Monitoring the evolution and benefits of responsible research and innovation in Europe

Summarising insights from the MoRRI project

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Summarising insights from the MoRRI project

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EXECUTIVE SUMMARY

Monitoring the evolution and benefits of Responsible Research and Innovation (RRI) in Europe has been a three-and-a-half year-long endeavour in terms of conceptual thinking, data challenges, pragmatic solutions, critical reflections and last but not least substantial findings.

The study programme started with an initial scoping of the RRI dimensions (Gender equality, Public engagement, Science literacy and science education, Open access, Ethics, and as overarching dimension Governance). A heavy data collection exercise - including the collection of existing data and the launch of different surveys - was complemented by qualitative research in the form of case study analysis and the identification of benefits. Testing the data results for robustness and significance led to identification of core indicators and a clustering of EU countries. Conceptual ideas about the identification and measurement of benefits led to the development of impact pathways, which suggest that RRI dimensions are overlapping and self-reinforcing and creating a range of benefits.

While this provides a description of what the project has done and achieved, the following summarises the main insights from our work. We include a few 'to-do's' - suggestions for actions that will help in further monitoring activities but also provide some hands-on ideas how organisations can embrace the concept and keep mainstreaming RRI in their routines and procedures.

Keep learning from each other

Initially starting from 36+ indicators for the six RRI dimensions, the analysis of how they actually relate to each other and the latent variables, 11 RRI dimensions materialised empirically, and 25 indicators turned out to be particularly strong indicators for the 11 dimensions. They can be used to characterise individual countries, but also to **explore similarities and differences between and within clusters of countries**.

The analysis reveals four country groups with distinctive RRI patterns:

- The first cluster is made of *Austria, Luxembourg, Ireland, Malta, the Czech Republic, Greece, Cyprus* and *Hungary*. It is characterised by having below-average scores on most of the 11 RRI dimensions. Within this cluster, there is a rather moderate level of accomplishment overall concerning RRI.

- The second cluster includes Bulgaria, Poland, Slovenia, Croatia, Lithuania, Estonia, Latvia and Slovakia. The cluster performs particularly well on 'GE status', 'Science literacy and science education', and 'Ethics in RFOs', and also rather well on both sub-dimensions of open access. The average score of countries within this cluster on 'GE action' and 'governance' is considerably lower than for the other clusters. An interesting observation concerns the distance between gender equality status and action: countries