, Tilghman & Varmus, 2014).

Moreover, for these and other reasons, **peer reviews are not reliable enough**: they tend to produce diverging and unreliable results (Rothwell & Martyn, 2000; Starbuck 2005), are too influenced by the beliefs of reviewers (Lawrence, 2003) and are too conservative, rarely contradicting mainstream thinking (Campanario, 1998). Social and power dynamics may also influence the outputs of peer reviews (Newton, 2010). According to research on peer reviews in the medical sector (Schroter, Black, Evans, Godlee, Osorio & Smith, 2008), only a few of the errors present in papers were reported on average (one major error out of three on average).

The perceived reduced reliability of qualitative peer reviews is leading to an **increased use of quantitative indicators** (citation indexes, impact factors, etc.) based on bibliometrics. This approach has started to dominate science governance with the production of rankings (of departments, publications, etc.) which may greatly influence scholarly careers and the future of research institutions (Osterloh & Frey, 2015; Hudson & Laband, 2013).

However, according to other scholars (for example: MSCS Editorial Board, 2009; Ernst, 2010; Gunsteren, 2015), the use of quantitative indicators **cannot measure quality effectively** and may produce **distorting effects on science**. For example, citation indexes (Kermarrec, Faou, Merlet, Robert & Segoun, 2007):

- Are often exposed to manipulation
- Do not correlate with the originality of a scientific publication (being citations, for example, often linked to momentarily emerging trends)

- Produce fluctuating classifications of journals
- Do not include sources of scientific information (for example, conference proceedings are usually not covered) other than journals.

As for **research rankings**, they are not consistent over time (Lawrence, 2003) and tend to have a low prognostic quality, i.e., capacity to identify the future influence of a publication (Starbuck, 2006; Hudson & Laband 2013). A set of recurrent problems have also been observed in the use of citation indexes for evaluating scientific journals (see the box below)

PROBLEMS IN THE USE OF THE IMPACT FACTOR

Technical ISI (Institute for Scientific Information) database problems
• Biased towards the English language. • Biased sample of journals included in the database, • Database coverage different for research fields. • Books, conference proceedings, letters not included as source items. • Delayed registration of citation. • Frequent misprints (up to 25%). • Synonymy (several variants of the same article). • Homonymy (several authors with the same name). • Publishing time penalises disciplines with longer turnover times.

Research field effects
• Field size. • Field dynamics (expansion or contraction). • Research theme. • Inter-field relations (e.g., clinical medicine draws heavily on basic science, but not vice versa). • Bias towards research fields with literature that rapidly becomes obsolete.

Reference selection and citer motivation
• Primary criterion for reference selection is not quality but utility in research. • Incomplete referencing due to journal space limitations. • Reference copying. • Flattery (citation of editors, potential referees). • Self-citation. • In-house citation (friends and close colleagues). • Review articles heavily cited. • Utility in research rather than pure scientific quality is the primary criterion for reference selection.

Problems associated with using the journal impact factor
• Journal Impact Factors (JIFs) are determined by technicalities unrelated to the scientific quality of their articles. • JIFs are not statistically representative of individual journal articles. • Distribution of citations in articles within same journal is not uniform. • JIFs correlate poorly with actual citation rates of individual articles. • No mechanisms to correct self-citations. • Selective journal self-citation: articles tend to preferentially cite other articles in the same journal. • JIFs are a function of the number of references per article in research field. • Short publication times result in high JIFs. • National bias in reference selection favours American journals. • Review articles are cited in particular, resulting high JIFs.

Source: Ha, Tan & Soo, 2006

The **falsity of published research findings** is also concerned with this process. According to Ioannidis (2005), it is possible to identify a number of correlations between the falsity of published research findings and other variables. For example, the greater the financial and other interests in a scientific field, or the more fashionable a scientific field is (with more scientific teams involved and higher competition), the less likely the research findings are true.

In addition to this, scientific knowledge is also increasingly measured according to **criteria** which regard aspects (potential economic exploitation, utility from a problem-solving perspec-

tive, etc.) **different from intrinsic scientific quality**, involving "hybrid fora", i.e., mixed committees of researchers and public users in charge of evaluating research proposals and research products (Dijstelbloem, Huisman, Miedema & Mijnhardt, 2013). This choice reflects changes in the definition of the social relevance of science and technology (Hessels, Van Lente & Smits, 2009) as well as deep changes in the way in which research institutions work. It is also true to say that the introduction of selection criteria related to the social or political significance of a research proposal remains highly controversial (Lamont, 2009).

All these critical issues do not necessarily lead to a search for radical alternatives to the existing assessment procedures. Rather, the main tendency is to improve, adapt or integrate existing assessment approaches or to change the ways in which they are used (for a discussion of this issue see, for example, Birukou et al., 2011; House of Commons, Science and Technology Committee, 2011; Mulligan, Hall & Raphael, 2013).

2.9. Governance shift

Another problematic issue which is connected to the major trends of change affecting science is the modification of **university and research institute governance models**. The overall tendency is to **shift from the Humboldtian or traditional** model of university to the so-called **Entrepreneurial model**.

As maintained by some authors (De Boer, Enders & Schimank, 2005; Fried, 2006), this shift cannot be understood in black-or-white terms, since many different mechanisms of coordination and collective control are involved. De Boer, Enders and Schimank (2005), in particular, identify five main mechanisms concerned with this process:

- **State regulation** (i.e., state rules under which universities are allowed to operate)
- **Stakeholders guidance** (i.e., the guidance provided by state authorities or other delegated entities to other actors/stakeholder representatives, such as university board members)
- **Academic self-governance** (i.e., the processes and procedures of consensus building within and among academic components)
- **Managerial self-governance** (i.e., the governance exerted by the senior leadership and management of an institution)
- **Competition** (as the underlying rationale for the coordination of priorities and decision making).

According to the authors, what is changing is the balance among these mechanisms. In the traditional model, state regulation and academic self-governance are the strongest components, while in the entrepreneurial model, the strongest components are stakeholder guidance, managerial self-governance and competition. However, new forms of equilibrium among the involved mechanisms are not always simple to attain.

This shift does not occur in a uniform manner, owing also to the different types of academic institution. For example, McNay (1995) distinguishes four ideal types of university on the basis of two variables: the level of policy definition (i.e., the level of control by external factors, such as state intervention); the level of control over implementation.

		CONTROL OF IMPLEMENTATION	
		Loose	Tight
POLICY DEFINITION	Loose	A. COLLEGIAL	B. BUREAUCRATIC
	Tight	C. ENTREPRENEURIAL	D. CORPORATE

Thus, the **collegial type** tends to be the most traditional type of university, being scarcely influenced by external control and policy constraints, while the **corporate type** is strongly driven by political decision-making processes and tight control systems. The **entrepreneurial type** of university institution is strongly oriented to the outside world but the management style is based on a devolved leadership, where small project teams are the dominant unit. Finally, the **bureaucratic type** is mainly based on rules and regulation, formal control mechanisms and the strong power of senior management, while political definition is loose.

The general shift from traditional to entrepreneurial model is also greatly influenced by the **national context** (regulations, legal frameworks, cultural traditions), which heavily affect, for example, the structure of higher education governance, funding mechanisms, the role of private institutions or the culture and structure of academic staff (see, for example, Eurydice, 2008). The dynamics of science (in terms of pressure for productivity and practical application of research outputs) varies greatly according to disciplinary field (Hessels, van Lente, Grin & Smits, 2011)

All in all, scientific literature shows that the general shift from traditional to entrepreneurial model of university ends up generating a **wide range of situations** which are difficult to compare with each other and even more difficult to include in predefined categories and typologies. This is to say that research institutions are increasingly characterised by the typical de-standardisation processes of the post-modern age.

Moreover, the process of change is **far from being linear and smooth**.

On the one hand, the many actors involved (governments, governing bodies, rectors, academic staffs, central administrations, students, external stakeholders) adopt **widely different behaviours, orientations and strategies** to manage the change or interpret their roles in the changing context (Fried, 2005).

On the other hand, there is a lot of **resistance to the process of change**, with highly differentiated effects on how the change actually occurs. There are many voices against the adoption of a managerialist perspective (see, for example: Manne, 1999; Marginson & Considine, 2000; Fuller, 2001). More importantly, many stakeholders more or less actively tend to oppose change (Meek, Goedegebuure, Santiago & Carvalho, 2010; Mainardes, Alves & Raposo, 2011), producing different kinds of impact (Mainardes, Alves & Raposo, 2011; Lumijärvi, Arminen, Lähde & Koschke, 2012), including: the adoption of defensive routines so as to make it more difficult to implement change; development of poorly drafted plans often never implemented; lack of senior management commitment; tendency to maintain familiar communication chains thus reducing the introduction of new communicative configurations; conflictive attitudes towards new reforms; lack of compliance toward deadlines.

It should also be highlighted that, in a highly fragmented structure like academic institutions (Fried, 2005), resistance also emerges because of **mistakes and inadequate strategies in promoting change**. For example, reforms activated suddenly, started from outside, without any previous internal discussion aimed at explaining the reasons behind the process, planned in small circles or reserving too short a time for implementing the reform are most likely to exacerbate resistance (Lumijärvi, Arminen, Lähde & Koschke, 2012). More in general, both purely "top-down" and "bottom-up" approaches are limited as a way of fostering change, whereas an approach based on "**distributive leadership**" (Keppel, O'Dwyer, Lyon & Childs, 2010), in which change is jointly managed by different stakeholders, or a hybrid approach (Bolden, 2011) is more likely to succeed (Brown, 2013).

2.10. Increasing openness to external actors

No less important for research organisations is the capacity to manage their **openness to society**, where the term "openness" refers to a lack of restriction or boundaries in participation (including innovation-oriented collaborations), transparency and accountability in decision-making and receptiveness to change in processes (McCarthy, Fitzgerald, O'Raghallaigh & Adam, 2017).

The relevance of this issue is evident, considering how universities and research organisations as well as single researchers increasingly interact with actors other than scientists for different reasons, such as: contributing to the development of national or local policies by serving as experts; fostering research-based innovation programmes; cooperating with the private sector; participating in public debates on science-related issues; participating in or supporting the local cultural and social life (community engagement); encouraging public participation in research programmes (citizens science); cooperating in science communication and education initiatives.

This issue will be further analysed in Part Three, since openness clearly is at the core of RRI. However, some issues can be highlighted.

- **Increased complexity**. Openness entails increased complexity in the management of research institutions. Openness-based strategies cannot be adopted by considering openness as a new organisational function to be added to the existing one while at the same time continuing "business as usual". Rather, a general reconfiguration of management and cultural approach is needed (Boogaard et al., 2013).
- **Openness level**. A problematic aspect is finding the "right" level of openness for a project or an institution towards external actors. For example, a study on the impact of openness on information system development projects shows that «*while openness contributes to higher levels of project success, a tipping point also exists, beyond which openness actually begins to contribute to diminishing returns*» (McCarthy, Fitzgerald, O'Raghallaigh & Adam, 2017).
- **Institutional undervaluing**. Openness, in its many forms, is usually overlooked in its relevance and potential role by research institutions, as shown by different studies on the level of importance attached practically to Public Engagement (for example: Neresini & Bucchi, 2011; Bauer & Jensen, 2011). This leads to openness-related practices being left as optional and not structurally embedded in research organisations (Burchell, 2015; Watermeyer, 2015), with the result that scientists involved in openness-oriented activities are

not rewarded for their activities (Burchell, 2015) nor get any reputational benefits , and may be even be considered «*'not good enough' for an academic career*» (The Royal Society, 2006).

- **Conceptual ambiguities and interpretive mismatches**. Many conceptual frameworks have been developed to deal with the many forms of openness, including, e.g., Public Engagement with Science and Technology, Triple and Quadruple Helix, Citizens Science, Universities' Third Mission, Universities' Civic Engagement, Science communication, Innovation Ecosystem, Innovation Networks, or Innovation Districts (see the analysis by Lassnigg, Hartl, Unger & Schwarzenbacher, 2017). However, the presence of these different frameworks (which usually correspond to different communication circuits and communities of experts) produces ambiguities and new boundaries. For example, the approach focused on Public Engagement tends to exclude industry and to focus on citizens and stakeholders; the Third Mission approach is focused on industry and tends to exclude citizens. Moreover, the same framework may be interpreted in different ways. For example, it is not rare for scientists to include among the components of public engagement purely communicative activities (such as relations with media), student recruitment, knowledge transfer, or working with policy makers (Research Councils UK et al., 2010).
- **Resistance and barriers**. The process of opening up research institutions to society often comes up against different types of resistances and barriers. For example, obstacles to university-industry collaborations can be found, for example, in the different institutional norms governing public and private knowledge, the different culture of public and private researchers, conflicts over patenting issues, the lack of clear views by scientists about the benefits of working with industry (Bruneel, D'Este & Stalter, 2010). Other examples of resistance and barriers to openness among researchers and research institutions can be of a managerial nature (e.g., time constraints; lack of funding and other resources, etc.), a cultural nature (e.g., passivity of decision makers, limited relevance accorded to laypeople, etc.), related to the lack of capacity and skills (for example, communication skills, managerial skills, etc.) or to political issues (e.g., resistance to changes in existing power relationships, lack of political frame and will to invest in openness, etc.) (Rask et. al, 2016).
- **Distrust in science**. As regards openness in science, another emerging issue is the decreasing trust people have in science and scientists, recorded also statistically (for example, Eurobarometer, 2010 and 2013; Scientific America, 2010). Scientific judgments on matters of practical concern are not infrequently suspected of being incompetent and biased (Carrier, 2017). Distrust also tends to increase in sectors or on questions where science is perceived to be in close connection with industry (Chilvers & Macnaghten, 2011) or political interests (Bolsen, Druckman & Cook, 2013). Distrust is also fed by bias, manipulation and misinterpretations which may occur at any step of the research process, up to the communication of research results to the public (Ferrante, 2016). This means that participation of citizens, NGOs or stakeholders in science and innovation cannot be taken for granted.
- **Impacts on open data on science**. Another trend, strongly connected to the progressive openness of science, is the increasing impacts of ICT and, especially, open data on the way in which science is produced, disseminated, deployed, used and managed (OECD, 2015b; European Commission, 2016b). Hence, the idea of an open science (i.e., a science that fully use the opportunities provided by ICTs) which goes far beyond the concept of open access. In fact, ICTs not only make it possible a different way to access publications, but provide a wide range of opportunities related to the «*interoperability of scientific infrastructure, open and shared research methodologies (such as open applications and informatics code), and machine-friendly tools allowing, for example, text and data mining*» (OECD,

2015b), which, overall, make science necessarily more transparent and more embedded in societal ethos and dynamics. Nevertheless, technological opportunities cannot be turned into real changes without concurrent social, cultural and policy transformations involving the many actors involved in the production and use of scientific knowledge (OECD, 2015b). It is also important to note that, as RRI, also the concept of Open Science can be considered as an "umbrella concept", encompassing different assumptions and views of science (Fecher & Friesike, 2014)

2.11. Critical dynamics affecting the quality of research products

There is much debate about the extent to which the new organisation of research work influences research quality. Views are polarised in this regard.

On the one hand, many authors maintain that **changes are already occurring** and scientific **institutions cannot but rapidly adapt their internal organisation to them**.

Different models have been developed for orienting research and university organisations in managing this adaptation process, including the Entrepreneurial University Model (Etzkowitz, 1983 and 2004; Jacob, Lundqvist & Hellsmark, 2003; European Commission-OECD, 2012), the application of New Public Management in science policies (De Boer, Enders & Leisyte, 2007; Elzinga, 2010; Enders, De Boer & Westerheijden, 2011) or the so called Emerging Global model (Mohrman, Ma & Baker, 2008). Moreover, interpretative models like the Mode 1 - Mode 2 model or the Triple Helix model, as well as many others focusing on innovation (Innovation Systems, Strategic research, etc.) undoubtedly have been intended, at least partially, as prescriptive models (Hessels & Van Lente, 2008).

From this perspective, problems related to research quality are prevalently viewed as the effect of delays, mistakes and lack of political will in promoting serious reforms of research systems or single research institutions.

On the other hand, other authors maintain that it is **precisely the adoption of these models that bring about problems** in research quality. Some aspects can be considered here.

- **Safe research strategies**. The tendency towards the "projectification" of science (Vermeulen, 2010; Ylijoki, 2014a), i.e., organising research work as a set of manageable processes based on projects, roadmaps and precise timing, is pushing scientists to favour safe research projects (Stephan, 2012) with limited risks of failure. In many cases, projects are viewed by researchers not for their potential in terms of knowledge production, but for their capacity to facilitate their own access to funds needed, e.g., to retain PhD students or Postdocs, to get external support to keep lab going, to get support for one's own salary, or to match productivity standards adopted by one's own research organisation. Moreover, past research results play an important role in accessing new research funds. Thus, having research projects with limited results in terms of discoveries and publications in one's own curriculum may be highly problematic for career advancement. All this is conducive to conservative, short-term thinking in applicants, reviewers and funders, and penalises more creative and unorthodox approaches (Alberts, Kirschner, Tilghman & Varmus, 2014).

- **Irrelevant science**. The increasing need for scientists and especially for PhD students and Postdocs to publish papers in order to "remain in the research market" may have the distorting effect of pushing them to produce meagre and sometimes bad publications «*which do not serve science, but which scientists need to advance their careers*» (Dijstelbloem, Huisman, Miedema & Mijnhardt, 2013).
- **Redundant papers**. Another phenomenon linked to increased competition in science is that of redundant papers, i.e., the tendency to publish the same data or even the same paper in different journals, with the aim of increasing the impact factor of one's own publications (Brochard, 2004; Noè & Batten, 2006; Amado Senaris, 2008).
- **Short-term orientation and instrumentalisation**. The tendency to "commodify" science may lead to a narrow focus on short-term achievement and results and on research able to produce patentable and profitable results, penalising long-term projects (Radder, 2010; Irzik, 2013).
- **Increasing malpractice**. Hypercompetition and the adoption of new forms of research organisation is sometimes also viewed as one of the main factors fostering scientific malpractice (plagiarisms, data fabrication or manipulation, etc.), thus producing a decrease in the integrity of science and its quality (Kaiser, 2014).
- **Decreasing reproducibility of scientific data**. For different reasons (pressure to publish, selective reporting, insufficient replication in the lab, poor oversight, low statistical power and scientific malpractice), often connected to the accelerated pace of the research process, around 50% of all research data (European Commission, 2016b) and probably more (Baker, 2016) are considered not reproducible. Lack of reproducibility is also connected to increased competition in accessing high-impact-factor journals, which encourage behaviours – such as exaggeration of claims, selective reporting of data, cutting corners, exaggerating the values of findings, and overstating the significance of publications – which undermine the integrity of published work and adversely affect the conduct of science (Alberts, Kirschner, Tilghman & Varmus, 2014; Patterson, 2016).
- **Negative impacts of commodification of scientific research.** Commercial interests may also have undesirable impacts on research methods and their results and may lead to a higher level of secrecy that could slow down the overall advance of science, raising a variety of legal, moral, and philosophical questions about the patentability of the results of academic research. Commodification will be detrimental to those areas of academic inquiry that are seen to be useless from the perspective of economic instrumentalisation and may entail the problem of potential abuse of public funds for private purposes (Radder, 2010).

2.12. Discussion

The key idea at the basis of this literature review is that the difficulties met by RRI to diffuse and be adopted (especially in STEMs) are connected to the change processes which are affecting science as a social institution. In particular, it is supposed here that RRI is or is perceived by scientists to be irrelevant or not useful enough to manage such change processes.

In this framework, an effort has been made in this section to develop a "**reasoned inventory**" of change processes occurring in science, focusing attention on the "**grass-root problems**" facing scientists and research organisations, i.e., the critical issues which have a direct impact on

the professional and personal condition of scientists or on the daily activities of an organisation.

The main issues emerging from the analysis are summarised below.

TRENDS	DESCRIPTION
1. Hypercompetition	Science as a hypercompetitive environment where the traditional process cycle has collapsed due to time constraints and equilibrium is impossible to sustain
2. Acceleration of the research process	Working faster seen as a requirement for high quality research; changes in the organisation of academic life and in the researchers' lifestyle; researchers under condition of stress and pressure
3. Shrinking of research funds	Scientists and research organisation working in an increasingly competitive environment, especially in accessing to funds and publishing; decline in the success rate for grant applicants, with an increasing waste of time
4. Task diversification	Market-oriented organisation of the research process, in which research is required to engage with a wider range of different types of activities (participation in extended research networks, direct involvement in innovation and technology transfer, activities related to accountability, transparency and public scrutiny, administrative work, etc.). This is leading to a decrease in the time devoted to scientific work.
5. Increased staffing	Increased numbers of contingent staff (PhD students and Postdocs), due to the need for cost containment; increased use of soft money to pay the contingent staff: fewer opportunities for young researchers to access permanent positions; increased pressure on young researchers to make more in less time, creating hardships especially for women scientists.
6. Increased segmentation	Segmentation of staff based on age and contractual status, producing impacts such as: - Decrease in productivity among young researchers - Increased control over academic tasks - Overtraining (tendency to retain PhD students and Postdocs longer than necessary) - Decrease in teaching quality (increasingly done by ever cheaper teaching staff) - Changes in internal labour relationships (research organisations no longer as a "community of peers" but merely as employers) - Individualisation (researchers increasingly acting as individual professionals and not as part of a staff) - Attitude of self-promotion among scientists - Stratification and polarisation of academic staff (academic staff split between those benefit from change and those who are damaged by it)
7. Increasing mobility	Mobility as a factor promoting an increase in scientific performance but having possible critical impacts on the lives of researchers, such as: delays in accessing permanent positions; difficulties in returning to one's home country; problems in managing family life, especially for women scientists;

TRENDS	DESCRIPTION
	loss of social ties
8. increasing pressure on research assessment systems	Traditional research assessment procedures are no longer able to manage the hyperproduction of scientific knowledge; systematic problems and errors in peer review, lessening its reliability; problematic tendency to use quantitative indicators to assess researchers, research institutions and scientific journals, with distorting effects on science quality
9. Governance shift	Tendency to adopt entrepreneurial models for managing research organisations, requiring a balance of different steering mechanisms; high variability in types of research organisations; differentiation in terms of national contexts; strong resistance to change; need for highly participatory approaches.
10. Increasing openness to external actors	Rising complexity in managing research organisations due to growing need to interact with external actors (political authorities, civil society, industry, etc.) for different reasons (innovation, providing expertise, public engagement, policy issues, societal engagement, science communication, etc.); need to find the right openness level; institutional undervaluation of openness-related initiatives; conceptual ambiguities and interpretive mismatches about openness; resistance and barriers to openness; decreasing trust in science
11. Critical dynamics affecting the quality of research products	Impact of changes on the quality of research, such as: - Tendency of researchers to adopt safe and low-risk research strategies (favouring conservative and short-term thinking and penalising more creative and unorthodox approaches) - Tendency to produce irrelevant science (producing publications for career advancement rather than producing advances in science) - Tendency to produce redundant papers (publishing the same data or papers more than once) - Tendency to work on research project that ensure short-term achievements and profitable results - Increasing malpractice - Decreasing reproducibility of scientific data - Undesirable impacts of commercial interests on research quality

It is interesting to notice the convergence between the main outputs of this analysis on the main changes affecting science and the results of an opinion poll (Belluz, Plumer & Resnick, 2016) carried out in 2016 involving 270 scientists about the biggest problems facing science (see the box below).

THE 7 PROBLEMS FACING SCIENCE

The results of an opinion poll about the problems facing science was published in the information website *Vox* on September 7, 2016, on the basis of interviews involving 270 scientists (including graduate students, senior professors, and laboratory heads) from different disciplines and research fields.

Ranking based on the seriousness of the problems is as follows.

1. Academia has a big money problem

Funds, in many fields, are shrinking and the way money is handed out puts pressure on labs to publish a lot of papers, breeds conflicts of interest, and encourages scientist to overhype their work.

2. Too many studies are poorly designed. Blame bad incentives

Scientists are ultimately judged by the research they publish. And the pressure to publish means that scientists often design their studies poorly, to game them so they turn out to be a little more "revolutionary" through specific research decisions and cutting corners in how they analyse their data.

3. Replicating results is crucial. But scientists rarely do it

Scientists tend not to replicate scientific results as they should and, when they attempt to replicate a study, they often find they cannot do so.

4. Peer review is broken

Numerous studies and systematic reviews have shown that peer review does not reliably prevent poor-quality science from being published and frequently fails to detect fraud and other problems.

5. Too much science is locked behind paywall

Many scientific works are not easily accessible, being locked away in paywalled journals, difficult and costly to access.

6. Science is poorly communicated to the public

Lack of appropriate communication approaches leads many laypeople to hold on to completely unscientific ideas or have a crude view of how science works.

7. Life as a young academic is incredibly stressful

Many tenured scientists and research labs depend on small armies of graduate students and Postdoctoral researchers to perform their experiments and conduct data analysis. However, young researchers are poorly paid, work very hard, encounter family problems, and have limited career prospects. This situation tends to disproportionately affect women.

Source: Belluz, Plumer and Resnick, 2016

On the basis of these trends, some considerations can be made.

A. TRANSITIONAL PROCESS

The first consideration concerns the **desirability and acceptance of the transformations**, as well as the fact that the way these transformations are actually managed is still controversial.

Some authors (for example, Benessia et al., 2016) maintain that **science is in crisis**, which manifests itself in different ways (many of them already discussed above), affecting the different components of the science process:

- **Science quality** (e.g., decreasing reproducibility of scientific data, increasing malpractices)

- **Assessment procedures** (e.g., problems of peer-review, abuse of metrics)
- **Reward systems** (the usual systems now producing perverse incentives)
- **Organisation of labour** (increasingly based on a division of labour on an industrial scale)
- **Recruitment mechanisms** (increasingly training people who will never access to permanent positions)
- **Public image of science** (increasingly affected by the science quality crisis)
- **Self-perception of scientists** (from being part of a peer community to being part of an industrialised sector).

It should also be said that the idea of a crisis in science is not at all new (see, for example, Mohr, 1977). However, the present-day crisis does not only concern science as a cultural force (and thus its cultural influence in society), but also science as knowledge-producing institutions (and thus its internal production, regulation and control mechanisms). In other words, science is becoming a **weak institution**, not only in **social and cultural terms**, but also, so to speak, in **technical terms**, i.e., in terms of the functioning of its own technical procedures.

Using a problematic term like "crisis" could be excessive or uselessly pessimistic. However, a **transitional process** is surely taking place, and a growing demand to move towards a new and more advanced equilibrium is also emerging. The EC-promoted consultation on *Science 2.0* (European Commission, 2015) or the programme *Science in Transition*, developed in the Netherlands (Dijstelbloem, Huisman, Miedema & Mijnhardt, 2013), are good examples. Overall, scholars seem to be prevalently worried about this changing picture, although recognising the potential benefits that some changes may have in the future.

B. The Contradictory Impacts of the Proposed Solutions

A second consideration concerns the **different solutions** proposed to manage changes.

As we already observed, various models have been developed in the last two decades (such as Mode 1 - Mode 2, Triple Helix or Academic Capitalism; see Part Two, Para. 1.3.) as drivers for change in research systems. More or less, the proposed solutions tend to overlap on some key orientations for research institutions and researchers, such as:

- Adoption of forms of anticipatory and dynamic governance
- Increased and smoother relations with external actors and the public at large
- Increased engagement with innovation and stronger cooperation with industry
- Higher level of transparency, accountability and self-reflexivity
- Higher capacity to manage the ever-increasing amount of scientific information produced by adopting more advanced ICT technologies
- Boosting trans-disciplinary work and a problem-solving approach.

As shown in the literature review, the adoption of these models or the principle behind them often leads to **unintended consequences** and **side effects** (difficult to prevent and appropriately manage) which affect, to different extents, the activities of research organisations and especially the lives of researchers.

For example:

- The increasing orientation towards the **utility of scientific knowledge** is also, for example, leading to an acceleration in the research process, unsettling the lives of researchers, an extreme segmentation of the research work (with the exploitation of contingent staff, like PhD students and Postdocs) or a decrease in the quality of scientific products
- Making science a **multi-actor process** also entails or may entail a weakening and distortion of research quality assessment practices, a complexification of the management of research organisations or an increase in internal resistance to the openness of research institutions towards societal actors
- Greater **political steering** of science may be accompanied by task diversification and increased competition over accessing funds
- The orientation toward **accountability, transparency and public scrutiny** may lead to an increasing segmentation of research work, greater diversification of the tasks to be performed and an increased complexity in implementing reforms in the organisational and governance structure of research institutions.

In this framework, the introduction of new models or principles may be experienced subjectively by scientists and university managers mainly in terms of the short-term **problematic effects** they bring about (on research organisations, quality of research products, or the lives and professional conditions of researchers), and not their benefits in the long run. This may raise resistance (both active and passive) or open opposition within research organisations.

Therefore, in this picture, it is important to understand the **actual and potential role RRI** can play. In the next part, devoted to RRI, we will try to examine this issue in greater depth.

Part Three

Responsible Research and Innovation

In this section, the focus moves from research and innovation processes to Responsible Research and Innovation. We will try to explore this issue first by analysing RRI from a theoretical perspective (section 1) and then looking in depth at "RRI in action", dealing with methods and especially critical issues connected to its practical application (section 2).

1. Theoretical approaches

1.1. Conceptual RRI models

It is inevitable that an analysis of Responsible Research and Innovation (RRI) will start by noticing the extent to which this notion is becoming popular among policy makers and research communities focused on science and innovation.

Its success is certainly also due to the strong support given by EC to the adoption and spread of this notion. Many of the projects intended to develop theoretically and apply practically RRI policy framework and tools (including FIT4RRI) are directly propelled by EC funds (Kuhlmann, 2016).

However, it could be simplistic and reductive to consider the success of RRI as a mere effect of a political will. Rather, RRI has emerged as a **mobilising concept** (Ribeiro, Smith & Millar, 2017) able to captivate, often for different reasons, the interest of various scientific and policy circles and to interpret needs and expectations of different kinds.

This capacity is also probably due to the fact that RRI, like many other concepts related to science, society and innovation (for example, "Public Engagement", "stakeholders" or "smart technology") is characterised by an interpretive flexibility, making it a buzzword (Bensaude Vincent, 2014) or an umbrella word (Owen, Stilgoe, Macnaghten, Gorman, Fisher & Guston, 2013; Rip, 2016), so it can be used and applied by different (disciplinary and policy) "communities", in principle foster boundary work involving them (Gieryn, 1983).

Precisely this characteristic – which can also be simply interpreted as vagueness and lack of determination – potentially helps RRI to express the **growing interconnections** between science, industry, society, economics and politics (Bensaude Vincent, 2014), as also the **ambivalent status of science** in the post-modern context (considered contemporaneously both increasingly beneficial and increasingly dangerous for society; see Eurobarometer, 2013).

It is, however, also true that the success of RRI (both as policy narrative and practical approach) is much more limited when STEM communities are concerned, which still appear to be little attracted by it (Bensaude Vincent, 2014).

In order to see why, we shall start by discussing the conceptual dimension of RRI.

There is a lot of theoretical literature now available on RRI, and various attempts have been made recently to conduct "meta-analyses" of the different theoretical approaches to RRI. We will consider six meta-analyses, developed respectively by:

- The GREAT Project
- Gwizdala and Sledzik

- Ribeiro, Smith and Millar
- Burget, Bardone and Pedaste
- Glerup and Horst
- Lubberink, Blok, van Ophem and Omta.

A. GREAT PROJECT

A comparison of the major accounts of RRI (those by Grundwald, Sutcliffe, Von Schomberg, the EU, the RRI Expert Group, etc.) has been carried out the Governance of Responsible Innovation project (GREAT, 2013), drafted by DMU, Job Timmermans and Bernd Stahl. The following table contains a summary of the results of the comparison. The different accounts are described on the basis of four items: what is RRI; why it is should be done; how it works, i.e., what is its core mechanism; who is directly involved.

Von Schomberg (2012)	
What	Process by which societal actors and innovators become mutually responsive to each other with a view to the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products
Why	Proper embedding of scientific and technological advances in our society
How	Mutually responsive to each other; transparent and interactive
Who	Social actors and innovators
Owen, Macnaghten & Stilgoe (2013)	
What	Collective commitment of care for the future
Why	Responsibility gap, the nature and impact of consequences of R&I; care for the future
How	Responsive stewardship of science and innovation in the present
Who	Collective
Geoghean-Quinn (2012), reflecting the official position of the EU	
What	Alignment to R&I process and its outcomes to values, needs and expectations of European society
Why	Aligns values, needs and expectations of European society
How	Working together; inclusive and participatory; gender equality and integration; enhancement of educational processes; open, transparent, engagement
Who	All societal actors; research industry; policymakers and civil society
Sutcliffe (2011)	
What	Deliberate focus of research and the products of innovation to achieve a social or environmental benefit
Why	Achieve social or environmental benefit; being mindful of the public good
How	Deliberate focus; openness and transparency; adapt and respond; oversight mechanisms; assessing and effectively prioritising social, ethical and environmental impacts, risks and opportunities; involvement of society; anticipation and management problems; adapt and respond
Who	Society; public & non-governmental groups; civil society stakeholders
Grunwald (2011)	
What	Involving/addressing ethical and social issues in the R&I process
Why	N/A
How	Responsibility reflections; making distribution of responsibility transparent; bridge the gap between innovation practice and a range of other practices; integrative approaches

Who	Ethicists, political and social scientists, philosophers of science, governance researchers, affected natural scientists
Stahl, Jirotka & Eden (2013)	
What	Social construct of ascription that defines entities and relationships between them; meta-responsibility
Why	Socially desirable consequences
How	Defining or producing both entities, i.e., actors and stakeholders in R&I and the relationships between these entities
Who	N/A
Van den Hoven (2013)	
What	Activity or process which may give rise to previously unknown designs
Why	Expand the set of relevant feasible options regarding solving a set of moral problems
How	Outcome of innovation processes and activities
Who	N/A
Expert Group on the State of Art in Europe on RRI (Jacob et al., 2013)	
What	Part of the R&I process; comprehensive approach of proceeding in research and innovation
Why	N/A
How	Obtaining knowledge of and evaluating consequences of R&I; in terms of societal needs and moral values; setting functional requirements for design and development of new research, products or services
Who	N/A

Combining the approaches, the authors highlight some emerging orientations.

- **What is RRI**. Three main accounts are provided about the nature of RRI, i.e.:
  - As a process or, better, a second-order process (especially a governance process) orienting R&I (Von Schomberg, Owen et al, Stahl, Jirotka & Eden)
  - As a requirement to be embodied in the R&I process (Grunwald, EU/Georghean-Quinn, Sutcliffe)
  - As part of the R&I process (Expert group, van den Hoven).

  The contents of RRI largely overlap, i.e. ethical and social issues (or goals) and the alignment of values, needs and expectation of European society. The expected outputs also tend to overlap, i.e., activate innovation process incorporating these contents.

- **Why RRI**. Although differing in their phrasing and terminology, the accounts analysed seem to converge in recognising RRI as «*necessary when taking into consideration the current societal problems mankind is facing or 'grand challenges*». In other words, RRI is understood mainly as an attempt to enlarge the responsibility scope of science and innovation (and scientists and innovators) so as to include the so-called "global challenges" or "societal challenges". In this sense, what is at stake with RRI is the social relevance of science and the recognition of its potential benefits and risks (see, in this regard, Hessels, Van Lente & Smits, 2009).

- **How**. The implementation of RRI is in general connected to a set of requirements which should be incorporated, at different levels, into R&I. Some of them concern the R&I process, which – according to the authors – is expected to be transparent, iterative, responsive, anticipatory, reflexive, deliberative, collective, open, inclusive, participative, integrative and connected to education. Other requirements relate to the goals of R&I, i.e., addressing risks and dilemmas, being ethically acceptable, being socially desirable, producing

social benefits, sustaining fundamental rights, being respectful of moral values and ethical standards, addressing societal needs and expectations, pursuing the co-evolution of science and society, and so forth.

- **Who**. This aspect is the least developed in the different accounts. All them, however, seem to refer to stakeholder involvement, not excluding, in principle, any actor.

B. GWIZDALA AND SLEDZIK

On the basis of a literature review (2017), the Polish economists Jerzy P. Gwizdala and Karol Sledzik have made a comparative analysis of RRI, focusing on its conceptual dimensions. The results of their analysis are summarised in the following table.

DIMENSION	DESCRIPTION	AUTHORS/RESEARCH
Inclusion	Inclusion is a conceptual dimension which can be considered as fundamental for most of the discussions within the RRI area. Inclusion is also associated with all other conceptual dimensions, it engages different stakeholders in the early stages of research and innovation process. When it comes to the discussion of technology transfer and technological issues, it is important not to forget about societal, economic, political and human aspects. Engaging the public stakeholders in early stages of R&D is supposed to positively influence technological development. The example of inclusion in the view of RRI is the Code of Conduct (CoC), which leads various actors to follow the principles of a safe, ethical and effective framework. Many followers of RRI concept see inclusion as the ''ongoing involvement of society'' in various stages of the research and innovation process, without wasting taxpayers' money or time at the same time. Inclusion is the conceptual dimension that characterizes RRI the most.	- Barben, Fisher, Celin & Guston, 2008 - Owen, Macnaghten & Stilgoe, 2012 - Mejlgaard, Bloch, Degn, Nielsen & Ravn, 2012 - Stahl, 2013 - Kearnes, 2013 - Asante, Owen & Williamson, 2014 - Levidow & Neubauer, 2014 - Stahl, McBride, Wakunu-ma & Flick, 2014 - de Saille, 2015 - Bozeman, Rimes & You-tie, 2015 - Burget, Bardone & Pe-daste, 2016
Anticipation	Anticipation is a dimension that aims at envisioning the future of research and innovation. It takes into account understanding how current dynamics help design the future. In research, RRI is also linked to "Real−Time Technology Assessment" or "anticipatory governance". Anticipatory governance includes the technologies which provide value added advantage and, at the same time, avoid the emergence of potentially negative consequences. Successful anticipation means understanding the dynamics of economy that help shape technological futures. Anticipation of potential impacts of technology serves the purpose of: – reflecting on the motivations and implications of a research project, – being clearer about uncertainties and dilemmas,	- Robinson, 2009 - Stirling, 2010 - Selin, 2011 - Roco, Harthorn, Guston & Shapira, 2011 - van den Hove, McGlade, Mottet & Depledge, 2012 - Owen, Macnaghten & Stilgoe, 2012 - Stilgoe, Owen & Macnaghten, 2013 - Stahl, 2013 - Stahl, McBride, Wakunu-ma & Flick, 2014 - Rose (2014) - Burget, Bardone & Pe-daste, 2016

DIMENSION	DESCRIPTION	AUTHORS/RESEARCH
	– opening visions to a broader public, – using the outcomes to shape the research and innovation trajectory. Anticipation plays an important initial role in research and development, indicating the direction to take to achieve better and more desirable results.	
Responsiveness	Responsiveness is linked to risk, which is the probability of an occurrence of an event multiplied by the cost of that event, which new technologies may bring about. The risks involved in new technologies can be medium or long term, economic, environmental, security or societal. In this case, identification and analysis of risks as part of responsiveness is linked to the anticipation dimension. In research, discussions involving responsiveness are also primarily linked to ethics, risks, transparency and accessibility.	- Pellizzoni, 2004 - Owen, Macnaghten & Stilgoe, 2012 - Stilgoe, Owen & Macnaghten, 2013 - Torgersen & Schmidt, 2013 - Schaper-Rinkel, 2013 - Levidow & Neubauer, 2014 - Maynard, 2015 - Burget, Bardone & Pe-daste, 2016
Reflexivity	Reflexivity is linked to public dialogue, science and public collaboration, and anticipation. It can be defined as "holding a mirror up to one's activities, commitments and assumptions, being aware of the limits of knowledge and being mindful that a particular framing of an issue may not be universally held". Responsibility turns reflexivity into a public matter. Involving the public in the research may help researchers reflect on the ethical and social dimensions of their work. Science and public collaboration is a key component of reflexivity. By linking reflexivity and anticipation we can avoid the risk of making wrong predictions, especially in the early stages of technological development.	- Wynne, 1993 - Fisher & Mahajan, 2006 - van der Burg, 2009 - Schuurbiers (2011) - Stilgoe, Owen & Macnaghten, 2013 - Forsberg, Quaglio, O'Kane, Karapiperis, van Woensel & Arnaldi, 2015 - Burget, Bardone & Pe-daste, 2016
Sustainability	Although sustainability issues can be found in most research work, it is not clearly referred to as a dimension. In recent research, sustainability is identified as a key driver of innovation, research and development. Sustainability is already starting to affect the competitiveness concept, which will force organizations and business to change their strategy. Research focused on science, technology and innovation for sustainable development is also conducted in the economic field. Sustainability often refers to the so-called resource-efficiency of new products. Research and innovation are closely connected to social responsibility, because they can implement more sustainable innovations (products) in economy. In general, therefore, it can be concluded that sustainability as a conceptual dimension may form part of Responsible Research and Innovation.	- Wright, Gellert, Gutwirth & Friedewald, 2011 - Flipse, van der Sanden & Osse-weijer, 2013 - de Martino, Errichiello, Marasco & Morvillo, 2013 - Stahl, McBride, Wakunu-ma & Flick, 2014 - Levidow & Neubauer, 2014 - Bozeman, Rimes & You-tie, 2015 - Bremer, Millar, Wright & Kaiser, 2015 - Forsberg, Quaglio, O'Kane, Karapiperis, van Woensel & Arnaldi, 2015 - Burget, Bardone & Pe-daste, 2016
Care	The main challenge of future-oriented ethics is to answer the question of how to deal with uncertainties derived from social practices like technology and	- Groves, 2009 - Stilgoe, Owen & Macnaghten, 2013

DIMENSION	DESCRIPTION	AUTHORS/RESEARCH
	innovation. Care is a "public domain" dimension so that society is responsible for the decisions and actions carried out on its behalf. Care is also explained as a process through which people develop abilities to perceive, act and judge together. What is important, as regards care as a conceptual dimension of RRI, is the fact that it is crucial not to see inclusion just as a means to meet the "grand challenges" but as a way of bringing together people's high objectives and day−to−day practices.	- Burget, Bardone & Pe-daste, 2016
Economic	Concerns about the impact of new technologies on economy and society explain growing calls for the responsible innovation concept, the sustainable transition of social and technical arrangements, and stronger engagement between science-driven innovation and society. Such issues as those related to RRI are better understood as "aspirations" which may never be fully achieved, suggesting they could only be instantiated through the observation of the practice of science-driven innovation. Innovations are not created only for the creation process. Innovations are implemented in the economy and comply with the requirements of meeting needs in terms of value creation for the company, the public and other stakeholders in the process of economic development.	- Schumpeter, 1934 - Rogers, 1962 - Nelson & Winter, 2002 - Geels, 2010 - Owen & Goldberg, 2010 - Garud & Gehman, 2012 - Armstrong, Cornut, Delacôte & Lenglet, 2012 - Owen, Bessant & Heinz, 2013 - Pandza & Ellwood, 2013 - de Saille, 2015

According to the authors, from the analysis of the conceptual dimensions of RRI, it can be seen as «*fundamentally a cluster of ideas for promoting an idea of science governance, which are essentially about responsible processes as opposed to processes that are not supervised responsibly*». In fact, they notice, all the conceptual dimensions refer to a particular type of process.

C. RIBEIRO, SMITH AND MILLAR

A comparative analysis of different concepts of and approaches to RRI has been made by Barbara E. Ribeiro, Robert D. J. Smith and Kate Millar, who discuss two main issues relevant to theoretical considerations on RRI, i.e. the **definitions of RRI** and the **motivations for developing RRI**.

C1. DEFINITIONS

As for the **definitions of RRI**, the most popular is the one developed by Von Schomberg (2011, 2013) and quoted by many authors (such as: Stahl, McBride, Wakunuma, & Flick, 2014; Owen, Macnaghten & Stilgoe, 2012; Douglas & Stemerding, 2013), in which RRI is viewed as «*a transparent and interactive process that spans and acknowledges mutual responsibility across dif-*

ferent actors», which addresses the ethical acceptability, sustainability and societal desirability of R&I. This view of RRI leads to a focus on the "right impact" of R&I (Von Schomberg, 2011).

Owen, Machnagthen and Stilgoe (2012) share this same interpretation of RRI, according the authors, albeit emphasising the notion of "**shared responsibility**" among actors, so as to make R&I pathways more responsive in face of uncertainty. As a consequence, RRI emerges as a process aimed at «*taking care of the future through collective stewardship of science and innovation in the present*» (Stilgoe, Owen and Macnagthen, 2013).

Ribeiro, Smith and Millar also notice that other authors (for example, Guston & Sarewitz, 2002; Pidgeon, Parkhill, Corner & Vaughan, 2013) added to this definition with a focus on **appraisal processes**, which need to be embedded in R&I, to evaluate the worth, impacts, unintended risks and ethical implications of new knowledge and technologies. As a consequence, in addition to early-stage appraisals of potential impacts and ethical implications of emerging technologies, RRI also started to include the ideas of **anticipatory governance** and the **involvement of different actors** in the process (Robinson, 2009; Shaper-Rinkel, 2013, Zwart, 2013), thus fostering the notion of **anticipatory dialogue** to modify R&I trajectories (Rose, 2014).

Another component which comes into play in this conceptual framework is **interdisciplinary collaboration** involving STEM disciplines, social sciences and humanities (van der Burg, 2010; Schuurbiers, 2011; Flipse, van der Sanden & Osseweijer, 2014).

C2. MOTIVATIONS

With reference to the **motivations for developing RRI**, two emerging lines of argumentation are identified by Ribeiro, Smith and Millar.

The first line is focused on the **risks** posed by technology development on the environment and society, which in principle can be anticipated before technologies are fully developed (Owen, Baxter, Maynard & Depledge, 2009; Robinson, 2009; Schaper-Rinkel, 2013; Stahl, McBride, Wakunuma & Flick, 2014).

The second line aims at changing societal and environmental **governance from reactive to proactive forms**, by focusing on the alignment of innovation processes to social expectations and needs (Betten, Roelofsen & Broerse 2013; Rose, 2014; Zenko & Sardi, 2014).

In both cases, the **engagement** of stakeholders and the public is part of the narrative, viewed as necessary to evaluate technologies and embed them socially, countering the tendency towards expert-driven processes (Stahl, 2012) by supporting the participation of societal actors in technology development.

Other motivations include the promotion of **democratic governance** for R&I, fostering an integrated, participatory, reflexive and responsive process vis-à-vis the **uncertainties** and co**nsequences** of R&I and extending the notion of responsibility so as to make it a **collective care duty** (Owen, Macnaghten & Stilgoe, 2012; Stilgoe, Owen & Macnaghten, 2013).

To sum up, in the **definitions of RRI**, the main components are:

- Being an interactive process addressing the ethical acceptability, sustainability and societal desirability of R&I

- Fostering among actors a shared responsibility of R&I
- Oriented to anticipate the future intended and unintended impacts of R&I
- Thus, including early-stage appraisal of such impacts, and
- Grounded in interdisciplinary collaborations.

As for **RRI motivations**, they overlap with the components found in its definitions, i.e.:

- Preventing and promptly managing the risks of R&I
- Aligning R&I to social expectations and needs through proactive governance
- Supporting societal actors in participating in technology development, so as to foster a democratic R&I governance and rendering responsibility on ER&I a collective duty.

D. BURGET, BARDONE AND PEDASTE

Mirjam Burget, Emanuale Bardone and Margus Pedaste (2016) also conducted a literature review in order to identify **definitions** and **conceptual dimensions** of RRI.

D1. DEFINITIONS

With respect to **definitions**, the authors (following Zwart, Laurens & van Rooij, 2014) make a distinction between **administrative definitions** (developed by science policy makers and funding agencies, especially EC-related entities) and **academic definitions** (developed by scholars).

As pointed out by Sutcliffe (2011), **administrative definitions** tend to include the following:

- **Focus of research and innovation** to achieve social or environmental benefits
- Consistent, ongoing **involvement of society** (including the public and non-governmental stakeholders), from beginning to end, of the innovation process
- Assessment of and priority given to **social, ethical and environmental impacts, risks and opportunities**, both now and in the future, alongside the technical and commercial impacts
- Oversight mechanisms so as to **anticipate and manage problems and opportunities** and to react quickly to changing knowledge and circumstances
- Openness and transparency as part of R&I.

More or less, all these components are included in the definition of RRI developed by Von Schomberg (2011), which is one of the most widely used. This definition, in fact, includes inclusiveness, participation, anticipation, societal desirability and ethical acceptability.

As noticed by some authors (Levidow & Neubauer, 2014; Stahl, McBride, Wakunuma & Flick, 2014), this concept of RRI has been mainly developed in order to **open up a broader policy** prospect capable of redefining actors' roles in society. Von Schomberg (2013) also speaks of RRI as a "**design strategy**" for steering innovation towards socially desirable goals. Similarly, in another European Commission policy document (2013b), RRI is viewed, not as a process, but as an **approach** aimed at orienting R&I.

As for the **academic definitions**, most of them, according to Burget, Bardone and Pedaste, share the same components identified in Von Shomberg's account of RRI. However, the academic definitions seem to distinguish better RRI **levels of analysis**, such as products, process and purposes (Stilgoe, Owen & Macnaghten, 2013) or actors, activities and norms (Stahl, 2013), focusing not only on collective but also on **personal responsibility** in the research and innovation process (Wilford, 2015). The **scope of RRI is also narrowed**, not including the entire innovation process but only its quality, measured in terms of desired outcomes (Spruit, Hoople & Rolfe, 2015).

D2. CONCEPTUAL DIMENSIONS

Burget, Bardone and Pedaste also analysed different conceptual dimensions of RRI, starting with those proposed by European Commission (public engagement, gender equality, science education, ethics, open access and governance), and then other dimensions which were originally not associated with RRI (such as liability, accountability, care, responsiveness) or which emerged from the public debate on RRI, often overlapping (such as transparency, sustainability or reflexivity).

At the end of the analysis, **four major dimensions** were selected by Burget, Bardone and Pedaste as the most significant for RRI, i.e., **inclusion**, **anticipation**, **responsiveness** and **reflexivity**.

Inclusion mainly refers to the engagement of different stakeholders in the early stages of research and innovation, thus defining a moral obligation for everyone «to engage in the collective debate that shapes the context for collective decision making» (Von Schomberg, 2007). This also implies the need to define the outcomes which are socially desirable. This, in turn, can be achieved only through public involvement, which becomes a sort of technical requirement for implementing RRI. According to Burget, Bardone and Pedaste, «*Inclusion is the conceptual dimension that characterizes RRI the most*» and «*a major characterizer of RRI needs more reflective and critical academic discussion*».

Anticipation means envisioning the future of R&I and understanding how current dynamics help design the future. This dimension is closely linked to governance and, in fact, various authors (e.g., Robinson, 2009; Karinen & Guston, 2010; Schaper-Rinkel, 2013, Stahl, 2013), refer to this dimension as "anticipatory governance". Anticipation emphasizes the importance of being aware of the motivations and implications of a research project, as well as the uncertainties and dilemmas connected to it and the need for opening up to the public and shaping R&I trajectories, so as to finally promote a "desirable application" (Edelenbosch, Kupper & Broerse, 2013) of scientific knowledge.

Responsiveness, originally introduced by Pellizzoni (2004), is mainly linked to the proactive management of medium or long term economic, environmental or societal risks involved in new technologies. This implies a capacity to identify related risks (in this sense, responsiveness is connected to anticipation) and develop adequate responses, in ethical terms, too. According to the authors, responsiveness also relates to transparency (responses should be open to the public debate) and accessibility (scientific results about risks and responses should be openly accessible to everyone). Responsiveness is found considerably less often in the articles reviewed by Burget, Bardone and Pedaste.

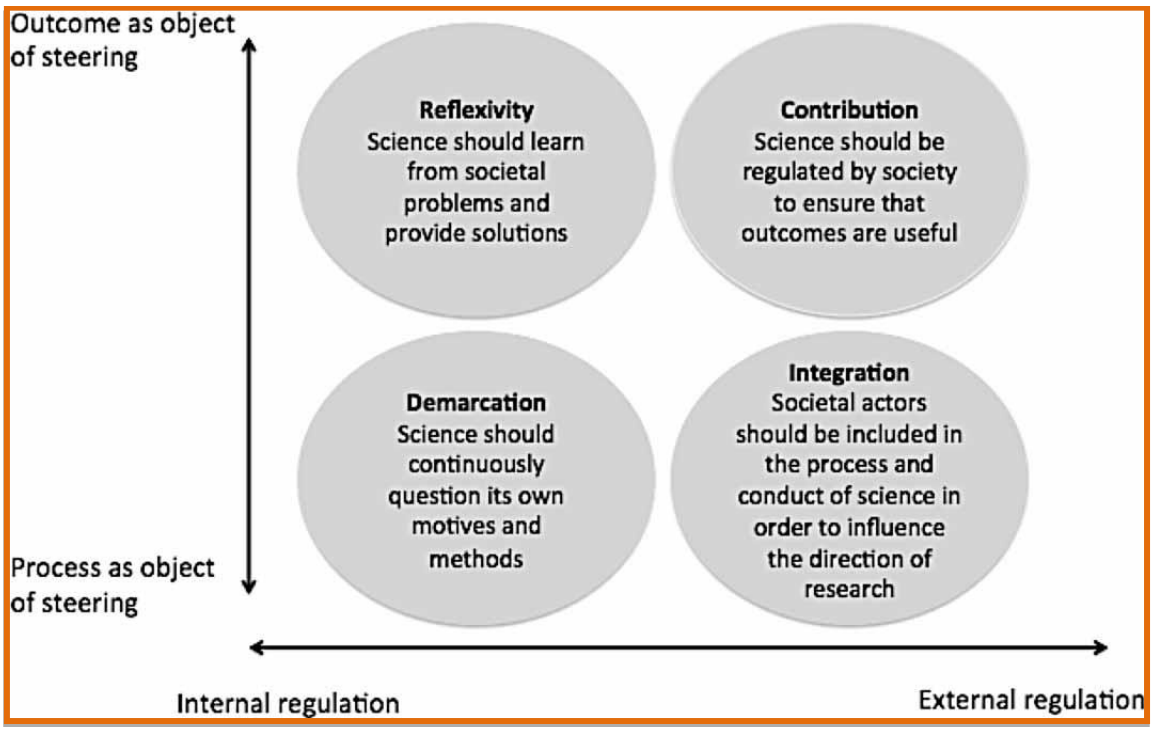
Finally, **reflexivity** is mainly seen as the capacity of the research system to keep control of its own activities and assumptions, to be aware of the limits of the knowledge produced and of the framing processes connected to the identification of the issues to be addressed, as well as to reflect on values and beliefs connected with R&I (Stilgoe, Owen and Macnagthen, 2013). Reflexivity is linked to public dialogue and collaborative approaches in science (Fisher & Mahajan, 2006; Van der Burg, 2009; Schuurbiers, 2011; Stilgoe, Owen & Macnagthen, 2013), dialogue and collaboration being the two main weapons to combat research systems which are self-referential and closed to external inputs.

Burget, Bardone and Pedaste also identify two **emerging conceptual RRI dimensions**: **sustainability** (which mainly concerns control over the use of resources); and **care** (which refers to the capacity of people to play an active role in R&I).

E. GLERUP AND HORST

Cecile Glerup and Maja Horst (2014) also conducted a literature review based on 263 contributions to academic journals about "social responsibility" in science, with the specific aim of identifying the various "**rationalities**" that have been conceptualised about responsibility in science.

The analysis can be summarised in the form of a matrix, based on two dimensions, the first describing whether regulation of science should be internal or external and the second whether issues of responsibility relate to the process or to the outcomes of science. The resulting matrix can be seen below.



(From: Glerup & Horst, 2014)

Demarcation rationality mainly focuses on the research process in a context of internal regulation. It is based on the recognition of science as an «*honourable profession*», but «*increasingly*

tormented by fraud and misconduct threatening its ability to do good for the people». This rationality tends to connect fraud and misconduct to the increasing pressure placed on scientists to get results and deliver publications (Brice & Bligh, 2005) which in turn may lead to an increase in public mistrust of science. According to demarcation rationality, the solution is to reinforce the moral code covering almost every domain of science, including data management, conflicts of interest, authorship, peer-review or collaboration, so as to create a moral culture favouring the use of a strict scientific method.

Reflexivity rationality mainly focuses on research outputs in a context of internal regulation. Differently from demarcation rationality, science is here seen as fully involved in the solution of societal problems but scientists as not fully aware of the risks and wrongs produced by science. Thus, changes need to be made to the scientific profession, so that scientists are able to foresee and manage the consequences of their own scientific activities, incorporating these considerations in their research. Reflexivity rationality considers scientists socially responsible, self-aware of being part of society and prepared not only to produce high-quality scientific products (as in demarcation rationality) but also to oversee and reflect on the consequences of their own practice.

Contribution rationality also focuses on research outputs but in a context of external regulation. This rationality considers science as a societal institution (like any other institution, such as healthcare or education systems) pursuing specific goals for the benefit of society. Especially, science is asked to match the demand for innovation (contributing to economic growth) and the demand for democracy (aligning scientific activities to the needs and preferences of society). In this framework, scientists are understood as «*public servants working to materialize the objectives of society in their knowledge production*»; and problems arise precisely because of the tendency of scientists not to perceive themselves in this way, since they are not interested in the use of the knowledge they produce and they have been allowed to cut themselves off from public inquiry and criticisms. The solution, then, is to get scientists to be more responsible, preferably of their own accord but above all by increasing public control over science, at different levels and with different tools.

Integration rationality focuses on the research process in a context of external regulation. Under this rationality, science and society are asked to work together, as equal partners, to produce better results. This partnership should include all the different aspect of research activities, starting with the definition of societal objectives up to the use of scientific knowledge, with a view also to preventing the possible negative side effects of science. This entails enhancing dialogue between scientists and other actors to develop a new kind of "integrative" responsibility across roles and specialisations, thus favouring scientific knowledge which is socially contextualised and aligned with societal norms and values.

F. LUBBERINK, BLOK, VAN OPHEM AND OMTA

Another literature review addressing the dimensions of RRI was carried out by Rob Lubberink, Vincent Blok, Johan van Ophem and Onno Omta (2017), which turns around the concept of responsible innovation, their interest being focused on the business sector rather than on research itself.

The literature review led to the identification of four main dimensions of RRI, which, according to the authors, can be used heuristically for anticipatory governance of innovation, i.e., anticipation, reflexivity, inclusion/deliberation, responsiveness.

Anticipation «*involves systematic thinking about any known, likely, plausible and possible implications of the innovation that is to be developed*», so innovators need to understand the dynamics shaping innovation and envision desirable futures.

Reflexivity refers to a critical scrutiny of one's own activities, commitments and assumptions, including an awareness of the limits of knowledge. For innovators, also important is reflexivity focused on the influence of their own values and beliefs on the development of the innovation.

Inclusion/deliberation are concepts widely used in literature on RRI. They involve the upstream engagement of stakeholders and the public to identify and manage the social, political and ethical implications of innovation. The two terms – inclusion and deliberation – can be considered as interchangeable, even though those who use "deliberation" tends to emphasize the link between RRI and decision-making.

Responsiveness concerns the capacity to change the shape and direction of innovation on the basis of the values and needs of stakeholders and the public. Moreover, responsiveness implies a collective response and therefore co-responsibility of innovation.

1.2. Empirical models of R&I governance

An aspect related to the theoretical approaches to RRI are those that can be labelled "**empirical models of R&I governance**". In the framework of this literature review, this concept is used to include any attempt to identify governance models of R&I actually used or claimed by the concerned actors and therefore not developed by the authors.

We consider these models to be of a theoretical nature insofar as they are developed on the basis of theoretically-based categories or interpretations of RRI.

Five typologies will be analysed, developed by:

- the EC Expert Group on science governance
- Landeweerd, Townend, Mesman and Van Hoyweghen
- Ruggiu
- Felt
- GREAT Project.

A. EXPERT GROUP ON SCIENCE GOVERNANCE

The European Commission Expert Group on science governance, chaired by Brian Wynne and with Ulrike Felt as rapporteur (2007) offered some reflections on the governance of innovation, which may be useful to repeat while discussing RRI.

The authors identify **two main regimes of innovation** (i.e., a model or a "notion of how things must be done") in the policy discourse, called respectively by the authors the **Regime of Economics of Technoscientific Promises** and the **Regime of Collective Experimentation**.

The **Regime of Economics of Technoscientific Promises** is based on a set of assumptions, i.e.:

- If appropriately funded, new technologies can solve human problems
- Our future is increasingly uncertain and uncertainties can be solved through upstream solutions based on innovation
- Europe will only be able to sustain its social model in a context of increasing world competition by boosting innovation
- Scientists and technologies require intellectual property rights to be safeguarded at an early stage, thus fostering new relationships between research, higher education and industry and emphasizing patenting of basic knowledge.

On the basis of these arguments, industrial and scientific entrepreneurs are viewed as performing a pivotal role in innovation and especially in creating the conditions for raising expectations and building "technoscientific promises". Governments and governmental agencies play an ambivalent role, promoting specific interests around the technoscientific promises, taking, at the same time, public interest into account.

The general culture is one of celebration of innovation, requiring civil society not to interfere. Citizens are, in fact, considered not directly involved in innovation but "*happy customers*" of technologies and "*citizens profiting from the European social model*" made sustainable through innovation, while civil society is seen as an outsider, to be taken into account but irrational, prone to irrational fears and monitored by opinion polls

The **Regime of Collective Experimentation** focuses on the idea that innovation is not based on techno-scientific promises but on goals constructed around matters of concern. The assumption is that the participation of a variety of actors is productive, albeit depending on the effort each of them makes.

In such a regime, new forms of interaction between scientists and other actors need to be devised, since the traditional authority of science is not sufficient. Moreover, selective forms of participation should be identified, since what is important is engagement in the experimentation of new solutions, not by the public at large but only the groups concerned. Under such a regime, innovation is likely to become laborious, loosely-coordinated and slow. Moreover, opportunistic behaviours may also occur, whereby people and stakeholders may wait for others to take the risks involved in new experiments.

Although alternative, **both regimes**, according to the authors, are part of the overall trend to recognise **open or distributed innovation**, i.e., the idea of an innovation emerging from the interaction of actors holding complementary pieces of knowledge, thus creating networks or creative communities, able to cooperate in prevalently informal ways and to co-construct and use new technologies.

B. LANDEWEERD, TOWNEND, MESMAN AND VAN HOYWEGHEN

Laurens Landeweerd, David Townend, Jessica Mesman and Ine Van Hoyweghen (2015) identify three main styles in the management of R&I: a **technocratic** style, an **applied ethics** style and a **public participation** style.

The **technocratic style** is dominant. It includes two main aspects of technical regulations. On the one hand, scientists and technologists are given the responsibility, by political powers, to assess the acceptability of risks for society. On the other hand, law and lawyers play the role of framers of governance procedures (e.g., providing suggestions about legal frameworks, self-regulations or new regulations). The focus is on risks and risk assessment and not on ethical issues or other criteria to be potentially used to assess whether a new technology deserves to be developed or not. The technocratic style sees scientific experts as neutral, rational and well-informed and the public as irrational and potentially biased because of a lack of knowledge. This style is mainly linked to "governing" (top down and centralised) as opposed to "governance" (bottom-up and decentralised). The main instrument is the law, viewed as effective and neutral, capable of setting up national or international reference frames (e.g., rights declarations, agreements, etc.) which can be translated into technical tools (e.g., codes of conduct, regulations, laws, etc.) for the structuring of R&I.

Various **deficiencies** in the technocratic style have been highlighted.

- Political decisions are reduced to technical decisions; and this does not work in practical terms since any decision includes a normative side.
- The technocratic style is too narrowly focused on risk assessment and incentive management, while other factors enter into play in the public acceptance of science and technology (for example, attitudes and cultural choices such as techno-scepticism, environmentalism, naturalness, religious orientations, etc.).
- Technocratic style considers societal dynamics only as triggered by products, while increasingly they start being visible upstream of the development chain.
- The pace of science and technology is often too rapid for legal frameworks and ethical discourse to be quickly adjusted.

The **applied ethics style** of governance is based on the positioning of ethical considerations at the core of the governance of science and innovation. Ethics, thus, comes to be institutionalised as a normative instrument placed at the basis of law and regulation, and viewed as a neutral normative tool. The increase in the relevance of this governance style can be also observed in the inclusion of ethical reviews in the evaluation of research applications (as in the case of the "Science in Society" programmes), in the creation of ethical committees inside research institutions, or in the incorporation of ethical experts at different levels of R&I process.

The main **deficiencies** of the applied ethics style are as follows.

- The directly involvement of ethics as a normative instrument led to the criticism that such an approach ends up being the "handmaiden" of science and technology rather than a critical observer or assessor of the impacts they create. In general, the institutionalisation of ethics is seen as problematic.

- There is a gap between moral principle and moral practice. Once ethics is institutionalised, this gap becomes evident and difficult to manage. The risk is that applied ethics becomes increasingly focused on the delimitations of the moral debate and not on its contents.
- The use of a specific "ethics expertise" is not fully justified, given that it is not clear why an expert view would be more reliable than a lay opinion.
- Ethics also risks becoming fully involved in the process as an institutionalised party among the other involved actors. Therefore, its independence may be put at stake when it is too embedded in science research projects.
- The use of applied ethics does not guarantee ethics advice actually being used. In many cases, ethical orientations and recommendations are not implemented.
- Ethics is too focused on intentional individual agency to also be effective in detecting the ethical and social (often unintended) effects of R&I.

The **public participation style** of governance is emerging as an effect of a loss of trust in science, technology, politics and "top-down" governing. It is based on bottom-up activism aimed at orienting decision making by values, including transparency and democracy. This style emerges in the multiple attempts to increase public participation by using different and multiplying Public Engagement approaches, formats and tools, justified on the recognition of participation as necessary both for exercising basic human rights and, instrumentally, for preventing protest against unpopular policies. Moreover, deep knowledge of public opinion helps policy makers and scientists enhance the success rate of innovation processes. More recently, public input starts being increasingly incorporated in national and international governance in formal or informal ways, including technology assessment, even though practical adoption is often viewed critically.

As for the **deficiencies** of the public participation style of governance, the authors highlight the following.

- Public participation suffers from a lack of evidence and empirical consideration over its quality and impact.
- It is not clear to what extent people who participate in Public Engagement initiatives are actually representative of the public at large or of specific parts of it. This fact calls into question the democratic legitimacy itself of participatory mechanisms.
- The ways in which public participation is interpreted and actually practised largely varies according to country and political culture.
- Public participation is exposed to the risk of legitimating self-selection processes (only those who wish to participate actually participate).
- There is the risk of taking any NGO or interest group as representative of the complex and multifaceted public.
- Public engagement formats and mechanisms are pre-formatted by specific political actors and through agenda-setting processes and, therefore, may be used for the benefits of specific actors.
- Public engagement may be also instrumentally applied to de-politicise science and technology, preventing protests and major tensions, and not to actually increase participation in shaping science policies.

The authors see **Responsible Research and Innovation** as a possible **fourth style of governance** of R&I, combining different stances, including the focus on the social and environmental benefits of R&I, the involvement of society at any level of the innovation process, the assessment and prioritisation of social, ethical and environmental risks, impacts and opportunities, both now and in the future, the role of anticipatory and management mechanisms in shaping R&I trajectories and the recognition of openness and transparency as components of R&I.

However, also in RRI the authors see possible deficiencies and risks, including that of allowing private interests to prevail, interpreting needs and desires of the public as mere consumer preferences or limiting the weight of ethical considerations pertaining to R&I.

C. RUGGIU

Daniele Ruggiu (2015) identifies two different versions of the RRI model: the **social-empirical version** and the **normative version**.

The **social-empirical version** is focused on the social dimension of participatory R&I and, therefore, on interaction processes among different stakeholders engaged in the development of participatory forms of co-responsibility.

In this version, Public Engagement plays a strategic role but it is also viewed in its empirical limitations, prevalently due to the difficulty of adapting participatory processes to the fast development of R&I. In fact, according to Ruggiu, there is a paradox concerning participation and R&I development processes: either participation occurs too early, at the beginning of the process, when it is possible to shape R&I trajectories but information about risks and opportunities are limited, or it occurs too late, when information about risks and opportunities are available but the possibilities to influence the R&I process are limited.

In this social-empirical version, the focus is not only on the products, but also on the purposes of innovation, especially understood in connection with the kind of future expected and the values we want it to be anchored on. Stress is also placed on the equal engagement of all societal actors, considered as an important factor for building a sound framework for excellence in the R&I process and for giving a voice to all represented interests. In this sense, the sole existing value to be preserved is precisely the negotiations leading to the creation of the values on which R&I should be anchored. For this reason, this version of RRI is not normative since it focuses on the deliberative process necessary to produce values and not on the values in themselves, nor does it define prefixed rules and principles to go by. This is the reason why this version can be defined as “empirical”, since principles and rules come not at the beginning but at the end of the participatory/deliberative process.

The **normative version** is, on the contrary, focused on the normative dimension of participation. It is focused on the aim of articulating «*processes of stakeholder co-responsibilisation around a set of normative filters by being simultaneously anticipatory and participatory*». These filters are primarily looked for in EU law, as factors steering EU policy towards anticipatory, participatory and responsible outcomes. Therefore, EU objectives are viewed as “normative anchor points” connecting R&I to EU treaties, thus providing RRI with a solid foundation and EU treaties with concrete opportunities for them to be implemented.

According to Ruggiu, using EU objectives to orient RRI may produce ambiguities. For example, one may agree on EU objectives in general but disagree on the meaning attached to them or on their application in concrete situations. Moreover, tension among them can also emerge when they are used as "normative anchor points".

While the social-empirical version of RRI considers values as intrinsically conflictual, especially in the context of the moral pluralism we live in, the normative version addresses very general values, referring to the interests of civil society and expressed in a rather bureaucratic manner (safety of products, individual rights, protection of health, growth of occupation, etc.).

D. FELT

Ulrike Felt (2016) analyses the dominant "narrative infrastructures" of science and science-society relations, whereas the concept of "narrative infrastructure" refers to a network of narratives «*through which meanings and values of academic knowledge/work and its relation to society can be articulated, circulated and exchanged across space and time*».

Felt identifies **three main narrative infrastructures**.

The **first** focuses on the idea of a substantial **reorganisation in the research system** – often subsumed under the label of new public management – which is expected to increase research organisation outputs and efficiency, as well as support the expectation of ever-faster innovation. On the whole, these narratives favour the establishment of auditing and ranking structures aimed at measuring research quality and outputs and making comparative assessments. In this context, researchers are induced to internalise self-auditing criteria and behaviours. This narrative infrastructure reflects an overall "projectification" of the research work (Ylijoki, 2015), leading to a radical change in the way research is organised and research time is structured (expressed also in the use of terms like "work packages", "deliverables" and "person months"). Overall, this narrative infrastructure is marked by the "obsession" to control and plan the future and pushes researchers into becoming entrepreneurs, who can promote themselves according to the logic of academic capitalism.

The **second cluster** of narratives revolves around the idea of "**reflexive work**". Under these narrative, researchers are expected to reflect on and anticipate potential impacts of their research and to get involved in engagement or, at least, communication activities with other societal actors concerned, with the aim of preventing or managing possible emerging problems. These narratives are now increasingly subsumed under the label RRI. This narrative infrastructure tends to expand the scope of researchers' action up and including the care of the infrastructure supporting academic life, the fulfilment of their civic mission, the care of services addressing communities and engagement with citizens.

The **third cluster** of narratives emerges from the backdrop of tension between the first two sets of narratives calling for auditable and reflexive work respectively. This cluster refers to the **past conditions of academic work**, with its rituals and mythical structures, in which researchers were freer in their research choices, had less time to spend on doing administrative work or selling their findings. This narrative infrastructure is a form of "inventing a tradition", in which the past is depicted as a sort of "golden age" for scientists when there was less time pressure and academic careers were still attractive. This fosters an "academic nostalgia" through which researchers try to feel a sense of continuity and stability in a fast-changing environment.

According to Felt, the **interaction between the three sets of narratives** is problematic, since the first promotes an individual ethic, the second emphasizes a collective ethic, while the third emerges as a form of resistance to both of them.

Finally, the author dwells upon **two risks concerning the implementation of RRI**, prevalently linked to the second set of narratives. On the one hand, there is the risk of translating reflexive work into specific standardised forms which make it a purely formal requirement (as has often happened in the case of some ethical requirements, such as informed consent in the medical sector). On the other hand, there is also the risk of ritualising reflexive work through specific procedures producing the effect of separating research and reflection, especially by entrusting the former to STEM researchers (who keep on working in a business-as-usual manner) and the latter to social scientists or experts in ethical issues.

E. GREAT PROJECT

In the framework of the GREAT Project (2014), Sophie Pellé and Bernard Reber offer a reflection on RRI starting with a **typology of technology governance** developed by Pierre Benoît Joly (2001) and inspired by Michel Callon (1998). This typology includes four models: the **Standard Model**, the **Consultation Model**, the **Revised Standard Model** and the **Co-construction Model**.

The **Standard Model** views the public as irrational because of their lack of comprehension of technical matters and aversion to novelties and risk, and scientists as rational, neutral and capable of objectively assessing risks. In this model, of a positivist nature, the purity of expertise should be preserved by not mixing facts (science) and values (public) and should be kept independent from any political, economic and social influence.

The **Consultation Model** keeps the opposition between an irrational public and expert rationality, but changes the way in which risks are managed. While in the previous model, only experts are supposed to be able to identify risks (and communicate them to the public), in the consultation model, risks can be correctly perceived both by experts and by laypeople, even though from different perspectives. Hence the need for a two-way communication process to identify risks and for the public to participate in decision making processes to manage them.

The **Revised Standard Model** sees the management of risks as a complex process involving various social groups in the public arena. Thus, the emphasis is placed on the interactions between regulation processes, social groups and media and on the paradoxes and hindrances which characterise them, including the public's overestimation of risks, the media's tendency to create an uncertain environment around risks or the incapacity of decision makers to produce effective laws. In this model – which relies upon a technocratic vision – core elements include the delegation of risk management to independent and competent administrative bodies, the distinction between risk assessment and risk management, the need to analyse risks not abstractly but in context, and a view of trust as based on reputation and perception of competence in managing risks.

The **Co-construction Model** adopts a social constructivist approach and calls into question the traditional image of science as based on universal independent truths. In this model, both facts and values are to be equally considered and risks are to be identified through participatory processes involving all the actors concerned.

According to the authors, RRI approaches fall under the consultation and the co-construction models. On this basis, they develop two different RRI models, taking into account five elements: the process of norm construction (substantive vs procedural); the ethics approach; the role of participation (as consultation or co-construction); relation to knowledge (rationalistic vs explorative); and degree of reflexivity (identification of ethical issues vs attempt to open the framing).

RRI Model 1 (Responsibility grounded in social acceptability) supports both substantive and procedural methods of norm production, substantive methods in that the model relies upon the existing (especially EU) rules, procedural methods in that it also includes practical norms to be incorporated in the "responsiveness" dynamic. The ethics approach is primarily consequentialist (acts are right to the extent that they produce good results and wrong to the extent that they produce bad results) and largely based on technology assessment and technology foresight. Participation is mainly understood as a consultation process (even though some forms of deliberation are sometimes evoked) aimed at favouring the social acceptability of new technological products, testing their social desirability and preventing costly market failures. As for the relation to knowledge, this approach adopts a rationalistic framework (although the unpredictability of many technology outcomes is acknowledged), while reflexivity is understood as merely aimed at identifying key ethical issues, i.e., a list of problems to be watched and answered (thus establishing a deterministic relationship between ethical issues and technology).

RRI Model 2 (Responsibility through responsiveness and deliberation) supports a procedural determination of norms, aims at achieving a co-construction of technology, relies upon anticipatory governance and explorative philosophy as normative tools, and promotes a relation to knowledge which is not purely rationalistic and consequentialist, but one in which the power of imagination and narratives of the actors involved are recognised. Finally, reflexivity is applied, not only on the substantive aspects of the debate (i.e., on the solutions), but also on how the problems are constructed.

1.3. RRI implementation models

In this section, we consider the literature on pathways (roadmaps, methods, principles, etc.) aiming at embedding RRI in R&I governance.

Six main proposals are considered, respectively developed by:

- Res-AGorA Project
- the EC Expert Group on the State of Art in Europe on Responsible Research and Innovation
- Stahl, Obach, Yaghmaei, Ikonen, Chatfield and Brem
- MATTER
- Jirotka, Grimpe, Stahl, Eden and Hartswood
- RRI Tools Project.

A. RES-AGORA PROJECT

In the framework of the Res-AGorA Project, Sally Randles, Sally Gee and Jakob Edler (2015), identify thirteen lessons on «*the effectiveness of a range of governance instruments and institutionalization processes to achieve the embedding of Responsible Research and Innovation*». These lessons can be viewed not as part of an RRI governance model but as components of an RRI-oriented governance process.

1. Responsibilisation and deep institutionalisation. The first lesson helps define the key goals of the entire process, i.e., activating a process of actor responsibilisation to internalise social values and apply these values in regulatory practices, inducing profound organisational and cultural changes favouring the embedment of these values into taken-for-given practices, routines and institutions.

2. Transformative interaction needs to be inclusive, open and transparent. This second lesson highlights that for interaction among actors to be transformative, it requires the adoption of a set of approaches, some of a technical nature, to make it inclusive (i.e., able to include the diversity of actors involved), open and transparent. This entails, for example, preparatory work, adequate process management, tools for encouraging the mobilisation of marginalised groups or capacity building processes.

3. Intermediation and moderation. Another lesson is that RRI governance needs intermediation and moderation, given that direct interactions are not always reasonable or feasible, because of a clash in interests and values, for example, or contrasting perceptions and framings, or limited willingness or ability to communicate. Intermediators must be credible and their functions and own interests transparent.

4. Anticipation. To be implemented, RRI needs to rely upon a set of anticipatory techniques and methods making, it possible to identify future scenarios, technologies and challenges.

5. Robust, inclusive and contextualised knowledge. The fifth lesson emphasizes the importance of underpinning the RRI governance process on robust and trusted knowledge, especially in consideration of uncertainties characterising the present and future development of R&I practices and products. Moreover, knowledge needs to be contextualised, by demonstrating that it is, on the one hand, valid in the specific and social condition of a given location and, on the other hand, potentially reproducible for any different local conditions.

6. The importance of time, timing and managing tensions of different temporal horizons. This lesson is about the need, for any governance process, to take into account the different dimensions of time (time horizons, timing of governance action, time needed to induce institution change, etc.) but also to balance the imperative for R&I to move fast (to promote use in economic and social terms) with that to move slowly (to promote deeper normative and behavioural changes).

7. Multi-level governance. This lesson concerns the importance of taking account of multiple levels of governance, including political levels (city, nation, EU, etc.) and hierarchical levels within the organisation. Multi-level governance also concerns the need to manage, balance and seek synergies between top-down and bottom-up processes.

8. Alignment. In this lesson, attention is given to the need to align and synchronise normative goals, objectives and procedures of different instruments and measures, across levels and through effective co-ordination mechanisms.

9. Boundary objects. Multi-level governance and alignment also require the recognition of the intermediary role played by boundary objects, i.e., objects of any nature (data, specimens, materials, etc.) which, by virtue of their interpretive flexibility, can link different groups of researchers and stakeholders.

10. Institutional change. Another important aspect is that RRI should be able to activate long-term changes in institutions at any level (regulative, normative and cultural-cognitive), modifying rules, routines and organisational forms. It is, however, important to be aware that institutional changes involve parallel processes to de-institutionalise the existing patterns, which usually triggers resistance, reactions and tensions.

11. Capabilities. RRI entails capability-building processes across the R&I spectrum encouraging and enabling the formation of reflexive actors that can participate fully in RRI processes.

12. Capacities. This lesson focuses on the need to guarantee resources (financial, organisational, and social and human capital) and adequate means (new institutions, new incentives structures, etc.) to create the conditions for responsibilisation processes.

13. Institutional leadership and entrepreneurship. This lessons concerns «*the enabling of key actors, groups, organisations and wider society to create spaces, resources, and support for values-driven institutional entrepreneurialism*» in RRI, at the level of key actors and champions, at the middle-management level in organisations, and at the level of organisational culture.

B. Expert Group on the State of Art in Europe on Responsible Research and Innovation

The Expert Group on the State of Art in Europe on Responsible Research and Innovation, established by the European Commission (2013b), delivered a report aimed at identifying policy options for strengthening RRI at European level.

Four scenarios were presented, developed and discussed, each based on a specific option.

B1. Business As Usual (Option 1)

In this scenario, the future approach to RRI in EU funding programmes does not change, nor are additional funds envisaged. The main trends in this scenario are: RRI standards remain scattered; no attempt will be made to coordinate the different national approaches towards RRI, while industry will move more and more towards international standards (for example, Corporate Social Responsibility as it is coded under ISO 26000).

B2. Improved Business As Usual (Option 2)

This scenario is based on the option of increasing the funding of RRI activities. Three main actions are included in the option.

Action a. is aimed at mainstreaming RRI in the EU funding programme, in order to raise awareness of RRI, creating incentives to apply RRI, restructuring research proposal evaluation processes, and including the consideration of RRI into research funding for training activities.

Action b. is aimed at increasing the share of funding for trans/interdisciplinary research including funding options for stakeholder participation in research processes.

Action c. should establish a specific line of funding for research on RRI, encouraging exchange among researchers, promoting further development of theoretical approaches, and supporting studies on conditions for the successful application of RRI in practice.

B3. Improved Coordination with Member States without a Legally Binding Initiative (Option 3)

This third option is based on a scenario which sees the promotion of improved coordination among Member States. It also includes the possibility of directly addressing Member States, business enterprises, research institutions and research funding organisations. Three actions are identified.

Action a. is aimed at fostering improved coordination of RRI activities in Member States. Each government could be asked to prepare, on a voluntary basis, a report on RRI activities using a common reporting scheme so as to promote exchange and set benchmarks. Member States may be involved in developing actions addressing barriers to RRI, such as new funding schemes on RRI, incentives, and training activities.

Through **Action b.**, new codes of conduct for RRI activities may be defined, to foster self-governance processes and collective reflection by researchers and innovators. The EU could oversee the process of defining a more general code of conduct.

Action c. involves developing RRI standards that can be adopted voluntarily and applicable for the design of research processes. In this scenario, dialogue could be initiated to develop a common framework for RRI activities. In order to harmonise the different standard systems, European RRI standards should be developed, in cooperation, also, with international standardisation bodies, like ISO.

B4. Improved Coordination with the Member States with a Legally Binding Initiative (Option 4)

This option is based on a scenario where standards and guidelines already presented in the case of the Option 3 become mandatory through European regulations and directives.

C. Stahl, Obach, Yaghmaei, Ikonen, Chatfield and Brem

Bernd Carsten Stahl, Michael Obach, Emad Yaghmaei, Veikko Ikonen, Kate Chatfield and Alexander Brem developed the **Responsible Research and Innovation Maturity Model** (2017), aimed at identifying progressions towards RRI in industry contexts.

The model includes an operational definition of the components of RRI, structured around the three main elements of R&I, i.e. purpose (why R&I is undertaken), process (the activities that

are undertaken in the pursuit of R&I) and product (the outcomes of R&I). This leads to the following scheme.

RRI Category	RRI Component
Purpose (motivation)	Motivation for doing the research Motivation for engaging with RRI Ethics (justification of intended outcomes)
Process (activities undertaken)	Anticipation Engagement Reflection Governance (research ethics) Responsiveness
Product (outcomes)	Gender/equality and diversity Open Access Social justice/inclusion Sustainability Science education

In defining the components, the authors mainly refer to Stilgoe, Owen and Macnaghten (2013) for those included in the category of process and to the RRI keys identified by the European Commission (2012), i.e., public engagement, open access, gender, science education, ethics and governance, for those included in the category of product.

The Maturity Model also includes an evolutionary scheme to assess the extent to which RRI is institutionally embedded in a given industry. Five stages are identified:

Level 1 – Unaware. Organisation is not aware of RRI or its components and does not incorporate it in its processes.

Level 2 – Exploratory/reactive. Organisation reacts to external pressure concerning aspects of RRI and experiments concerning appropriate processes.

Level 3 – Defined. Organisation has a definition of RRI (or components of it) and has integrated these into its business processes.

Level 4 – Proactive. Organisation realises the benefits of RRI and seeks to integrate these proactively and increasingly into its business process.

Level 5 – Strategic. Organisation has adopted RRI as a component of its strategic framework and aims to ensure all R&I activities cover all (or most) RRI components.

By combining these stages with RRI components and categories, a matrix can be developed to assess the maturity level reached by an organisation in embedding RRI into its procedures and objectives.

RRI CATEGORY	RRI COMPONENT	L1 UNAWARE	L2 EXPLORATORY /PROACTIVE	L3 DEFINED	L4 PROACTIVE	L5 STRATEGIC
Purpose	- Motivation for doing the research - Motivation for engaging with RRI - Ethics (justification of intended outcomes)					
Process	- Anticipation - Engagement - Reflection - Governance (research ethics) - Responsiveness					
Product	- Gender/equality and diversity - Open Access - Social justice/ inclusion - Sustainability - Science education					

D. MATTER

The UK-based organisation MATTER (2015) developed 8 principles for embedding RRI in a business organisation.

Principle One - Innovation for social benefit. The organisation designs its innovations to deliver social, ethical and environmental benefits, in addition to commercial goals.

Principle Two – Board leadership. The Board takes a leadership role in championing Responsible Innovation and is accountable for developing and managing its innovation strategy and associated responsibilities.

Principle Three – Consideration of social, ethical and environmental impacts. The organisation considers and is responsive to the wider social, ethical and environmental implications and impacts of its innovations, working alone or with others where appropriate.

Principle Four – Excellent public health, safety and environmental risk management. The organisation carries out thorough, technology specific, risk assessment and minimises any potential public health, safety or environmental risks relating to its products. It also considers the public health, safety and environmental risks throughout the product lifecycle.

Principle Five – Excellent worker health and safety. The organisation ensures high standards of technology-specific occupational health & safety. It also considers occupational health and safety issues for workers at others stages in the product lifecycle.

Principle Six – Involving commercial partners. The organisation engages proactively, openly and co-operatively with business partners up and down the supply chain to provide appropriate information and safety data throughout the supply chain.

Principle Seven – Stakeholder involvement. The organisation identifies its innovation stakeholders, including the general public, proactively engages with them, involving them in the innovation process and is responsive to their views and concerns.

Principle Eight – 'Radical Transparency' and disclosure. The organisation is innovative and daring in its approach to transparency and openness. In particular it is open about its involvement with and management of specific technologies or areas of innovation.

E. JIROTKA, GRIMPE, STAHL, EDEN AND HARTSWOOD

Marina Jirotka, Barbara Grimpe, Bernd Stahl, Grace Eden and Mark Hartswood (2017) developed a framework for embedding RRI in ICTs, being aware that «*RRI in ICT cannot be realised in a prescriptive manner*» but it is to be understood as «a *contextual process*» requiring an «*ongoing cultural dialogue*» that is iterative in nature.

The framework, called "AREA Plus Framework", can be summarised in a matrix where four key RRI components (anticipate, reflect, engage, act) are connected to the different stages of technology development (Process, product, and purpose) and the variable of people participation. Each cell of the framework «*expands into deeper questions, suggesting literature, more detailed discussion and problematisation*».

The matrix is reported below.

	Process (rhythm of ICT)	**Product (logical malleability & interpretive flexibility)**	**Purpose (convergence & pervasiveness)**	**People (problem of many hands)**
Anticipate	Is the planned research methodology acceptable?	To what extent are we able to anticipate the final product, future uses and impacts? Will the products be socially desirable? How sustainable are the outcomes?	Why should this research be undertaken?	Have we included the right stakeholders?
Reflect	Which mechanisms are used to reflect on process? How could you do it differently?	How do you know what the consequences might be? What might be the potential use? What do we not know about? How can we ensure societal desirability?	Is the research controversial? How could you do it differently?	Who is affected? How could you do it differently?

	Process (rhythm of ICT)	Product (logical malleability & interpretive flexibility)	Purpose (convergence & pervasiveness)	People (problem of many hands)
Engage	How do you engage a wide group of stakeholders?	What are the viewpoints of a wide group of stakeholders?	Is the research agenda acceptable?	Who prioritises research? For whom is the research done?
Act	How can your research structure become flexible? What training is required? What infrastructure is required?	What needs to be done to ensure social desirability? What training is required? What infrastructure is required?	How do we ensure that the implied future is desirable? What training is required? What infrastructure is required?	Who matters? What training is required? What infrastructure is required?

F. RRI TOOLS PROJECT

Under the EC-funded project RRI Tools, a set of practical guidelines for implementing RRI have been developed (RRI Tools, 2016), providing a wide range of examples concerning how to embed, for example, RRI principles into a business plan, or incorporate RRI principles in a funding call, incorporate RRI in policy or funding institutions or set up a participatory research agenda.

In a broader perspective, five "golden rules for achieving RRI" are proposed below, as they are described in the publication.

1. Think about what society wants. Research and innovation should not just take place in society, but for and with society. Citizens should be thought of not only as the end users of science and technology, but as partners in its development. This implies science education needs to play a key role in educating the responsible citizens, researchers and innovators of tomorrow from the early stages to higher education. There are various strategies to embed RRI in education and to engage with the public in the planning, design and implementation stages of R&I – many of which can be found in the RRI Toolkit.

2. Involve a wide range of stake-holders and societal actors. Responsibility needs to be shared among many different actors during R&I development. This not only allows the public a say on which and how research and innovation activities are conducted, but can also improve their outcomes by adding a wider range of expertise and perspectives, making R&I more socially acceptable and ultimately more relevant and impactful.

3. Consider all possible impacts. Key to truly responsible R&I is anticipation — predicting as many of the potential effects of a project as possible, and not just those that are intended. Impact exploration should be in-depth, considering how the research and innovation might shape our collective future and what these changes might mean for society and the environment. Linked to this is reflection, which means thinking about why research and innovation is being conducted, its goals and its implications. A key part of this deals with uncertainty, which is an understandably inevitable part of R&I. There are various strategies and approaches used to account for uncertainty, such as scenario planning — a systematic way of thinking about the future.

4. Be open and transparent. Being open about research and innovation is vital to build public trust. This means disclosing results, methods and data, and engaging in a transparent, meaningful and multiple-way dialogue with all relevant parties. This dialogue can foster social acceptance of R&I advances and lead to more robust outcomes. Openness and transparency are particularly important features of RRI because they lay the foundations for accountability — making scientists and innovators answerable for their actions and the consequences. Open Science also allows those who may not usually be involved in science and technology, such as members of the public or those working in business, to review research and innovation and make their opinions heard.

5. Respond and adapt. Opinions are of little use unless they are acted upon. Therefore, the final recommendation is to change ways of thinking, working and, if necessary, entire organisational structures in response to feedback from society. As well as the views of society, it is also important to respond to the perspectives of other stakeholders, such as policy makers and those who commercialise R&I, for which active listening and an open mind are needed. It is also key to adapt to the emergence of new knowledge and changing circumstances, such as changes to the funding landscape.

1.4. Discussion

In this section, attention has been given to the concept of RRI and the governance models designed either to improve management of R&I in the new "post-modern" context or to favour the spread of RRI in European research systems and research institutions.

Some considerations that could feed a discussion on these issues are offered below.

A. A POWERFUL CONCEPT

As highlighted at the beginning of the section, RRI is a "**buzzword**" or an "**umbrella word**", flexible and open enough to allow for different interpretations and applications. For this reason, RRI is or can be a **mobilising concept** that can spark the interest of different actors and eventually orient research policies at national or institution level. Probably, a more narrowly defined and less ambivalent concept could not have produced a similar impact on policy discourse on science and technology, although its spread is still limited, in comparison to expectations, especially among STEM disciplines.

Moreover, **RRI did not come out of the blue**, but is the latest t product of discussions and movements developed in the past, each producing different "cognate concepts" (Rip, 2016a). Its wide semantic domain allows it to subsume these concepts and issues and to express social values, needs and expectations related to practically any science-in-society issue such as science communication, transparency and accountability of public services, ethical demands, boost to innovation, equal opportunities, people participation, or good governance. This happens because RRI is grounded in real social processes and «*resonates with the ongoing concerns related to the role of science, particularly in society*» (Rip, 2016b).

Also to be noticed, is the massive extent to which these issues are present, and not just in debates and narratives on science and technology. The idea of "responsibility" has, in fact, already been applied to many life domains, thus generating concepts like "responsible politics", "responsible eating", "responsible consumerism", "responsible religion" or "responsible lifestyle".

In this sense, **RRI is a powerful concept**, precisely because it is a "boundary object" that can reflect, combine and coordinate different sets of meanings shared by different groups of people but intuitively comprehensible, albeit in different ways, to anyone.

B. A LOGICAL ASSUMPTION

One of the factors making RRI such a fashionable concept is that it is based on the critical assumption according to which science and innovation are (or have been so far) **under-responsible**, i.e., lacking control over the risks they produce, the social desirability of their impacts and the ethical correctness of their methods or outcomes, or **even irresponsible**, i.e., actively pursuing objectives or adopting practices which are, e.g., ethically doubtful or socially questionable. This assumption can be considered as "logical" since it is logically implicated in the very idea of a science and innovation which are required to be responsible, i.e., at least more responsible than they are now. It is also to say that many RRI advocates also fear being "accused" to share this assumption.

To a certain extent, such an assumption reflects quite common views of science and innovation, depicting them as (consciously or unconsciously) risky, increasingly profit-driven, ethically weak or questionable, insensitive to the demand of the public, ambiguous and opaque in their internal mechanisms, unaccountable for in both their inputs (money, resources, etc.) and outputs (results and their impacts, use of the knowledge produced, etc.), having great power over people's life but outside any democratic control.

It could be said that it is absolutely reasonable to knock science and scientists off their pedestal by showing (as science and technology studies started to do in the 1960s) that **science and innovation are like any other social institution** and, as such, exposed to any socially constructive or distortive dynamics. This helps understand the fallacy of once-dominant deterministic approaches to science and technology (in which they could shape society but not be shaped by it), as well as the inconsistency of the claim that science is regulated purely by meritocracy and rationality.

However, it can be equally misleading to take for granted that under-responsibility is a specific feature of science and innovation. As a matter of fact, not only science but all the social institutions of modernity (like politics, public administrations, trade unions, religions or media) can be and actually are often considered as under-responsible, according to current post-modern standards.

Hence the need to **make this assumption more explicit and less generic**: In the case of R&I, what does (or did) "being under-responsible" mean? Which effects and consequences is an under-responsible R&I producing or has produced in the past? And how? To change course, especially in a domain like science, it should be necessary to provide evidence and produce reliable information.

C. The Normative Nature of RRI

Another consideration concerns the nature of RRI. Although different, the many interpretations of RRI almost always see it as a **normative approach**, grounded in specific values, aimed at modifying research and innovation processes through different tools and strategies (norms, directions, codes of actions, etc.), regardless of the actual feasibility conditions (in this sense, they are normative rather than simply prescriptive; see Baron, 2012).

Thus, RRI appears to belong to the domain of the "having-to-be" (intentions, norms, ethical issues, etc.) with few connections to the domain of "being" (reality, actual social processes, actions, sentiments, etc.)[3]. Hence the conception of RRI as something necessary, to be built up anyhow and in its entirety, it being related to mandatory ethical standards.

This means that RRI does not have, in principle, limitations in **encompassing any possible desirable feature of science and technology**, including effectiveness, sustainability, inclusiveness, anticipatory orientation, responsiveness, reflexivity, transparency, care, proactivity, deliberation, accountability, equity and efficiency, with the risk that RRI becomes a sort of a "wishlist" about science and technology.

However, we should consider whether adopting a purely normative approach could be effective or only illusory. Promoting RRI should imply a radical change in stakeholder views, mindset and action patterns, which is unrealistic to do exclusively through new normative frames, regardless actual stakeholder interests, attitudes, worries and orientations.

D. The Difficult Pathway toward RRI

These considerations inevitably also lead us to consider the governance models developed in connection with RRI or to promote it, analysed in Para. 1.2. and Para. 1.3.

As we have seen, the **models of an empirical nature** (i.e., such as those by Felt, Ruggiu, or Landeweerd et al., aimed at identifying the governance approaches actually used or claimed) highlight the presence and sometimes the co-presence of different inclinations towards the implementation of RRI, depending upon, e.g., the weight assigned to ethical issues and societal issues, the tendency to resort to a narrow normative approach or to an open-ended "constructivist" approach, the type of connection (strong or loose) established between RRI and economic objectives, the level of participation expected (from consultation to co-creation) or the scope of RRI (focused on public engagement and ethics or expanded to encompass, e.g., the civic engagement of research organisations, gender issues, science communication or open access).

As for **RRI implementation models** (i.e., those aimed at developing a method for implementing RRI), we can distinguish two main streams:

- On the one hand, there are models interpreting RRI as a lever for deep and direct changes to the management of science (for example, those by MATTER and Res-AGorA). These models are **ambitious** and **unrealistic**, since they replicate, in terms of methodology, the

[3] We are mainly referring here to Martin Heidegger's thinking (Heidegger, 1996) and to the Hans Kelsen's distinction between "being" (*sein*) and "ought" (*sollen*) (Kelsen, 1967).

same tendency to expand the scope of RRI we noticed above as regards theoretical grounds

- On the other hand, there are models (for example, Jirotka et al., RRI Tools or Stahl et al.) which are more **practical in aims**, being mainly interested in providing research organisations with a "compass" or light tools to guide them into the complexity of RRI.

Under both perspectives, **linear pathways towards RRI appear to be difficult both to identify and to pursue consistently**.

The empirical model of R&I governance provides an account of the ambiguities and contradictions which may emerge once RRI is actually implemented. In turn, RRI implementation models either call for an overall and radical reform of scientific institutions for the sake of RRI or tend to provide a pragmatic (and sometimes over-simplistic) view of RRI, according to which the key problem is asking the "right" questions or adopting the "right" cognitive approach.

To overcome these hindrances (being unrealistic or over-simplistic), the only pathway possible is probably to recognise RRI implementation as a **highly context-dependent process**, as concerns RRI contents and dimensions, feasibility conditions and application strategies. This suggests that there is not a single "RRI" but many possible "RRIs", each related to the context of application (mainly at institution level) and its many variables (starting conditions, sensitiveness of key actors towards RRI, policy environment, disciplinary dynamics, private-public cooperation schemes, etc.).

E. RRI and Changes in Science and Innovation

The strength and direction of changes affecting science and innovation are other variables to take into consideration when speaking of RRI.

Quite paradoxically, RRI seems to be almost exclusively interpreted as something pertaining to science-society relations and not directly the "inner life" of scientific institutions. We could say that RRI concerns the "**foreign affairs**" of R&I processes but not their "**domestic affairs**", if not marginally. Indeed, only incidentally do the interpretations and models examined above consider the possible relations between **RRI** and the **main change processes** affecting science in its most intimate mechanisms (pertaining to, e.g., laboratory work, research assessment, publishing dynamics or scientific careers).

This is actually a strong limitation, since it is quite difficult to "embed" RRI in research systems and organisations without at least interfering with the ongoing change processes.

2. RRI in action

In this paragraph, attention shifts from RRI concepts and models to RRI experiences, in order to analyse in depth RRI drivers and barriers.

To this end, two different operations have been conducted:

- An analysis of a selected group of deliverables produced under **EC-funded projects** aiming to promote the spread of and reflection on RRI
- A **literature review of scientific papers** specifically focused on RRI barriers and drivers.

2.1. RRI in EC-funded projects: barriers and drivers

The first source of information consulted on RRI drivers and barriers was a set of EC-funded projects aimed at promoting the spread of and reflection on RRI. This is mainly made up of documents produced on the basis of either consultation and exchange exercises (workshops, meetings, focus groups, etc.) involving different stakeholders or the observation of RRI cases.

A. BARRIERS TO RRI

The issue of barriers to RRI is considered in various documents produced under EC-funded projects devoted to RRI or RRI components (typically, public engagement). However, the concept itself of "barrier" has been variably interpreted and different typologies have been developed, based especially on the "nature" of the barriers (for example, barriers related to personal attitudes, political barriers, institutional barriers, etc.).

In this section, a "purposive" typology of barriers is used, i.e., a typology that can help address the key question at the basis of FIT4RRI: why is it that RRI has not become as widespread (especially in STEM disciplines) as it was expected to be?

For the sake of simplicity, **four main explanations** can be identified, not alternative to each other.

- **Lack of awareness**. RRI is not sufficiently widespread because of the limited spread of information on it and the little awareness researchers have of it.
- **Lack of relevance**. RRI is not sufficiently widespread because, although the actors know about it and are aware of it, it is (or is perceived as) not relevant to the main problems the actors (researchers, research institutions, industries, civil society organisations, etc.) are concerned with and worried about.
- **Lack of effectiveness**. RRI is not sufficiently widespread because, although relevant, it is (or is perceived to be) ineffective in solving these very problems.
- **Lack of sustainability**. RRI is not sufficiently widespread because, although relevant and effective, it is (or is perceived to be) unsustainable in the long run.

We will try to distribute the barriers among these four categories, i.e., awareness, relevance, effectiveness, and sustainability. This attribution is **largely conventiona**l and has been done

considering **the prevalent impacts** these barriers are supposed to have, according to the sources, on the spread and implementation of RRI.

The documents selected have been drawn from ten EC-funded projects, i.e.:

- RRI Tools (Smallman, Lomme & Faullimmel, 2015)
- Engage2020 (Kuhn et al., 2013)
- PROSO (Bauer, Bogner & Fuchs, 2016; Porth, Timotijevic, Fuchs, Hofmaier & Morrison, 2016)
- FoTTRIS (Karner, Bajmocy, Deblonde, Balázs, Laes, Pataki, Racovita, Thaler, Snick & Wicher, 2016)
- Res-AGorA (Lang & Griessler, 2015)
- PERARES (Steinhaus et al., 2013)
- RRI-PRACTICE (Owen, Ladikas & Forsberg, 2017; Forsberg, Shelley-Egan, Ladikas & Owen, 2017)
- COMPASS (Iordanou, 2017)
- SYN-ENERGENE (König, 2016)
- PE2020 (d'Andrea & Caiati, 2016; Rask, Mačiukaitė-Žvinienė, Tauginienė, Dikčius, Matschoss, Aarrevaara & d'Andrea, 2016).

A1. Barriers Related to the Awareness about RRI

This section looks at the barriers hindering or impeding the main actors from becoming interested in or aware of RRI and RRI-related issues. Two sets of barriers falling into this first category can be identified.

The first set includes the **overall cultural attitudes of the players involved**. The following barriers have been identified.

- **Resistance to change**. Universities and research institutions – like other large institutions – are difficult to change because of their tendency to reproduce unwritten rules, procedures, norms, and internal practices over time (RRI Tools). RRI can be viewed as a threat to the established procedures, in that it tends to modify roles and responsibilities (RRI-PRACTICE). Therefore, some groups may be damaged by RRI and would put up resistance to change (RRI Tools)
- **Risk aversion**. Another attitude which prevents RRI from becoming widespread is the tendency of research institutions to see RRI as a potential risk for science governance, especially because it may fuel public controversies on scientific issues (RRI Tools).
- **Protection of academic freedom**. In many documents (RRI Tools, ResAGorA, FoTTRIS, Engage2020, RRI-PRACTICE), one of the major obstacles to RRI to be identified is the attitude of researchers who see RRI as a threat to academic freedom, understood both as the freedom of individual researchers to make their own research choices and as the autonomy of research organisations to develop their own policies and devise their own strategies.

- **Self-referentiality of RRI actors**. Research institutions tend to be self-referential and to give priority to what happens inside them, not usually being inclined to interact with external actors (RRI-PRACTICE). This is also true in the case of policy actors, who tend not to take into account scientific expertise, nor provide citizens with real opportunities for participation in the political process (RRI Tools). This is less true in innovation contexts, in which interacting with other actors and especially with end-users is quite a common practice (RRI-PRACTICE).
- **Short-term time frame**. Another attitude which makes it difficult for RRI to become widespread is the tendency for R&I actors to give priority to short-term processes (for example, rapid investment returns, rapid moving from experimentation to publication, etc.) while RRI requires or is perceived to require the adoption of medium to long-term perspectives, especially because of the need to involve many actors and to include additional steps in the research and innovation process (FoTTRIS). Short-term thinking also characterises the policy culture, which tends to focus on the "hot topics" and to neglect issues which need long-term solutions (RRI Tools).
- **Researcher specialisation**. The increasing tendency of researchers to focus on specialised research fields makes it difficult for them to become aware of the societal implications of their own research or investigate the relations between their own research and societal challenges (FoTTRIS).
- **Value systems of RRI actors**. Innovation is based on a value system which is overwhelmingly focused on economics and wealth creation with little room for other principles and criteria, such as those involved in the alignment of innovation outputs to societal needs and values (PROSO). It is also difficult to clearly separate economic benefits and societal benefits (SYN-ENERGENE). Moreover, in many cases, a dominant low-cost/low-quality business culture is still dominant, which tends to belittle any other process or step, which are perceived as unnecessary (COMPASS). Problems related to value systems do not only concern industry, but also citizens and researchers. Their values systems may also not be very compatible with RRI, and it is naive to think that RRI can modify such value systems and make citizens and researchers more responsible. Broader societal changes are needed (COMPASS).
- **Training approaches**. Researchers are not trained to critically observe scientific work and to reflect on its wider implications (ResAGoRA). This makes it more difficult for them to become interested in RRI.

The second set of barriers pertains to the **interaction between the actors concerned**, which is a requirement for any RRI-oriented action. The following barriers can be mentioned in this regard.

- **Stereotypes**. There are often preconceived ideas about particular stakeholder groups, such as researchers and industries (as they may be perceived by civil society organisations) or civil society organisations and researchers (as they may be perceived by researchers) (PROSO).
- **Lack of a collaborative culture**. A lack of a collaborative culture may be observed in many countries, which impedes RRI actors from proactively looking for other stakeholders to cooperate with (RRI Tools). In general, RRI requires high levels of mutual trust, which is often lacking (ResAGorA, PE2020), as is often lacking a shared knowledge about the issues to address (ResAGorA).

- **Diverging visions of societal benefits**. The visions stakeholders and researchers have of the potential societal benefits of R&I are usually so different and even divergent that any collaborative process is discouraged. For example, civil society organisations tend to approach sustainability issues by highlighting the need to limit economic growth, while industries tend to propose solutions based on the development of a synbio-driven bioeconomy precisely to fuel economic growth (SYN-ENERGENE).
- **Conflicts between local, national and international cultures**. RRI often requires interaction between cultures focused on the local, national or international dimension. This may lead to conflicts, since the same process may be differently interpreted and assessed according to the level assumed to be the priority (Engage2020).

A2. Barriers Related to Relevance of RRI

In this paragraph, the focus is on the barriers which make RRI not relevant (or perceived as such) to the problems, interests and worries which concern research actors, stakeholders and the public in general. The overall effect of these barriers is to hinder or limit the interest of the players concerned in getting involved in RRI, even when they are fully aware and informed about this issue.

The first set of barriers includes **existing priority schemes** preventing RRI from becoming a priority. The following barriers may be highlighted.

- **Excellence vs RRI**. Many documents (PROSO, ResAGorA, RRI-PRACTICE) identify a hidden opposition between excellence and RRI, viewed as two competing priorities. As a matter of fact, excellence in science is the absorbing motive for scientists and research organisations, to which all the available resources (time, money, equipment, etc.) should be devoted. The "struggle for excellence" is profoundly embedded in the epics and ethics of science. Also, the review systems are exclusively based on excellence and not on social impacts (PROSO). The entire picture is worsened by the rapid increase in the competition to access decreasing resources, permanent positions, rewards and recognition. In such a context, RRI is not only perceived as marginal, but in many cases a real obstacle to the search for excellence.
- **Pressure to publish**. In this same context, getting research published in the shortest time possible is becoming the number one priority for both researchers and research institutions (see Part Two, Section 2). This priority is so strong that it makes anything else irrelevant, including RRI (RRI Tools, PE2020).
- **Creating growth and making a profit**. Similar dynamics can be observed when the innovation side of the process is considered. The policy imperative for policymakers is making science and creating growth (RRI Tools), while the economic imperative for industries is making a profit, especially to develop new patents and to commercially exploit research results (RRI Tools, PROSO, FoTTRIS). RRI is, therefore, often viewed by both as an impediment to the accomplishment of these imperatives in that, on the one hand, RRI may attract resources that would otherwise go to growth and profit-making activities and, on the other hand, once implemented, it necessarily leads to increased production costs and to longer production times. In this way, RRI may turn into a competitive disadvantage for a firm or for a productive system (PERARES). Additional resources should then be found to balance the need for financial profit with the need to find resources to conduct activities in a responsible manner (COMPASS).

- **Open Access vs IP/patenting**. A specific, well-known but significant priority clash concerns Open Access. As a matter of fact, from an RRI logic, the free flow of scientific information is a requirement for a collective engagement in science and innovation. From an innovation logic, Open Access hinders IP recognition and patenting (RRI Tools). As for scientific publication, the system is still based on "paywalled journals", difficult and costly to access.
- **Distrust in scientific institutions and in RRI**. Another aspect which is necessary to mention is the scepticism that different stakeholders have toward RRI and Public Engagement (PE2020, Engage2020), as well as toward scientific organisations in general (PE2020). This produces a "motivational deficit" hindering these stakeholders from taking part in the implementation of RRI.

The second set of barriers refers to the **dynamics of RRI incentives**. The following issues can be considered in this regard.

- **Lack of material incentives**. RRI is time consuming, costly and, in many cases, its outputs are unpredictable. Therefore, promoting and implementing RRI requires money and resources, which, however, are rarely guaranteed (RRI Tools, Engage2020, RRI-PRACTICES, PROSO).
- **Lack of scientific recognition**. Another factor hindering RRI is the lack of scientific recognition attached to it. Scientists are not rewarded for societal engagement (Engage2020) and other RRI dimensions (RRI-PRACTICE). RRI is also not considered, except episodically and marginally, in the research evaluation process (RRI Tools). This also leaves researchers already involved in RRI-related activities without adequate institutional support (Engage2020).
- **RRI as a disincentive for scientific recognition**. RRI may even play a negative role in the dynamics of scientific reward and recognition. Often, research organisation leaders do not like RRI (PROSO), researchers' involvement in RRI is not acknowledged by peers (FoTTRIS) and may even be perceived as belittling the capacity of researchers to do research.
- **Lack of incentives for non-R&I actors**. The lack of incentives also concerns non-R&I actors. For example, it is not clear what benefits derive from RRI for civil society organisations and the public at large (FoTTRIS). This may also explain, at least partially, the limited interest civil society organisation have in lobbying for RRI (PERARES) and the presence of many relevant stakeholders that, even if asked, do not want to participate (ResAGorA).
- **Unclear benefits of RRI**. For researchers and other stakeholders, the benefits of RRI often remain often unclear or uncertain. Because of this lack of clarity, and in the absence of requirements for RRI, other things would be seen as more relevant to their objectives and interests (RRI Tools).

A3. Barriers Related to the Effectiveness of RRI

In this paragraph, the focus is on the barriers which make RRI ineffective or not sufficiently effective (or perceived as such). Therefore, these barriers have prevalently to do with how RRI should be implemented and under which conditions the implementation of RRI becomes possible.

The first set of barriers refers to **uncertainty about RRI and RRI implementation**. In particular, the following issues can be mentioned.

- **Uncertainty about the concept**. The conceptual structure of RRI lacks a clear definition and clear rationale (RRI Tools), and is susceptible of different interpretations (RRI-PRACTICE, ResAGorA) and of being applied "to very different things in very different contexts" (PROSO). So not surprisingly, there are also substantial differences among stakeholders in terms of how RRI is framed (RRI-PRACTICE), which makes it more difficult to attain a good level of cooperation among them. An integrated approach to the concept is lacking and little integration can be also observed in its key areas (public engagement, open access, gender equality, etc.), with the risk of encouraging "cherry picking of particular RRI keys that fit the current policy needs" (RRI-PRACTICE).
- **Uncertainty about the promoters**. RRI not only requires resources and incentives, but also groups, leaders and individuals fully engaged in triggering the process. Unfortunately, it is often unclear who the players responsible are and who has the power to activate the process (RRI-PRACTICE, PE2020).
- **Uncertainty about the process**. The lack of reliable visions about what RRI is and how to make it real is another serious obstacle to its implementation (RRI Tools). The same can be said of the uncertainties related to how to manage conflicts which RRI quite inevitably produces or how to manage the cases in which stakeholders are not interested in participating (FoTTRIS). Someone speaks of the "vagueness" of practical RRI (SYN-ENERGENE), especially as regards how RRI notions and principles may be linked to effective policies (SYN-ENERGENE). Lack of a shared methodological framework is also understood as a problematic aspect (RRI Tools).
- **Uncertainty about the impacts**. Finally, also the impacts of RRI are structurally difficult to predict, since many variables come into play, both in the implementation process and in stakeholder interaction (RRI-PRACTICE).

The second set of barriers are more technical in nature, concerning **requirements and conditions for RRI implementation**. The following main issues can be highlighted in this regard.

- **Lack of resources**. As already mentioned above, RRI requires significant investments in terms of money, resources, time and political power (RRI Tools, Engage2020, RRI-PRACTICES, PROSO, FoTTRIS, PE2020), which often are lacking or are largely insufficient to activate successful change processes. Lack of resources is particularly problematic for civic society organisations, since they usually cannot rely upon their own resources (PROSO).
- **Lack of skills and training opportunities**. In many cases, R&I actors and stakeholders also lack the necessary skills and training opportunities to implement RRI (RRI Tools, FoTTRIS, PERARES, Engage2020). This is particularly true for scientists and scientific institutions. In addition, expertise to help them implement RRI is also generally lacking (RRI Tools).
- **Lack of communication channels**. Stakeholders and researchers usually do not communicate with each other, thus making RRI difficult to be actually implemented (COMPASS, PE2020). Communication is even weaker in the case of actors (such as funding agencies and civil society organisations) that have never had common interests and opportunities to work together (Engage2020). The limited presence of communication channels (and shared languages) also reduces chances of communicating science-related issues without falling into oversimplification (ResAGorA).

The third set of barriers can be identified in **technical issues** intrinsically connected to RRI implementation. Among them, two issues deserve to be mentioned.

- **Management of public participation**. The management of public participation is characterised by serious problematic issues, including: how to raise the interest of different stakeholders (Engage2020, PE2020); how to manage the power dynamics among participants, (RRI Tools, PE2020); how can public participation be managed methodologically (RRI Tools); how to address the lack of shared knowledge to take decisions (ResAGora, PE2020), the lack of a common understanding of RRI (ResAGorA), the lack of a mutual trust (ResAGorA, FoTTRIS) or the presence of diverging worldviews and ideas about problems and solutions (PROSO, PE2020) or diverging beliefs about what is socially desirable (FoTTRIS).
- **Turning RRI outputs into policies**. The second technical (but also political) issue is how to turn the outputs of RRI into impacts, in terms of new decisions, policies and measures. There is actually the risk of a gap between RRI exercises and policy making, so that deliberative processes may have little or no effect on political decisions (Engage2020). This is also due to the tendency to consider Public Engagement merely as a set of single participatory events and not as a permanent function of research institutions (PER2020).

A4. Barriers Related to the Sustainability of RRI

This group includes all the factors making it difficult for RRI to be or be perceived as institutionally and temporally sustainable. Lack of sustainability prevents RRI from becoming part of the identity of the organisations, stakeholders or individual researchers concerned. Different sets of barriers or risks to RRI sustainability can be identified.

- **Bureaucratisation**. There is a risk that RRI merely becomes a formal aspect of the life of the organisations concerned, simply requiring ticking the appropriate boxes in a form, or a tokenistic practice, thus making RRI something to exhibit for symbolic reasons (RRI Tools, PROSO). In this way, RRI becomes a further bureaucratic burden for researchers that may hamper creativity, progress and innovation (RRI-PRACTICE) or “window dressing” that reinforces a status quo that continues to cement existing norms, behaviours and power relations (RRI-PRACTICE).
- **Lack of investments**. Embedding RRI in research institutions and stakeholder organisations necessarily requires significant investments at all level (funds, time, expertise, political willingness, political power, etc.) by the organisation and its management (RRI Tools, PE2020, FoTTRIS, PROSO, Engage2020), which are usually lacking or extremely limited.
- **Resistance and institutional barriers**. It is difficult to see RRI as something to be simply added to the existing organisational functions. Rather, it should be incorporated, although prudently, into the major functions and practices of the organisation, which would be modified to different extents (PE2020, RRI-PRACTICE). This inevitably triggers strong resistance to change from both personnel and leaders (RRI Tools), due to the persistence of the existing institutional structures (ResAGorA, RRI-PRACTICE), specific interests and power relations (PE2020), cultural gaps and lack of information (PE2020, RRI-PRACTICE), and consolidated behavioural patterns (PE2020, RRI-PRACTICE).
- **Inadequate legal and regulatory framework**. National legislation can be a serious obstacle to RRI, because it is often inconsistent, unclear and scattered (RRI Tools). This is also true when regulatory frameworks developed for specific research and innovation sectors (such as nanotechnology or health) are considered (COMPASS).
- **Inadequate policy framework**. Similarly, apart from some specific exceptions, EC member states have not developed adequate policy frameworks to promote the spread and consol-

idation of RRI (RRI Tools). The majority do not have national bodies in charge of promoting RRI as a policy framework for research organisations, nor infrastructure and incentives to support RRI (RRI Tools, Engage2020).

- **Difficulties in defining the objectives**. To be implemented, RRI requires, in principle, deep cultural and systemic changes (RRI-PRACTICE, PE2020) affecting, not only the ways in which research and stakeholder organisations work, but also, e.g., the redefinition of the concepts of research quality and excellence (RRI-PRACTICE), the modification of research assessment procedures (PROSO), the reform of research funding schemes (FoTTRIS), the modification of university curricula (ResAGorA), the adoption of new hiring and promotion criteria (PE2020, Engage2020) and the development of engagement infrastructure (for example, science shops) (Engage2020). It is evident that all these objectives cannot be pursued all together and more feasible aims should be identified at different level (e.g., research group level, institution level, national level, etc.) so as to prevent RRI from becoming a simple "wish list" with limited actual applications. However, identifying the "right" objectives for a given organisation or research sector is a difficult and complex exercise, especially in a context where many players are concerned.
- **Difficulties in defining responsibilities and implementation procedures**. As already highlighted above, RRI implementation approaches and methodologies remain largely uncertain and unclear. It is not clear, for example, "whether RRI should be implemented at a management level and be incorporated into programmatic activities (i.e., top-down) or whether it should be implemented at the level of the individual researcher via for example the creation of safe spaces for interaction amongst researchers, free of programmatic assessment criteria, that will feed directly into policy decisions (bottom-up)" (RRI-PRACTICE).
- **Lack of evidence and data about RRI**. Finally, an important barrier to the "institutionalisation" of RRI is the lack of evidence and data about its impacts and benefits. For example, there are "few available data or information on evaluations of societal engagement in research and innovation activities and no creditable outcome-based evaluations that have established that a public participation technique has led to a technically or socially sound outcome that otherwise would not have been reached" (Engage2020). The lack of this information makes it difficult to trigger new and more advanced interpretations of science and science-society relations, or to convince research managers and leaders to invest in RRI.

A5. A Summary Table

A summary table of the main barriers to RRI drivers is presented below.

Group of barriers	Sub-set	Barriers
Barriers related to awareness barriers hindering or impeding the main actors from becoming interested in or aware of RRI and RRI-related issues	Barriers related to overall cultural attitudes of the players involved	- Resistance to change - Risk aversion - Protection of academic freedom - Self-referentiality of RRI actors - Short-term time frame - Researcher specialisation - Value systems of RRI actors - University training approaches
	Barriers to the interaction between the actors concerned	- Stereotypes - Lack of collaborative culture - Diverging visions of societal benefits - Conflicts between local, national and international cultures
Barriers related to relevance barriers which make RRI not relevant (or perceived as such) to the problems, interests and worries of research actors, stakeholders and the public in general	Barriers related to existing priority schemes	- Excellence vs RRI - Pressure to publish - Creating growth and making a profit - Open Access vs IP/ patenting - Distrust in scientific institutions and in RRI
	Barriers related to the dynamics of RRI incentives	- Lack of material incentives - Lack of scientific recognition - RRI as a disincentive for scientific recognition - Lack of incentives for non-R&I actors - Unclear benefits of RRI
Barriers related to effectiveness barriers which make RRI ineffective or not sufficiently effective (or create this perception)	Barriers related to uncertainty about RRI and RRI implementation	- Uncertainty about the concept - Uncertainty about the promoters - Uncertainty about the process - Uncertainty about the impacts
	Barriers related to requirements and conditions for RRI implementation	- Lack of resources - Lack of skills and training opportunities - Lack of communication channels
	Barriers related to specific technical issues intrinsically connected to RRI implementation	- Management of public participation - Turning RRI outputs into policies
Barriers related to sustainability all the factors make it difficult for RRI to be or be perceived to be sustainable, so it can become part of the identity of the actors concerned		- Bureaucratisation - Lack of investments - Resistance and institutional barriers - Inadequate legal and regulatory framework - Inadequate policy framework - Difficulties in defining objectives - Difficulties in defining responsibilities and implementation procedures - Lack of evidence and data about RRI

B. RRI DRIVERS

It is preliminarily to be noted that the concept of driver is used here in its **broadest meaning**, since the consulted sources deal with different "objects" which can be directly or indirectly referred to the concept of "RRI drivers". They include:

- The **arguments** in support of RRI expressed by different stakeholders
- The actual or perceived **benefits** of RRI
- The **motivations** pushing the actors to adopt RRI
- The **factors** of any kind (social, economic or policy nature) and dimension favouring the adoption of RRI framework and policies.

In various cases, the consulted sources provide a more or less formalised typology of drivers.

For example, under the Engage2020 Project (Hennen & Pfersdorf, 2014), focused on Public Engagement, three types of "motives" are proposed: those which are functional to R&I to improve work; those of a political nature; those of a cultural nature. Similarly, under the MORRI project (Wuketich, Lang, Grießler & Polt, 2016), a typology of "potential RRI benefits" is proposed, including four main "families" of benefits: democratic benefits; economic benefits; societal benefits; benefits for science. In the case of the PROSO project (Bauer, Bogner, & Fuchs, 2016), also focused on Public Engagement, a key distinction is made between "functional positions", including motivations viewing public engagement as a means to pursue a set of objectives, and "normative positions", including motivations viewing it as a «*normative goal in itself*».

Beyond these specific typologies, the proposed drivers largely differ to each other in both **scope** and **level of abstraction**. In some cases, drivers are narrow in scope and concrete (for example, accessing new funds), while in other cases they are broad in scope and abstract (for example, aligning science with society).

We are not interested here in developing a new typology of RRI drivers (motivations, benefits, good reasons, etc.). Rather, we are more interested in identifying the most recurrent "**interpretive frames**" of RRI in which these drivers are grounded.

An "interpretive frame" (Entman, 1993; Porto, 2002) can be defined as a cognitive frame for the interpretation of events and issues. They are prevalently aimed at producing one or more of the following effects:

- Defining and describing the issue (problem, opportunity, event, etc.)
- Attributing responsibility(ies) for and cause(s) of the issue
- Assessing the significance of the issue ("what is at stake")
- Providing arguments about the consequences, and
- Providing recommendations about how to prevent or treat such consequences.

The use of the frame analysis appears to be particularly appropriate in the case of RRI, since such an approach is widely applied for the study of political discourse; and actually, to a large extent, RRI is a political issue which activates a political discourse.

To conduct the analysis, a selection of documents produced in the framework of EC-funded projects has been conducted, including projects dealing only with RRI in general or those pertaining to specific components of RRI (public engagement, education, etc.). At the end of the process, documents referring to 8 projects were selected, namely:

- RRI Tools (Smallman, Lomme & Faullimmel, 2015)
- Engage2020 (Hennen & Pfersdorf, 2014)
- MORRI (Wuketich, Lang, Grießler & Polt, 2016)
- PROSO (Bauer, Bogner & Fuchs, 2016)
- KARIM (Hin, 2014)
- ENGAGE (Okada & Bayram-Jacobs, 2016)
- FoTTRIS (Karner, Bajmocy, Deblonde, Balázs, Laes, Pataki, Racovita, Thaler, Snick & Wicher, 2016)
- Res-AGorA (Kuhlmann, Edler, Ordóñez-Matamoros, Randles, Walhout, Gough & Lindner, 2016).

The analysis led to the identification of **seven major interpretive frames**, which are described below, namely:

- The self-protection frame
- The quality frame
- The opportunity frame
- The democracy frame
- The management-of-future frame
- The alignment frame
- The science communication frame.

B1. THE SELF-PROTECTION FRAME

The first frame can be referred to as "**self-protection frame**". It assumes the point of view of R&I organisations (including industries) and scientists and highlights the need for them to protect themselves from the risks they are exposed to because of the changing relations between science and society.

RRI is therefore acknowledged as necessary for researchers and R&I organisations in order to prevent controversies (RRI Tools), to increase their trust and reputation (MORRI) in a context of decreasing public trust in science, to avoid litigation costs and conflicts (MORRI), to gain public appreciation for science in general (Engage2020), to increase the legitimacy of science (Engage2020) and their own legitimacy as well (RRI Tools), to prevent potential business loss (MORRI), to get early information about public concerns and resistances towards a new discovery, research path or technology (PROSO), to properly manage the greater public and political scrutiny of research activities and outputs (Res-AGoRA) and to show the benefits of science despite it being ever more politically and economically driven (ENGAGE)

What is at stake is the risk that science loses more authority, social recognition and social status, leading, for example, to diminished R&I funding or diminished influence in the political arena.

B2. The Quality Frame

The second frame, which can be referred to as the "**quality frame**", establishes a relationship between RRI and the quality of research and innovation, not only in substantive terms but also in terms of efficiency, effectiveness and impacts.

Thus, RRI appears to be necessary to improve the quality of innovation (RRI Tools, MORRI), to make R&I processes more effective (Engage2020), to limit costs (MORRI), to improve cost-effective outcomes and procedures (MORRI), or to favour the diversity of researchers, teams and research organisations, which, in turn, is a factor that has a positive impact on R&I quality (MORRI).

This frame is obviously based on the assumption – to be demonstrated – that RRI influences the quality of science and innovation. This assumption is prevalently motivated by the argument that RRI broadens the very concept of quality by adding new quality criteria (such as the "social robustness" of research) directly related to science-in-society issues.

B3. The Opportunity Frame

The third frame is the **opportunity frame**. Under this frame, RRI is depicted as a source of opportunities for researchers, research organisations and industries, which otherwise would be precluded to them.

Among these opportunities, the documents mention, e.g., accessing new funds (RRI Tools, MORRI), accessing new networks (RRI Tools, MORRI), improving one's own scientific career (RRI Tools) or acquiring new skills (MORRI). RRI, as interpreted under this frame, is, therefore, proposed as an ally of scientists and research organisations in helping them gain competitiveness in an increasingly complex R&I market.

The assumption at the basis of this frame is that RRI is actually able to provide researchers and R&I institutions with competitive advantages. Another assumption is that researchers and research institutions are actually interested in getting these competitive advantages, even when it would require, e.g., changes in their scientific interests or modifications in their career trajectories.

B4. The Democracy Frame

The fourth frame – the **democracy frame** – is recurrent in the RRI narrative. The core of this frame is the idea that citizens and stakeholders have the right to contribute both to the R&I decision making process and to the research and innovation process.

In this sense, RRI is understood as a powerful approach to put this into effect, in that it supports participation (RRI Tools, MORRI), makes citizens more informed and engaged (RRI Tools), defines more advanced standards for involving the public (RRI Tools), favours the empowerment of civil society (Engage2020, MORRI), strengthens the democratic system (MORRI), introduces new transparent institutional practices (MORRI), modifies the research system making it

more democratic and inclusive (FoTTRISS) and increases the accountability of R&I (Engage2020).

What is at stake with this frame is the right and capacity of people to participate, participation being viewed as a normative goal in itself (PROSO) and a necessary instrument to develop more democratic governance settings for science. The prevalent theoretical dimension of RRI recalled is "inclusiveness", while public engagement is the most mentioned RRI component.

Some assumptions can be found at the basis of this frame, including, e.g.:

- The interest and willingness of citizens to get involved in science and technology
- The capacity of RRI to ensure a democratic process within R&I and to represent the many societal groups and interests concerned
- The possibility for laypeople and experts to interact on a parity basis in scientific matters.

B5. THE MANAGEMENT-OF-FUTURE FRAME

This frame describes RRI as an approach for the "**management of our future**" by anticipating the future outputs of research and innovation and their intended and unintended consequences. RRI in itself can, therefore, be defined as an "anticipatory process" or an approach favouring an "anticipatory governance" of science and technology.

This frame implies having control over the potentially risky impacts R&I may have on society and citizens (FoTTRIS, Res-AGorA, ENGAGE, KARIM) and the maximisation of the future benefits of science and technology (ENGAGE, KARIM). This does not simply mean "scanning the future", but learning to manage the future by modifying the present, especially leveraging upon the engagement of citizens and stakeholders (PROSO) and improving the capacity of policy makers to assess R&I risks and benefits (MORRI).

This frame is based on some assumptions which are rarely made explicit, concerning, for example:

- The intrinsically risky nature of science and technology
- The limited capacity of scientists and research institutions as well as of policy makers to predict and manage the impacts of science and technology
- The inadequacy of the present governance arrangements to protect citizens from the risks produced by science and technology or to maximise their future benefits
- The capacity of RRI to promote improved assessment of R&I impacts.

B6. THE ALIGNMENT FRAME

This is probably the most widespread frame under which RRI is interpreted. The **alignment frame** focuses attention on science-society relations and especially on the lack of connections between them.

RRI is, therefore, interpreted as an approach bringing science closer to society (RRI Tools, FoTTRIS), enhancing the capacity of R&I to target societal needs, values and interests so as to increase its social robustness (Engage2020) and enhancing the relevance of research for the

specific values and concerns of citizens, also allowing these values and concerns to actually emerge (PROSO). The alignment frame also incorporates the idea of RRI as a tool for introducing socio-ethical thinking in science and technology (ENGAGE) or for developing a new ethical basis for science as a whole (FoTTRIS). This implies a reflective attitude for assessing whether and to what extent a research process or output is socially desirable, ethically acceptable and environmentally sustainable (FoTTRIS). Alignment requires more intense negotiations between science institutions and societal actors, leading also to the redefinition of roles and responsibilities in R&I (Res-AGorA).

This frame mainly relies upon the dimension of "responsiveness", understood as the capacity of science and technology to proactively provide adequate responses to present and future risks (thus, responsiveness is connected to the dimension of "anticipation") and to ethical and societal demands. Moreover, the alignment frame is strongly intertwined with the democracy frame, since public engagement is interpreted as the main enabling tool for science-society alignment.

Moreover, this frame is based on some implicit assumptions, including:

- The lack of alignment between science and society
- The relative "blindness" of scientists and research organisations to societal needs, expectations, interests and values
- The possibility to actually identify widely shared societal needs, ethical values or expectations to be used as reference points for science and innovation, notwithstanding the increasing fragmentation of contemporary societies.

B7. THE SCIENCE COMMUNICATION FRAME

The seventh frame can be referred to as the **science communication frame**. At the core of it there is the view that RRI, and especially Public Engagement, is a more advanced form of communicating science.

Substantially, RRI is interpreted as framework for going beyond the Public Understanding of Science approach, based on the largely questionable assumption that transferring scientific knowledge to the public increases the public's appreciation of science (the so-called "Deficit Model"). In fact, this frame is based on two assumptions, both countering the Deficit Model. The first assumption is that, to be effective, science communication requires equitable relations between experts and other stakeholders (especially laypeople). The second is that people's appreciation of science can only be modified if people are given the chance to really influence the trajectories of R&I.

In this sense, RRI is viewed as extremely helpful in enhancing science communication since it tends to establish new forms of scientific citizenship (Engage2020), improves science education (RRI Tools, Engage2020, MORRI), raises people's awareness about science-related issues (MORRI), contributes to the expansion of a highly competent labour force (MORRI), promotes communication among all stakeholders (Engage2020, MORRI), improves the communication processes among researchers and research teams (ENGAGE) and reinforces the capacity of the media to communicate science (ENGAGE).

This frame can be partially viewed as secondary to the democratic frame and the alignment frame, since better communication between science and society is a sort of pre-requirement for, and a by-product, of democratic participation and better alignment of science with society. However, it should be kept in mind that, in practical terms, many scientists and research organisations just see RRI as a more advanced form of science communication and public understanding of science.

B8. A SUMMARY TABLE

A summary table of the main interpretive frames of RRI drivers is presented below.

FRAME	CORE IDEA	MAIN ASSUMPTION(S)
The self-protection frame	RRI may help researchers and research institutions protect themselves from the risks deriving from changing science-society relations (decreasing public trust, decreasing authority of science, risks of conflicts, costs of litigation, etc.)	- R&I is losing authority, social recognition and social status
The quality frame	RRI may help researchers and research institutions improve the quality of research and innovation process	- RRI is concerned with the quality of science and innovation, facilitating high quality research and/or introducing new research quality criteria
The opportunity frame	RRI may help researchers and research institutions seize opportunities otherwise precluded to them in terms of funding, networks, careers and skills	- Researchers and research institutions get real competitive advantages from RRI - Researchers and research institutions are interested in getting these advantages
The democracy frame	RRI may help citizens and stakeholders contribute to R&I decision making process and in the research and innovation process	- Citizens and stakeholders have the right to contribute - Citizens and stakeholders are interested in getting involved in science and technology - RRI is able to ensure a democratic process within R&I and to represent the many societal groups and interests concerned - Laypeople and experts are able to interact on a parity basis in scientific matters
The management-of-future frame	RRI may help anticipate R&I risks and benefits, so as to prevent the former and maximise the latter	- Science and technology are intrinsically risky - Scientists, research institutions and policy makers alone have a limited capacity to predict and manage the impacts of R&I - Present research governance arrangements are inadequate to predict and manage the impacts of R&I

FRAME	CORE IDEA	MAIN ASSUMPTION(S)
		- RRI can improve assessment of R&I impacts
The alignment frame	RRI may help align science and innovation with societal needs, values, interests and expectations.	- Science is not aligned with society - Scientists and research organisations are relatively "blinded" toward society - It is possible to identify largely shared societal needs, values, interests and expectations
The communication frame	RRI may help communicate science to the public and enhance communication among researchers and research teams	- Science communication requires equitable relations among stakeholders - Science communication requires that laypeople be given the opportunity to influence the process (communication cannot be completely separated from action)

2.2. RRI in academic journals: barriers and drivers

This section of the report, drafted by Nina Kahma and Susanna Vase (University of Helsinki), analyses the reception and the adoption of Responsible Research and Innovation (RRI) in two academic databases (ScienceDirect and Scopus). The academic publications (articles, reviews and conference proceedings) offer a specific window to how RRI is received by individual researchers coming from different disciplines and the way in which RRI is perceived by the users responsible for applying the concept into practice.

The section focuses on how RRI and its drivers and barriers are seen and developed in academic journal articles, and further, how the concept is disseminated across academic disciplines and researchers located around European countries as well as outside Europe.

A. RRI IN THE ACADEMIC PUBLICATIONS

The theme of RRI is a recent theme in academic discussion, which is reflected in low number of peer reviewed articles on that topic. Moreover, only few articles are focused on RRI as most of the articles focus on other phenomena mentioning the concept of RRI, but not developing it further. As a result, the attitude towards RRI is in most articles very positive or unproblematic at the least. The lack of criticism towards RRI in the articles may relate to the concept being poorly known, but also the way in which it is understood and the standpoint the writers have on RRI.

We will first take a look on the article data and how the concept of RRI is adopted in the academic articles by looking at the year of publication as well as the background of the authors (country, discipline). Thereafter, we will move to the analysis of the content of the articles.

In the analysis, we will focus on the following themes:

- The barriers, hindrances and obstacles to the dissemination of RRI
- The drivers, that are considered to promote RRI.

On the basis of the analysis on the academic article corpus we aim to answer the factual question of why RRI has not yet become as diffused and institutionally embedded as it was initially expected to be (especially in STEM disciplines). In the next paragraph (2.3., point b.), we then sum up the recommendations on what can be done to promote RRI further.

B. The Article Data

The preliminary data collection was based on the searches being carried out on the basis of titles, abstracts and possible article keywords in ScienceDirect and Scopus databases. Using RRI as a search word produced multiple articles from traffic research and medicine, both disciplines, where the abbreviation RRI has altogether different meaning than "Responsible Research and Innovation." Therefore, we ended up using the term "Responsible Research and Innovation" in combination with the other search words. Other search words included were "drivers", "barriers", "trends" and "changes".

RRI was first mentioned in the article in the databases in 2009, but thereafter the number of articles either focusing on the topic or mentioning it has risen steadily. For the publication search in the two databases the search words "Responsible Research and Innovation" produced altogether 130 articles. The number includes the articles found in searches for "Responsible Research and Innovation" adding different search combinations to the term.

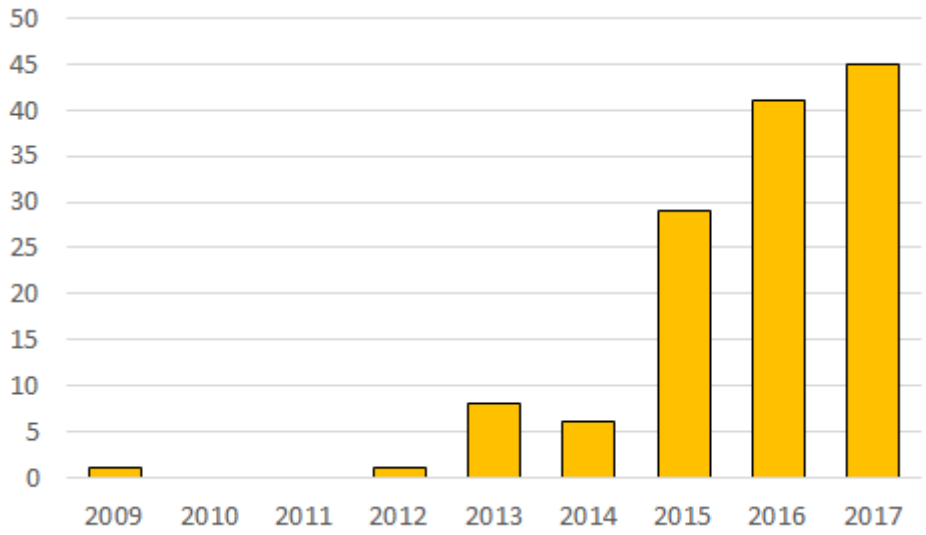


Figure 1. The number of articles on RRI in ScienceDirect and Scopus journals by the year of publication[4]

[4] Search on ScienceDirect database produced 85 publications that were published between the years 2009 and 2018 (2009: 1 original research article; 2013: 6 original research articles and 1 other article; 2014; 3 original research articles and 2 other articles; 2015: 14 original research articles, 1 other article (editorial) and 3 encyclopedias; 2016: 13 original research articles, 2 book chapters, 2 review articles and 4 other articles; 2017: 22 original research articles, 1 review article and 5 other articles and 2018: 1 original research article). 60 of all the publications were original re-

The term RRI can be seen as relatively recent in its origin. It has been claimed to appear first in a technology assessment workshop on nanotechnology in the year of 2007 in Netherlands. (Kaldewey & Flink, 2017; Robinson, 2009; De Saille, 2015). RRI was further pushed forward through a conference of the European Commission in April 2012, entitled "Science in Dialogue—Towards a European Model for Responsible Research and Innovation" (RRI Conference Report, 2012). Particularly the Commission's Directorate General Research and Innovation emphasized the need for bringing society and science closer. A year later RRI was taken abroad and named as one of the cross-cutting issues in Horizon 2020 programme. (Kaldewey & Flink, 2017.) The substantial increase in the number of articles covering RRI in 2015 and subsequent years can be explained by the above mentioned events and the release of the Rome Declaration in November 2014. The rise in the number of articles either developing RRI or considering scientific results from the viewpoint of RRI may simply be a result of RRI being domesticated in the academic research and on a practical level the uptake may relate to new (Horizon, 2020) projects focusing on RRI, but also the establishment of new bodies promoting RRI.

Few articles are focused on RRI and instead in most of the articles the focus is on other phenomena, which means the use of the concept of RRI is unproblematizing, although the need for more RRI is widely recognized throughout the article corpus.

search articles and the remaining 21 publications consisted of 3 review articles, 2 book chapters, 3 encyclopedias and 13 other articles, and 4 book chapters with no access to content. Scopus search produced altogether 48 publications, that were published between the years 2012 and 2017 (2012: 1 article ; 2013 : 1 article; 2014: 1 article; 2015: 11 articles; 2016: 18 articles; and 2017: 16 articles). The majority, 37, of these articles were research articles, 7 conference papers, 2 books or book chapters and 2 review articles. The five publications with no full text available on the net, included three articles, one book and one book chapter. However, we were able to read the abstracts of these publications. After removing three duplicate articles, the final article corpus included 130 articles.

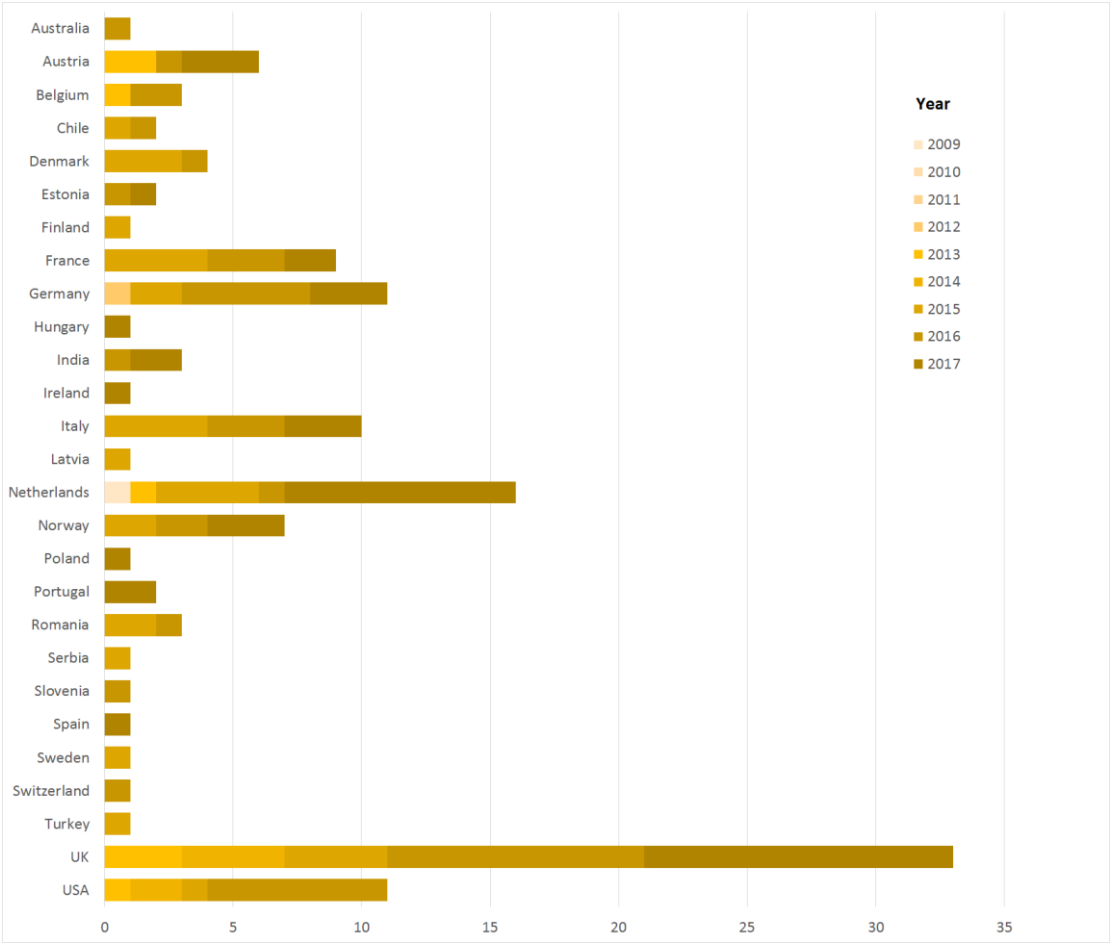


Figure 2. The number of RRI articles by the country of the first author and the year of publication

Figure 2. shows the number of published RRI articles by the country of the first author. Researchers with an affiliation in the UK (31 articles) contributed to the theme of RRI the most. Also authors coming from the Netherlands (16 articles), the United States (11 articles), and Italy (10 articles) had published a high number of articles on RRI. In other countries the number of RRI articles was lower.

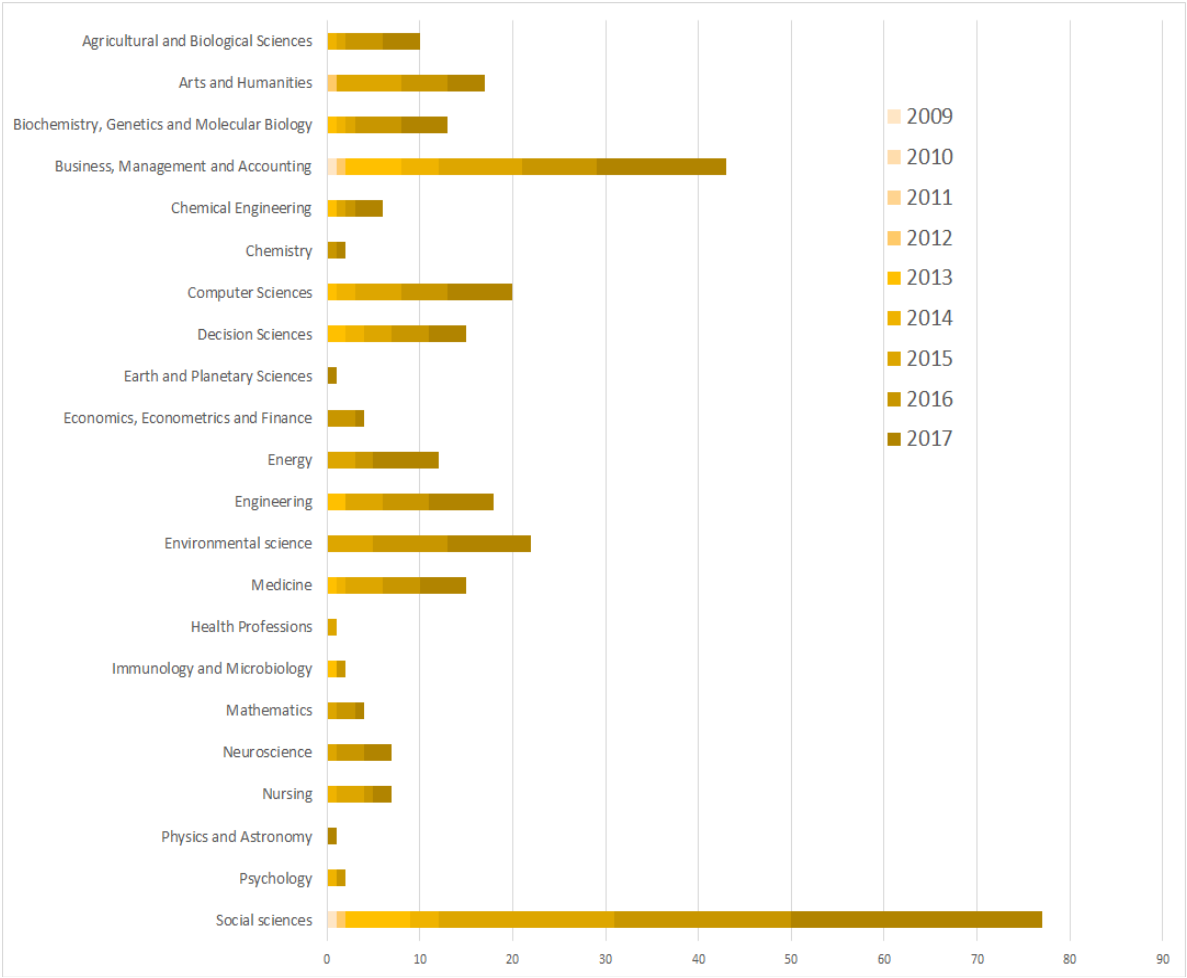


Figure 3. RRI articles by the discipline and the year of publication

In our data, most of the articles are multidisciplinary, and therefore the number of articles within disciplines can exceed the number of articles in the data. In Figure 3. we have presented the articles by scientific discipline and the year of publication. RRI received early attention from the researchers in the field of Business management and accounting (Robinson, 2009) followed by Social Sciences and Arts and humanities (Mali et al., 2012).

The figure shows, that the number of articles linked to social sciences is large (77 articles). RRI has also been covered by scholars in Business, management and accounting (43 articles) and computer sciences (20 articles). In recent years, RRI has also been mentioned in the articles in different fields such as Arts and humanities (17), Decision sciences (15), Engineering (18), and Medicine (15 articles). In other fields of study, the coverage has been modest, ranging from one to circa ten articles during the couple of years.

The low number of articles in the publication covering the so-called STEM-disciplines (science, technology, engineering and mathematics) may relate to the concept of RRI originating in social sciences and EU governance.

C. Barriers and Obstacles to RRI

C1. Conceptual Ambiguity

Conceptual ambiguity is an important hindrance to the adoption of RRI that is recognized in the articles. For example, Flink and Kaldewey (2017) characterize RRI as inclusive in regards to different strands of theorizing interactions of science and society. In the articles, the most frequent remark on RRI relates to the unclear definition of the term. Some of the conceptual confusion may result from the concept of RRI being a rather new concept that is used like a buzzword with a strong normative stance more so than a concept with an exact meaning (cf. Cairns & Krzywonszynska, 2016). Lack of contextualization to other academic discourses scrutinizing the change of science adds to the ambiguity, which may be a result of intentional ignorance or lacking awareness of alternative concepts (Flink & Kaldewey, 2017). The ambiguity of the concept of RRI can also be seen in the number of articles mentioning RRI as a dogmatic and fashionable concept that is used for re-branding and only acknowledged when the validity of results is reflected (cf. Cairns & Krzywonszynska, 2016).

It is clearly brought forward, that it is not yet clear, how RRI approach works in real life and with particular cases (see Ikonen et al., 2015). Unclarity is then translated to difficulties to operationalize and apply RRI (Burget et al., 2017; Lubberink et al., 2017; McLeod et al., 2017; Stahl et al., 2014; Garden et al., 2016; Owen et al., 2012; Blok & Lemmens, 2015).

Even where RRI is seen as an integral part of a programme or institutional strategy, it is not always clear, what is the RRI that is being applied. For instance, in an account on SmartSociety programmes, the principles of RRI are seen as an integral part of the programme. However, the lack of knowledge considering both RRI and its effects is nominated as a major impedance in the agenda (Hartswood & Jirotka, 2016). Therefore, Hartswood & Jirotka (2016) suggest, that the obvious challenge for these programmes is better articulation of the outcomes and social benefits that follow RRI.

C2. Lack of Ownership Related to Top-Down Governance

It is widely acknowledged across the articles, that EU promotes the concept of RRI as a key governance framework and that EU has made considerable investments in its development through research and technology funding under its vast research programmes. In an article by Ravesteijn and colleagues (2015), RRI is seen as a natural result of innovation actions in a situation in which technologies and innovations provoke serious public concern.

As the focus of RRI lays currently on the project and policy level of publicly funded research instead of industry contexts (see Stahl & Yaghmaei, 2016), lack of ownership is a central problem to its appropriation and development. Tim Flink & David Kaldewey (2017) state that RRI's rhetoric is grounded on a bottom-up approach although it is organized through a top-down approach by the European Commission. They subsequently state that it is unclear whether RRI discourse is relevant outside of the assigned, formal programs especially when it comes to the actual research and identity work of organizations (see also Burget et al., 2017). At the present moment they see RRI more as a bureaucratic frame conducted by policy makers and policy scholars and not by the scientists themselves. However, it is possible that RRI starts to build up its own trajectories and becomes more than one of the concepts related to responsibility (Flink & Kaldewey, 2017).

Governance and research models on a global and a national level can be seen as major a macro level hindrance to RRI posing limitations to what can be considered in the field of research (see Rodriguez, 2017).

Lack of ownership is reflected in the viewpoints on individual disciplines as well as individual researchers. Stahl et al. (2014) are aware of the fact that there may be various actors that see RRI as a threat to the autonomy and academic freedom of research. In their case study focusing on healthcare robotics, Stahl and Coeckelbergh (2016) see, that the underdevelopment of RRI results from that scholars in healthcare robotics do not believe that RRI raises interesting issues in terms of research process and methodology. Moreover, the scholars believe that existing governance mechanisms are insufficient to address such issues where they arise. Stahl and Coeckelbergh (2016) expand their interpretation to cover also other new emerging and poorly understood branches of research, such as synthetic biology. The root cause for the lack of ownership seems to link to the poor ability of governmental institutions to understand the substance of individual disciplines. McLeod et al. (2017) point out that RRI is one of the agendas and structures that are not in scientists' control. Therefore, the lack of ownership may be reflected in the non-adoption of RRI.

C3. LACK OF GUIDELINES FOR IMPLEMENTATION OF RRI

Researchers, policy makers, users and scholars alike were expected to manage and maintain a continuous multi-stakeholder conversation and to implement the different elements of RRI into practice (de Jong et al., 2016; Garden et al., 2016). However, in some accounts on RRI, it was recognized that implementation of RRI was not a simple task. Further, shortcomings in the administrative procedures can manifest as a lack of concrete RRI guidelines for specific areas of research and disciplines. RRI can be seen as distant and inoperative from the viewpoint of rapidly developing disciplines (Rodríguez, 2017).

The relationship between knowledge about RRI and its implementation is seen to relate to complex power relations that can be facilitated through specific methods such as organizing meaningful multi-stakeholder dialogue and active facilitation of the discussion. «*The number of methods of RRI has increased rapidly over the past decades. Some of these methods are designed to facilitate dialogue between citizens, such as consensus conferences, citizen panels and public advisory boards*» (Betten et al., 2013). Yet, few articles address specific methods for implementation of RRI.

McLeod et al. (2017) see the lack of clear guidelines on the operationalization of RRI as a pivotal restraint on applying RRI. They notice, that RRI has been operationalized in a varied of ways depending on governance and geographical contexts (McLeod et al., 2017; de Saille, 2015; Ribeiro et al., 2016; Rip 2014). In the area of engineering, for instance, weak or lacking ethical guidelines tend to lead to individual agents acting on their own and shifting moral responsibility in techno-scientific innovation to others. Also Garden et al. (2016) call for context-specific guidelines. They state that despite the excellent guidance materials and toolkits (for example http://www.rri-tools.eu) that can help in the implementation of RRI, there remain challenges on how to apply the RRI framework to different emerging technologies. They name neurotechnologies as an example of a discipline, where integrating RRI with research and technology development while advancing new kind of innovation is difficult.

The overall uncertainty both in the political and economic realm in Europe has, in recent years posed challenges for implementing RRI. According to Mali et al. (2012) *a situation of heightened uncertainty* is a core feature of any attempt to govern new and emerging science and technology.

C4. INADEQUATE INSTITUTIONAL STRUCTURES

On a general level, involvement of multiple stakeholders in RRI was recognized as an important challenge. The precarious situation both politically and economically may result in lack of commitment of stakeholders such as policymakers and experts in the RRI process, who are left to questioning the legitimacy of policies and institutions. The barriers that were introduced in the articles were linked to specific stakeholders or societal realms. Some barriers were found also between and within disciplines, between policy actors, and within industries and corporations.

Criticism towards implementation of RRI by institutions concerned a) governmental institutions, b) funding bodies, c) ethical boards, d) academic institutions, e) Industry and corporations, and f) inoperable or non-existent networks between the bodies.

Governmental institutions

A central barrier for the dissemination of RRI are the relationship between governmental institution promoting RRI and scientific disciplines. Laird & Wynberg (2016) have in their study on new, emerging, and poorly understood activities such as synthetic biology found, that the integration of RRI into policies has not been a simple task. Based on their findings, they enumerate administrative deficiencies such as limits to government capacity, jurisdictional confusion, shortages in funds, and an absence of strategic approaches (Laird & Wynberg, 2016) as deficiencies of RRI policy. Hence, as Chaturvedi et al. (2016) point out, the poor integration of RRI and science is also result from the complexity of the science and the unpredictability of its effects, and the different speeds and styles of policy-making and research and development (R&D). The non-synchronization of these realms is an important stumbling block to the integration of RRI into new, emerging, or poorly understood fields of study.

On a societal level, weak national RRI policies are believed to have led to the emergence of radical anti-movements against the proponents of science and technology. According to Coenen and Grunwald (2017), France is an example of weak RRI proponent, which can be seen in the emergence of radical anti-movements against quantum technology. Correspondingly, strong national innovation policies are considered an important driver of RRI concurrently impeding public concern from escalating to social movements (see Ravesteijn et al., 2015).

Funding bodies

Khan et al. (2016) suggest that in the area of food and health, a gap remains between the research funders and RRI on how innovation is comprehended. In order for RRI to progress cognitive frames need to change. According to Khan et al. (2016) funders' framings on innovation seem currently to be influenced more by the linkage of economic growth and innovation than RRI. They call for a shift on how innovation is perceived in funding decisions to provide more space for research proposals stressing RRI.

The coordination between funding bodies on an international and national level are also seen as a problem. There are differences between EU level funding and national funding schemes in their relation to RRI, although on both levels of research funding, considerable emphasis is placed on consultation and engagement (Hartswood & Jirotka, 2016).

Ethical boards

Ethical Advisory Boards all over Europe as well as the professional advice issued by them, are faced with new kind of pressure by multiple stakeholder groups such as decision-makers interested in future advances in science and technology, and academic researchers. In spite of the skeptical outstand, the EABs are expected to secure the good governance of science and technology and of a new strategy of Responsible Research and Innovation. (Mali et al., 2012; Borras, 2003; IRGC, 2006.)

Academic institutions

Researchers' and scientists' lack of knowledge about RRI as a reason for not adapting it comes across in many of the articles in our data. In some accounts, adaptation is thought to prerequisite mere awareness of RRI. Bernd Carsten Stahl et al. (2014) also state that researchers' and scientists' unawareness on the nature of the process and how their daily work practices will be affected by it, is one of the barriers on the way towards a successful practical framework of RRI.

In the realm of academic research, niche barriers are seen as structures that hinder discussion and dissemination of knowledge about RRI (Metze et al., 2017). The barriers may also relate to evaluation criteria and structure of study within university. Virgine Pirard (2015) state that scientists need to increasingly define and justify the interest of research in a wider perspective and in relation to its broader impacts. Scientific studies may not, however, prepare researchers enough for the kind of responsibility required.

Putting RRI into practice is sometimes seen as specific task for **certain new disciplines** (such as synthetic biology and nanotechnology), whereas policy makers and regulating bodies set the frame for these implementation of RRI in these disciplines (see Laird & Wynberg, 2016, Chaturvedi et al., 2016). Challenges were thought to concern the research system as a whole, even if they were often approached from a viewpoint of singular disciplines; «*As the main challenge in realizing RRI in the field of synthetic biology and global health, we would point at the difficulty in realizing a transition towards a more responsive research system; a research system that is demand-driven, takes societal responsibility as an important value, and considers the interaction with societal stakeholders and their experiental knowledge to enrich the research process*» (Betten et al., 2013).

Problems with putting RRI into practice may also occur when working in **multidisciplinary teams and performing cross-disciplinary work** (see deGrandis & Efstathiou, 2016; Viseu, 2015, Davies 2011). John Gardner (2017) states that individual researchers may have differing understandings and values based on their own disciplines. Working together may cause tension even if the team members share the same goals. According to Gardner, tensions are not necessarily a negative matter as they can foster a more reflexive and evaluative discussion which is indeed an essential component of RRI (see also Nuffield Council on Bioethics, 2013). In concordance, McLeod, Nerlich and Mohr (2017) see, that the unevenness in the power relations between scientist coming from different disciplines and the government setting up

the agenda can be seen both as a barrier, but also as an opportunity: «*Social scientists and anthropologists working with scientists in the same space can facilitate conversations and interactions that bring tensions into the open, thus laying the groundwork for a better management of scientific, economic and RRI expectation*s» (McLeod et al., 2017).

The poor understanding of individual disciplines is linked to lack of funding, jurisdictional confusion and absence of strategic approaches what comes to RRI (Laird et al., 2016; Chaturvedi et al., 2016).

Industry and corporations

On one hand, as Chatfield, Borsella et al. (2017) point out, one of the most important barriers for RRI is the lack of ambition in its dissemination, by which they mean the promotion of RRI focusing on publicly funded research and omitting a substantial proportion of the company-based innovation activities.

On the other hand, the disengagement of the stakeholders within the industry has to do with their reluctance and the conservative attitudes prevalent in the industry. An empirical study on the attitudes of industry professionals (Kimmel et al., 2016) revealed that adopting RRI in the industry was a matter of personal characteristics of individuals, their ideological affiliations and sense of social obligation. In other words, RRI was not embedded in the corporate culture nor seen as natural part of the occupational role of an engineer.

An example from the United States on the reception of RRI shows, that institutional incentives to adopt RRI for engineers working in the industry were weak, as they were not experienced as a part of the institutions long-term objectives, but rather as an additional norm (Kimmel et al., 2016).

Inoperable or non-existing networks

Setting goals in multidisciplinary networks. Stahl & Coeckelbergh (2016) acknowledge that RRI is likely to have many challenges most of which will not be straightforward or simple to solve as different as well as contradictory interests will be involved. They discuss an example of cases where industry wants to sell robots but researchers target for other goals, such as publishing their findings.

The lack of networks to disseminate RRI can be seen as an important barrier in many fields of science. According to Calvert and Frow (2013) responsibility in relation to innovation should be shared among the whole network of different people and organisations that are involved in the research process. According to them, patenting systems, for example, can raise questions about the ownership, distribution and eventual public good of a technology (Calvert & Frow, 2013).

Walter Leal Filho et al. (2017) state that research is still often conducted in silos when it comes to departments within the academia. The same can also be argued when looking at the scientific community as an actor in a vast community of different stakeholders. It is possible that career evaluation criteria are not giving enough encouragement for inter- and trans-disciplinary collaboration, especially in the case of young researchers starting their career. (Ibid.)

C5. Lack of Proof of the Benefits of RRI

The most important obstacles for engagement in RRI can be found in the stakeholders not being able to see its benefits. RRI is often seen as an external element, a constraint or an additional norm imposed from the outside to science and innovation. As the immediate value for the industry seems absent, the realization of RRI seems secondary (Stahl & Yaghmaei, 2016).

At the core of not seeing the benefits of applying RRI, are financial issues, such as budget constraints and unpredictable costs (Chatfield, Borsella et al., 2017) framing business and industry. In the articles, the scholars widely recognize the imperatives of a global, knowledge-based, capitalist economy (Rodríguez, 2017) which set boundaries for technological innovations and the dissemination of RRI. Lubberink et al. (2017) suggest that the concept of RRI is poorly adaptable in business, which roots in the concept having been developed by researchers and policy makers focused primarily on science and technological development. Therefore, the link between research, development and commercialization remains unproblematized, and issues such as admittance of social innovations and commercialization of innovations remain untouched. They (2017) also note, that the interests and values of the actors in business context may differ from those of the research in the academia.

There are also some arguments related to EU's research policy generally which might affect the attitudes also towards RRI as it is an EU-funded research agenda under the Horizon 2020 programme, even though Pollex & Lenschow (2016) are not speaking of RRI in particular. They state that the article (2016) showed that the evidence of degrowth agenda in the EU's research policy is limited even though there are some degrowth positions found in the policy documents. When it comes to green growth and S&T policy, they appeared to be co-dependent on the frame of GDP-growth, and sustainable development was being used as a bridging concept. Even though there are political groups, societal actors and agendas that are clearly stating a degrowth position (for instance the Beyond GDP & Circular Economy Agenda), GDP-focused growth agendas seemed to dominate in the Horizon 2020-programme. McLeod et al. (2017) also argue that RRI has been chosen as part of the growth agenda.

D. Drivers

Wide acknowledgement on the benefits of RRI comes across the article corpus although the ideas of the benefits remain abstract and general (see, for instance Stahl & Yaghmaei 2016). We analyse the drivers for RRI by identifying Political (and legal), Economic, Social, Technological, and Environmental factors (so called PESTE model that is widely applied in futures studies, see e.g. Mendonça et al., 2004). Moreover, we will take into account a sixth category of drivers, namely values. The added category consists of general permeable societal concepts such as considerations of responsibility and ethics, public reflection, anticipatory politics and deliberative democracy.

D1. Political Drivers

Innovation policies are a major driver behind RRI. RRI is seen as a part of strong innovation policies, which is relevant in overcoming the economic crisis and "ensuring smart, sustainable and inclusive growth" (Burget et al., 2017; Forsberg et al., 2015). In the data, EU as an actor carrying out conceptual work that promotes the awareness of RRI well as its strong input on

the concept being rooted in EU policies is widely recognized as a key driver for RRI. Evidently, RRI is seen as an important aspect of Horizon 2020 and its different funding programmes that can set new norms for research and commit the whole of research community in RRI.

Strategic RRI programmes have also been introduced in specific local contexts. In an example on a responsible port innovation case, described in the article by Ravesteijn et al. (2015), a strategy for research and innovation in port development considering and reconciling a range of stakeholder values related to topics such as employment, safety, economic growth, participation and livability to natural values. The parties in constructing the strategy included governmental bodies, business and development actors, all contributing to suggestions for improvement as they continued the devilment of the port. By applying the framework of RRI, Ravesteijn et al. (2015) formulated a methodological and procedural plan on how successful application of RRI can be applied.

Another example of successful political action and RRI programmes in the area of nuclear technologies is presented in the article by Turcanu and colleagues (2016). They point out that RRI programmes as such have created an enriching dynamics between relevant organizations and stimulated collective learning and transdisciplinary. In the area of nuclear technologies, there are international radioactive waste management networks (e.g., OECD-NEA, IAEA).

D2. ECONOMIC DRIVERS

European Union has articulated that the main goal of RRI is to «*ensure that research and innovative ideas can be turned into products and services that create jobs and prosperity, as well as help preserve the environment and meet the societal needs of Europe and the world*» (Zwart et al., 2017; Von Schomberg, 2013; Stahl & Yaghmaei, 2016; Rome Declaration, 2014). In the article corpus, **there is a general agreement on that RRI leads increase in economic growth and employment**. As stated by Coenen and Grunwald (2017) the existence of this kind of social impacts can be used to justify the implementation of RRI approaches. Moreover, RRI being an essential part of innovation policies, that are perceived to ensure smart, sustainable and inclusive growth (Burget et al., 2017; Forsberg et al., 2015) can further encourage its implementation.

The driver for the adoption of RRI in the companies could be the value seen in the ability to better understand customer needs and satisfaction (Chatfield, Iatridis et al., 2017b).

D3. SOCIAL DRIVERS

RRI is seen as a relevant concept, on which to build social development projects (and infrastructural projects in general) where the projects involve a variety of goals or values, have a broad set of objectives, and awake public debates and protests (see Ravensteijn et al., 2015). Social drivers manifest in the articles as 1) right kind of culture and environment to putting RRI into practice, but also 2) specific institutions for promoting RRI.

Culture as social driver for RRI

Chatfield, Borsella et al. (2017) emphasize the need for RRI values to be embedded within the culture of organizations. They call for conscious efforts for raising awareness and promoting reflection of ethical issues amongst all personnel working in ICT companies.

According to Stahl & Coeckehbergh (2016) the ability of RRI to take contradictory interests into account is one of its benefits. RRI is not suddenly going to make the conflicting or contradictory interests between the actors disappear but it can however help in addressing the problems and subsequently providing grounds for a more intelligent discussion of options and possible solutions.

Academic institutions and companies as a social driver for RRI

Universities are seen as the leading institution in conducting the actual RRI procedures (Flick, 2016). The means for promoting RRI are university studies and more specifically researcher training. Discussing topics of cutting edge research and their linkages to RRI among the students was presented as an important tool for raising awareness on RRI in and outside the universities.

The idea of transmitting proper knowledge base through education, as formulated in the Horizon 2020 Science with and for Society Work Programme, is evident in many articles. Teaching proper knowledge on RRI is thought to require both deep technical knowledge and broad disciplinary and social competence irrespective of the specific discipline of the researcher. For example, Burget et al (Burget et al., 2017; Felt, 2014; Levidow & Neubauer, 2014) see the ability of RRI to promote interactions and collaboration between social sciences and humanities and hard sciences and engineering as an important factor indicating its relevance.

Referring to experiences from Great Britain and elsewhere, Coenen and Grunwald (2017) suggest, that educational activities organized as part of large-scale science communication events and science fairs operate as an interesting example of applying RRI. Bringing up, that this kind of project workshops including discussions on RRI issues in quantum science and technology that were not open to the public and didn't include multiple stakeholders. However, they suggest, that "organized discussions and workshops with multiple stakeholders can be used to promote RRI in any field of technology" (Coenen & Grunwald, 2017). According to them, however, the general deliberation and dialogue processes in Germany have tended to focus on stakeholder and expert interactions instead of targeting citizens (Coenen & Grunwald, 2017; Fleischer et al., 2012).

Therefore, the main driving force behind RRI relates to the social and scientific networks that can be achieved. Filho et al. (2017) expect that universities may also address new issues by re-thinking evaluation criteria to better acknowledge inter- and transdisciplinary collaborations as well as foster issue and problem driven thinking in relation to research. Also non-formal education environments could be used for fostering RRI (cf. Gorghiu et al., 2015; Petrescu et al., 2015).

Citizens as a driver of RRI

Betten et al. (2013) suggest that research programmes should allow multi-stakeholder dialogue as «*Increasingly – at least in the Netherlands – research agendas are set and research programmes are formulated using multi-stakeholder processes, such as the ILA approach. For example, about half of the Dutch charity funds on disease-related health research have developed a research agenda that explicitly includes the perspectives of patients and sometimes citizens*» (Betten et al., 2013).

D4. TECHNOLOGICAL DRIVERS

Technological drivers to facilitate the uptake of RRI presented in the articles mostly link to developing ICT and different kinds of electronic platforms. In an article *Automated Learning Support System to Provide Sustainable Cooperation between Adult Education Institutions and Enterprises* Andra Jakobsone & Sarma Cakula (2015) present a concept of Knowledge Sharing Platform (KSP) that can be used to federate RRI communities and to make RRI and its key dimensions more effective research and innovation policy support tools. The platform is targeted to be used particularly in adult education in companies. The platform can promote the development of companies through providing content- rich and demonstrative information on RRI for their employees.

The concept of New Product Development (NPD) also concerns end-user involvement and bringing stakeholders into development work. NPD is seen to enhance RRI but at the same time involving different stakeholders is seen as a pivotal challenge. In order to manage end-user involvement and stakeholder participation better, Baskin Yenicioglu and Ahmet Suerdem (2015) discuss the possibilities of an integrative online platform that would be based on the revolutionary principles of Web 2.0. The platform could offer a democratic space for negotiation, integration and coordination of the complex phases in innovation process. Social media are also seen to bring many opportunities in relation to participatory activities that can be organized within an electronic platform.

Another example of a technological platform promoting the relevance of RRI can be found within the area of Synthetic Biology. According to Le Feuvre and colleagues (2016), SYNBIOCHEM's has developed a RRI platform, that "seeks to initiate early multiway dialogue, provide expertise, guidance and training in the responsible governance of SynBio innovation, and foster public engagement and training for the research community, in order to anticipate, prepare for and if necessary mitigate the impacts of SynBio technology in the wider society, economy and environment" (Shapira, 2016; Le Feuvre et al., 2016).

The paradigm of co-creation between the stakeholders and the end-users seems to be at the core of the discussion of the technological drivers of RRI. Concepts, such as user-led innovation as well as human centered design (HCD), are raised as important drivers behind RRI, as these concepts are able to link together interests of multiple stakeholders (Khan et al., 2016). Multiple articles in the data suggest, that involvement of citizens in the development of singular disciplines might prove useful for RRI. For instance, adopting a specific RRI **Interactive Learning and Action (ILA) approach**, Betten and colleagues (2013) build a strategy that could involve stakeholders and end-users in a process, where experiential knowledge is articulated and knowledge co-created in an interplay between science and society. Integrating users early on in the development of technologies is recommended because this way different societal risks and ethical issues in relation to innovations can be reduced (see Chadwick, 2015). In the article *Design and development of a digital farmer field school. Experiences with a digital learning environment for cocoa production and certification in Sierra Leone*, Loes Witteveen et al. (2017) see that RRI perspective enhanced design accountability and encouraged to include co-creation. This led to searching new alternatives for bringing designers and the end users together in a situation where they weren't located in a close proximity and the contact was hindered by an Ebola context (Ibid.). Baskin Yenicioglu & Ahmet Suerdem (2015) also state that involving stakeholders in New Product Development (NPD) process fosters RRI as well as sustainable development of products.

D5. ENVIRONMENTAL DRIVERS

From the viewpoint of sustainability, RRI is expected to be beneficial as it leads to ethically, environmentally and socially acceptable, sustainable and desirable innovations addressing societal needs (Owen et al., 2012; Von Schomberg, 2013) and emphasizes the importance of transparency and interactiveness within research and innovation projects (Lynch et al., 2017). The acknowledgment that grand social challenges such as climate change cannot be addressed without transdisciplinary approach involving stakeholders from various backgrounds also outside of academia can been seen as a major driver for RRI and its beneficiality in relation to sustainability (Cairns & Krzywoszynska, 2016; De Grandis & Efstathiou, 2016).

RRI can be seen as an instrument focusing on processes and profound changes in society, not just the outcomes and temporary band-aids on some existing structures. RRI is subsequently criticizing the linear model of technological innovation and sees innovation rather as a complex and collective phenomenon that requires a dynamic approach and deliberation on motivations and purposes of innovation. (Markusson et al., 2017; Flink & Kaldewey, 2017; Owen et al., 2012). In between economic, environmental and social drivers, are reflective institutions performing RRI. Effective innovation actions that could help the implementation of RRI in the business context were studied in a review article by Lubberink and colleagues (2017). On the basis of their review, they suggest that in business context reflexivity on the organisations' activities, commitments and assumptions is the key element in explaining the adoption of RRI. However, this reflexivity may not be universally held, but instead linked to new corporate practices in terms of innovation activities.

D6. VALUES AS DRIVERS FOR RRI

Responsibility and ethics

Ethical and moral reasons for implementing corporate social responsibility are recognized as important drivers for RRI. Values of individual employees may be reflected in the internal efforts in the companies involving the promotion of RRI in companies (Chatfield, Iatridis et al., 2017).

Social problems are rarely covered in the articles. However, responsibility is thought to be embedded in RRI. Chatfield, Iatridis and colleagues (2017b) state the drivers for the adoption of RRI in the companies could be reputational gains through RRI-based risk management procedures.

The positive outstand towards RRI is manifested as encouraging technological innovations instead of focusing on social concerns related to RRI them: «*in the context of RRI, for instance, ethics is primarily seen as a 'stimulus' for science and technology*» (Zwart et al., 2017; Von Schomberg, 2012). The principles of RRI are also considered as a basis for different ethical guidelines. In the case of ICT, Bernd Carsten Stahl et al. (2014) argue that RRI could be the next phase of computer ethics as well as the next step for fostering ethical framework and concerns within Information systems (IS) "a field of academic research and business practice". Much IS research tends to focus on the organizational aspects and use of ICT taking for granted the different socio-economic contexts of the IS usage. Through the perspective of RRI, IS researchers may better understand grand challenges that societies are facing and be encouraged to contribute to addressing them. They state that a profound reevaluation of the

technologies, the way they are used and understood, is needed (Ibid.). Another example of RRI being used as a foundation for ethical guidance is observed in a report on novel neurotechnologies where the following RRI influenced principles were recognized by UK Nuffield Council on Bioethics: 1. Clearly identified need, 2. Securing safety and efficacy, 3. Generating robust evidence, 4. Continuous reflexive evaluation, 5. Coordinated interdisciplinary action, 6. Effective and proportionate oversight (Singh et al., 2017.).

Public reflection

In most of the articles RRI is seen as an answer to the need for some kind of a new ethos. Zwart and his colleagues (2017; 2015) claim, that RRI is not a specific method, but rather an attitude that sees the societal stakeholders not as consumers of knowledge, but as sources of information and inspiration.

An important value driving the diffusion of RRI is that it allows responsiveness and has capacity to change shape or direction in response to stakeholder and public values and changing circumstances (Stilgoe, Owen & Macnaghten, 2013; Khan et al. 2016). RRI can also provide a basis for more intelligent discussion of different options and possible solutions in the field of research (Stahl & Coeckelbergh, 2016).

Deliberative democracy and anticipatory politics

When it comes to the question of ownership and RRI, it is also possible that the potential impacts of S&T may be brought back to the scientists. The anticipatory nature of RRI may enable them to reflect on the purposes and impacts of their research as well as different uncertainties and dilemmas. They can further open up a broader deliberation with the public on different visions and this way influence the direction of the research and innovation process. (Rose, 2014.) As there is an increasing plurality of different legitimation strategies, scientists may also be able to switch discourses in which they work more easily and thus increase the freedom of scientists (Flink & Kaldewey, 2017).

Public engagement can be seen as essential to RRI, and according to Krishna Ravi Srinivas (2016) it should not be seen as something that distrusts, destabilizes or politicizes science, a concern that was addressed by Marcel Kuntz (2016) in his critique of RRI. Democratizing science rather relates to engaging with public and not assuming it to be irrational, taking the social and ethical aspects of science into account and making scientists more aware of societies' concerns and values.

2.3. Discussion

This section has analysed two issues – RRI **barriers** and **drivers** –, using two different kinds of sources (documents drafted under EC-funded projects and scientific literature). Two different conclusions can be drawn out of the analysis of the two kinds of sources.

A. Conclusions from the Analysis of the Documents of EC-Funded Projects

The analysis of the documents produced under the EC-funded projects lead us to primarily notice the different logic underlying the documents while speaking of barriers and drivers.

Analysing the four groups of barriers (regarding the dimensions of culture, agency, action and identity, respectively), the element that emerges is the **complexity** of the RRI implementation process. RRI entails deep and broad changes of a different nature, and inevitably, in order to succeed, has to deal with deep and broad obstacles and challenges.

The logic underlying the seven major interpretive frames defining motivations and objectives for RRI is radically different. As a matter of fact, RRI is prevalently viewed as a policy framework which "**adds something**" to science and innovation (new quality criteria, new opportunities for researchers, new players to involve, broader timeframes, new values and ethical parameters to take into consideration) on the basis of a "**normative logic**". On the strength of this logic, RRI expands the scope and responsibility of science and scientists on the basis of the need to "be open to society", regardless of the actual feasibility conditions for RRI implementation.

It should also be said that these interpretive frames are indeed "frames" (i.e., narrative constructions serving to convince someone about something) developed by players who wish RRI to be developed. Therefore, they tend to conceal or overlook difficulties and risks as well as emphasize benefits and opportunities.

This logic is in tune with the conceptual models of RRI (see Section 1), defining it as a normative approach potentially embracing everything science and technology should be but are still not (e.g., responsible, anticipatory, sensitive, proactive, efficient, equal, accountable, open, and the like).

We found out again the distinction between "having-to-be" (intentions, norms, ethical issues, etc.) and "being" (reality, actual social processes, actions, sentiments, etc.). In theoretical terms, RRI belongs to the domain of "having-to-be", and seems to be driven by a linear logic. However, its application belongs to the domain of "being", and its implementation seems to be driven by a non-linear logic.

Another issue emerging from the analysis of "RRI in action" is that the **transitional processes affecting science** (such as increasing competition, decreasing pressure on and questionable use of research assessment, the lower reproducibility of scientific data, or the overexploitation of young researchers, especially women) **are substantially ignored**, although many of them are deep, broad in scope and fraught with potentially highly problematic consequences.

As we have seen in the previous section, these trends are not considered in the conceptual models of RRI, apart from those (undoubtedly important) occurring in science-society relationships. In RRI implementation processes, many transitional processes are considered (for example, increasing competition, increasing researcher specialisation, the pressure to publish, the pressure to produce economic benefits through science), but only to the extent that they may hinder RRI implementation, i.e., as contextual factors influencing RRI and not as targets for RRI-oriented actions.

B. Conclusion from the Literature Review of Academic Journals

The majority of academic articles that focus on RRI see the concept as a positive and welcome opening which can enhance the effectiveness of academic research. The majority of these positive articles underline the importance to build better connections between science and

other realms of society, such as the government and the industry. In a vast majority of the articles in the two academic databases, however, RRI was mentioned without criticizing, developing or thinking the concept further. The large number of non-reflexive articles may relate to the concept of RRI being ambiguous and yet unknown for the academic writer- and readership.

The novelty of the concept of RRI is visible in the article corpus, as the concept was first mentioned in the academic articles in 2009 and again in 2012. Thereafter the number of articles on RRI has risen steadily. However, in 2017, eight years after the publication of the first article, the number of articles was still modest, just 45 articles. Discussing RRI and research on a general level in the body of articles rather than reflecting and developing the concept of RRI can be a symptom of distance felt to RRI, which may link to unawareness and irrelevance. What is discussed, are the relations and the division of work between organizations and researchers in the field of research in applying RRI. In fact, most of the articles discuss, how the field of research and governance could be better arranged to deploy RRI.

The small number of accounts on RRI may result from five kind of barriers we found in the data. First, the conceptual ambiguity of RRI. For the authors of academic journal articles, the concept seems to be too inexact, wide and inclusive. At the core of the conceptual critique is, that the concept can be seen as a buzzword or a new wrap for old concepts. Hence, the relevance of RRI from the viewpoint of real word issues becomes an issue. Second, the lack of ownership felt towards RRI comes across in the articles. RRI promoted forcefully by the EC is sometimes seen as a concept imposed top-down instead of a concept deriving from and in benefit of the scientific community. What follows, is that RRI is in danger of being restricted to publicly funded research. Third, lack of guidelines for implementation of RRI was raised as an essential question for its' dissemination. In research environments with multiple actors and complex power relations the lack of specific methods for the uptake of RRI was seen as a central barrier for its adoption. Fourth, inadequate structures in the training, funding and governance of R&I were regarded as a hindrance for dissemination of RRI. Criticism was targeted at research systems as a whole, in other words governmental institutions, funding bodies, ethical boards, academic institutions, industry and corporations, and inoperable or non-existent networks between them. Fifth, the lack of proof of the benefits of RRI could be seen as a barrier for its uptake. This is certainly a matter of communicating the benefits to researchers and stakeholders.

The drivers of RRI were analysed by using PESTE frame, which can be used to depict political, economic, social, technological and environmental aspects of different phenomena.

Political drivers of RRI that were identified in the articles, include the strong vision from the EC and its manifestation in the funding programmes. The programmes also work as a tool for enhancing interaction between different actors in the field of research as well as promoting transdisciplinary research.

Economic drivers for RRI are also embedded in the mission of innovation policy. Innovation policy is expected to result in the development of better products and services, but also further in employment and economic growth.

Social drivers of RRI were found in the accounts on research and organisational cultures. The main cultural driver for RRI was found in RRI's cultural inclusiveness and its' potential to take into account conflicting and even contradictory interests simultaneously. Academia was also

seen as an important driver for RRI, as university teaching was seen at the core of raising awareness of RRI. In accounts on Horizon 2020, the ability of human and social sciences were acknowledged for their potential in raising awareness on RRI also in hard sciences.

Technological drivers of RRI were interlinked with the social drivers. Platforms were nominated as an important tool for knowledge sharing between different stakeholders and end-users as well as an important means for involving users in the innovation processes. In disseminating RRI, the concept of co-creation becomes important especially in involving the public.

Environmental drivers of RRI could be described as the environmental value that RRI is presumed to have, as it is targeted at fostering environmentally and socially sustainable research. Social sustainability was most clearly articulated in the hopes to encourage more self-reflexive research practices.

The focus on interaction between the stakeholders in RRI is accompanied by accounts on the value of performing RRI, namely the public good it produces and the general value in the involvement of multiple stakeholders, and citizens in particular. Indeed, on the basis of the broad content of RRI, it may be well-suited for addressing complex societal challenges and configuring the direction of scientific and technological development. It appears that these directions in relation to different stakeholders and general terms such as sustainability, need to be addressed and discussed more widely.

Part Four

Framing RRI in a changing science

1. Summary of the main issues

This literature review was aimed at collecting and organising useful information to start answering the basic question underlying FIT4RRI, i.e., how to match the little dissemination of RRI practices across disciplines and national research systems.

To this end, a pathway was followed, which focused on the changes affecting science and, partially, innovation (Part Two) and on RRI (Part Three).

As for the **transformations affecting science and technology**, the following points deserve to be mentioned.

- **Science and innovation are undergoing a long transitional phase**, variably interpreted through different (half-descriptive and half-prescriptive) models, (Mode 1 - Mode 2, Post-academic science, Post-normal science, Triple Helix approach, Academic Capitalism).

- **This transitional phase is part of a broader shift from modern to so-called post-modern society**, which affects in similar ways all social institutions (politics, religion, family, state administration, etc.). Whereas in the context of modernity they were solid, highly structured, authoritative, standardised and self-contained, in the post-modern context they appear to be weak, uncertain both of their own boundaries and internal procedures, and de-standardised.

- **This critical turn makes science socially weaker**. Indeed, science is now characterised by diminishing authority, uncertainty about internal mechanisms and standards, declining and increasingly uncertain access to resources, while public distrust and disaffection toward it increase.

- The transitional phases is also characterised by a **set of critical changes placing science at risk also in its most intimate mechanisms**, such as:

  - Hypercompetition and accelerated pace of research process
  - Structural shrinking of public research funds in a context of increasing costs of research activities
  - Task diversification and decreasing time devoted to scientific work
  - Increasing staffing combined with growing use of PhD students and Postdocs, mainly paid through research grants, and parallel reduction of permanent positions
  - Staff segmentation and polarization on the basis of age and contractual status, leading, e.g., to overexploitation and overtraining of young researchers, decline in teaching quality, changes in labour relations and modifications in researchers' identity
  - Increasing researchers' mobility, impacting on life quality and gender equality
  - Critical dynamics affecting the quality of research outputs such as, e.g., the crisis of reproducibility of scientific data, the production of redundant or irrelevant publications and the increasing spread of malpractices
  - Decreasing pressure on research assessment systems, due to lower quality peer review, combined with questionable use of quantitative indicators and rankings
  - Governance shift with broader of entrepreneurial models, leading to highly diversified governance approaches

- Increasing openness of research institutions toward external actors, producing benefits but also risky impacts on the life of research organisations.

Such trends suggest that, notwithstanding its advancements, science is not only socially weaker now than it was in the past but also less reliable in terms of its own technical procedures. This not necessarily affects purely innovation-oriented institutions (such as private research firms or developers) which are, on the contrary, acquiring an increasing role also in influencing how science works. This decreasing social relevance of science should be also interpreted as a progressive loss of the "exceptionality" recognised to research institutions in the modern world (Zwiek, 2015).

– All this is happening while the **political steering** of science and innovation is increasing, putting pressure on research institutions to get directly involved in innovation processes. Consequently, the management of science-in-society relations are becoming more complex and difficult to master.

As concerns the **analysis of RRI**, the following points can be highlighted.

– **RRI is a powerful concept**, thanks to its interpretive flexibility, its capacity to mobilise actors of different types, its capacity to encompass other similar concepts and its trendiness (to be noted, in this regard, is the massive presence of concepts referring to "responsibility" in many social domains, such as "responsible politics", "responsible eating", "responsible consumerism", "responsible religion", "responsible management education", "responsible mobility" or "responsible lifestyles").

– **RRI is a normative concept**, aimed at modifying R&I through different tools and strategies (rules, directions, codes of actions, etc.) on the basis of the hidden assumption that R&I has until now been under-responsible. Therefore, it is to be seen as a "system" to be applied wholescale, regardless of the applicability conditions, because of its intrinsic "ethical force". This means that, in principle, RRI has no limitations in terms of encompassing any possible desirable feature of R&I (including effectiveness, sustainability, inclusiveness, anticipatory orientation, responsiveness, reflexivity, transparency, care, proactivity, deliberation, accountability, equity, and efficiency) and has a broad application scope (promoting economic growth and innovation, anticipating risks for society and environment, fostering inclusiveness, etc.).

– **RRI is a social process**. At the same time, RRI is difficult to master since its implementation is a highly context-dependent, requires broad consensus from the many actors, needs considerable investments (in terms of resources and time), and may generate many unintended and undesirable effects. All this suggests that RRI, in practical terms, cannot but be a social process, entailing, e.g., activation of societal actors, new cultural inputs, resource mobilisation and, inevitably, resistance and obstacles

– **RRI is a concept that is almost exclusively applied to science-in-society relationships and not to the inner life of scientific institutions**. We could say that RRI concerns the "foreign affairs" of R&I institutions but not their "domestic affairs", except marginally. This means that many of the critical changes affecting R&I mentioned above (which are at the core of the worries and interests of researchers and research organisations) are not seriously considered or not considered at all by RRI.

2. Open questions

In this Section, an attempt is made to provide some possible orientations for the future steps of FIRT4RRI by identifying a set of key issues to be addressed.

As said in Part One of this report, the basic assumption of FIT4RRI is that there is a gap between the actual and the potential role RRI could play in managing the rapid transformation processes affecting science.

This literature review was therefore included in the project precisely with the aim of collecting pieces of information and knowledge that could help gain a **better grasp of the nature and size of this gap**.

Overall, the literature review allows us to single out **two mismatches** which contribute to producing such a gap:

- The mismatch between the concept and practice of RRI
- The mismatch between RRI and the transitional changes affecting R&I.

2.1. The mismatch between RRI concept and practice

There is a mismatch between how RRI is prevalently conceptualised and the actual nature of RRI when attempts are made to implement it.

Conceptually, RRI is prevalently expressed in **normative terms**, as a set of principles or even imperatives to be implemented, sometimes regardless of the actual application conditions (in this sense, it is more a normative than a prescriptive concept). Such principles are numerous and broad in scope, thus making the conceptualisation of RRI quite vague. However, this makes RRI a notion characterised by an interpretive flexibility which undoubtedly has favoured its success at least among the different scientific and policy circles particularly interested in science-in-society issues. Moreover, the reference to the notion of "responsibility" is symbolically effective in a post-modern context, since the weakening of the social structures is producing an emphasis, in every social sphere, of the mechanisms that allow individuals and organisations to be and feel responsible for the long-term effects of their own actions and choices.

The mismatch emerges when one **moves from theory to a practical plan**.

RRI is a notion too broad in scope and vague in its contents to be applied in its entirety. As we have seen in Part Three (Para. 1.3.), the models developed to make RRI actually implementable are either too ambitious and unrealistic or over-simplistic, reducing RRI simply to a set of aspects to keep under control. In both cases, they tend to overlook the many and complex barriers described in Part Three (Section 2), which may make RRI culturally extraneous, irrelevant, ineffective or unsustainable in the long run.

In this sense, RRI can be considered, in practical terms, not a simple approach, a project or a policy, but a **factual process** entailing, e.g., the activation of societal actors, new cultural inputs, resource mobilisation and, inevitably, resistances and obstacles.

These two spheres of RRI (the normative and the social) are often intertwined or confused. Rarely are they clearly distinguished or coordinated, thus making coexistence difficult to manage, since it may lead to paradoxes, simplification and inconsistent approaches.

2.2. The mismatch between RRI and changes affecting R&I

There is a **second mismatch** which can be observed, the one **between RRI and the transitional changes affecting science** (such as the increasing competition, the decreasing reliability and questionable use of research assessment, the lower reproducibility of scientific data, or the overexploitation of young researchers, especially women), which are basically ignored or their relevance and impacts overlooked.

This second mismatch is probably due to the misleading perception that the transitional changes affecting science have **nothing to do with science-in-society relations**.

This is not true at all. All these changes actually reflect general trends occurring in society (see Part Two) and pertain to modifications in culture, social practices, and social configurations which involve a variety of societal actors. This means that issues like peer reviewing, reproducibility of scientific data or the use of PhD students and Postdocs are also the expression of the changing relations between science and society and **may require the adoption of RRI principles** (anticipation, responsiveness, inclusion, reflexivity, etc.) and keys (ethical issues, public engagement, etc.).

This mismatch could be considered another factor which makes it difficult for RRI to become widespread, especially among researchers.

Researchers are challenged and worried by the transitional processes affecting science and innovation, such as publishing papers in as short time as possible, finding permanent positions for Postdocs and PhD students, successfully applying for research funds, performing the increasing number of non-scientific tasks required to compete in the research and innovation market, keeping the quality of research as high as possible. Thus, why should they be interested in RRI, if RRI prevalently concerns things they are not interested in? Why should they help RRI to spread while RRI does not help them to manage their problems?

3. A provisional framework for the experimentations

The literature review was aimed at identifying the problems and not to indicate solutions. However, this literature review is part of a broader project which also includes the organisation of RRI experimentations, the development of new training tools and the drafting of guidelines concerning the establishment of effective governance settings for RRI. Hence the need to start drawing a provisional framework for action.

3.1. Managing the mismatches

Thus, some possible albeit very provisional suggestions may be made about how to manage this double mismatch and, more in general, to realistically promote RRI in the areas of research less open to it. In particular, three main general orientations may be put forward.

- **RRI as a set of opportunities**. To start with, it might be useful to weaken the normative view of RRI. Rather than a set of principles and orientations to be applied to research practices, RRI should be more usefully viewed as a set of opportunities available to researchers, research institutions and other stakeholders to address the major problems they have to deal with in their daily business.
- **RRI as a regime of change**. It is necessary to recognise RRI as relevant to all transitional changes affecting science (and not only to those related to science-in-society issues), since all of them are connected to the changing relations between science and society. Moreover, RRI could be viewed as a regime helping research institutions, researchers and other relevant actors to manage such changes effectively.
- **RRI as a context-sensitive approach**. It is also important to affirm the context-sensitive nature of RRI. This means that any attempt to implement RRI principles and tools should be necessarily tailored to the actors involved in it.

These three orientations should, at least in principle, be able to reduce the double mismatch we mentioned above.

- If RRI is understood as a set of opportunities for research actors, the mismatch between RRI concept and practice can be managed in a much more flexible way. One takes from RRI only what is relevant to the issues he or she is facing.
- If transitional changes affecting R&I are viewed – as they actually are – as pertaining to science-in-society issues, RRI can be applied to them, both theoretically and practically. In this way the mismatch between RRI and transitional changes can be better managed.
- Finally, if RRI is viewed as a context-sensitive approach, both the first and the second mismatch can be managed not abstractly but within precise and verifiable experiential fields, i.e., those the actors are immersed in (research, innovation, teaching, gender relations, publishing, laboratory work, research grant application, etc.).

3.2. A model of social actor

In this perspective, **social actors** come to the forefront.

Indeed, it is up to the actors to identify the problems they are facing, to assess which opportunities RRI may provide to managing them better and to define the context of application in which such opportunities can be actualised.

This suggests that there is **not a unique RRI** but **many RRIs,** according to the actors who apply it in their own environment and work.

All these considerations, however, are of a mere theoretical nature. Practically, how to make them happen?

The basic assumption is that for RRI to function it needs to permeate, to different extents, the way in which social actors think, work, and manage their own internal dynamics and their external relations. “Social actors” here are mainly to be understood as research organisations or any other collective entities concerned with R&I.

In this regard, we could look again at the model sketched above and deepen it to distinguish the different barriers to RRI (Part Three, Section 2), this time in order to provide a model of the actor applicable to our needs.

According to this model, any collective actor can be analysed as made up of four **main components**, each one involved with an aspect of RRI:

- Culture
- Agency
- Action
- Identity.

Culture concerns any cognitive and cultural element providing the set of shared meanings necessary for the group to exist as a group. For example, the culture of a research unit may include its research mission and objectives, the disciplinary culture(s) of the members, the governance styles, the attitudes towards novelties, the symbols and rituals shared by all the members, and the like. From the RRI-implementation perspective, culture concerns the level of **awareness** the organisation and its members have about what is at stake in RRI.

Agency concerns the actor’s orientation to act and the energy (in any sense, from money or time to emotional energy) the actor is interested in investing. For example, a research group may be interested in investing in a given kind of research, in cooperating with the private sector, in increasing its visibility in the university, in constantly enlarging the group, in getting engaged with science communication, or in other things. All in all, the concept of agency refers to the the quantity and quality of energy the actor accumulates and is interested in investing and in what. Even though we are speaking of a collective actor, it is quite evident that a pivotal role is played by an individual’s interests, passions and mobilisation. From the RRI-implementation perspective, agency concerns the way in which RRI becomes **relevant**, i.e., something the organisation and its members recognise as useful for them to address the problems they are facing and worried about.

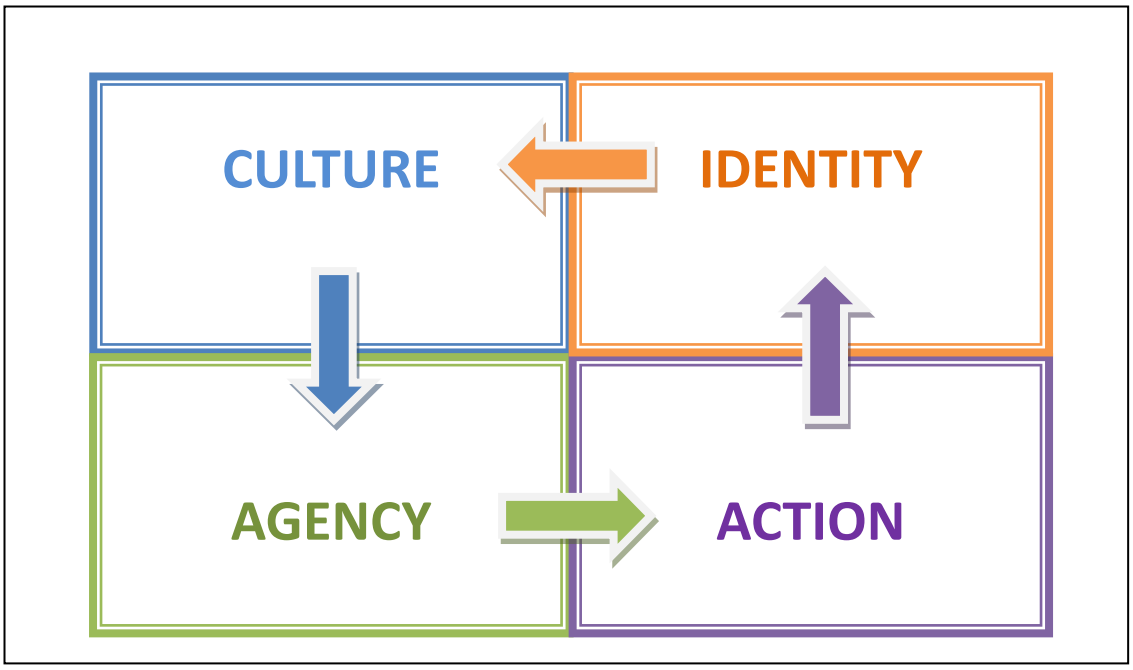
Action concerns what the actor actually does, how it is to be done, and what effects are produced. While agency represents the cognitive side of the action, the latter represents the actualisation of the former, even though the overlaps between the two may also be limited because of the many contingencies and constraints of the real world. From the RRI-implementation perspective, the action component concerns the way in which RRI becomes **effective**, i.e., actually useful for the development of the organisation.

Identity concerns the way in which actors control their own internal and external environment (Luckmann, 1982). Identity, therefore, includes any action aimed at ensuring this control and, especially, the interaction systems and networks, as well as all the practices enabling the organisation to coordinate internally and externally. The concept of identity is therefore also linked to and partially overlapped with that of **continuity**, intended as “the capacity to embed new activities in existing institutions or otherwise building bridges between separate interventions”

(Rask et al., forthcoming). From the RRI-implementation perspective, identity concerns the way in which RRI becomes part of the daily practices of the organisation, thus becoming **sustainable** in the long run.

The four components can be viewed as part of a **cycle**, by virtue of which changes in culture (awareness) are expected to modify actor agency (relevance) and, consequently, to produce changes in the actions performed (effectiveness), up to the modification of the internal and external configuration of the organisation (sustainability).

These dynamics can be schematised as follows.



Now, our assumption here is that RRI can only function if it influences, to a certain extent at least, these four components, thus raising actor awareness and achieving relevance, effectiveness and sustainability.

As a matter of fact, all these components play a pivotal role in these dynamics. In fact:

- Agency mobilisation not based on a RRI culture is **unproductive**, since it leaves mobilised agents isolated within the organisation and without any support
- Agency mobilisation which does not turn into action is **fruitless**
- RRI actions without agency mobilisation reflect a **top-down** and **unrealistic** approach
- RRI actions which do not result in permanent or long-term change in an organization, thus becoming part of the identity of the organization, can be useful from many respects but **useless** for embedding RRI in the ordinary activities of research institutions.
- An identity which does not change the culture of the organisation is **destined to fail.**

In this way, the key questions become why and to what extent RRI may contribute to improving the quality of all the components of an organisation and how to introduce practically the "enzyme" of RRI in the system.

3.3. An outline for an action scheme

To appropriately address these questions, a set of practical orientations can be given, so as to define an outline for an action scheme.

Four main steps can be isolated.

The **first step** is to **establish the actor**, i.e., the group which is involved in the RRI implementation process. To do that, it is necessary to start by operationally identifying the actor in, so to speak, institutionally terms (for example, a research group, a university department, a university institution, a firm, a research group in the firm, a civic association, etc.), and attempting to make a self-analysis of it in terms of culture, agency, action, and identity.

The **second step** is to **identify the critical issues** an actor is facing, should face or is interested in facing in the next future. This may include both the general trends affecting R&I in general (mentioned in Part Two) or local problems (for example, access to resources, interactions with other groups or departments, lack of skills, lack of time, etc.).

The third step is **develop a self-tailored profile of RRI**, i.e., an idea or vision of RRI which can be applicable to the nature and features of the actor (first step) and which can help solve the problems the actor is facing (second step). The key here is to understand the added value of RRI for the actor both to address present or future problems and to open up new opportunities. At this stage, the option of not engaging the organisation in RRI-oriented actions is also seriously to be considered.

The fourth step is to **establish an action plan**, identifying problems and issues, RRI-oriented actions and their expected outputs pertaining to the four components, so as to make RRI something useful and feasible.

Needless to say, the complexity of such a scheme is quite variable, depending on the size, nature and organisational structure of the actor.

It is advisable for each step to lead to a **document** summarising outputs and paving the way to the next step. A participatory approach may be adopted, to avoid also any form of tokenism or "imposing" RRI as something external.

The scheme is summarised in the table below.

STEPS	CONTENTS	OUTPUTS
Establishing the actor	Self-analysis of the actor in terms of culture, agency, action, and identity	Defining boundaries and features of the actor, including internal components and external relations
Identifying critical issues	Self-analysis of the actor in terms of present or future problems	Defining the problems and risk for the actor and actual or possible consequences
Developing a self-tailored profile of RRI	Self-analysis of the actor in terms of the added value of RRI in addressing the problems identified	Defining a profile of RRI tailored to the actor's features, needs and expectations
Establishing an action plan	Identification of problems, issues, actions and expected outputs in applying RRI	Defining an action plan to address the actor's problems

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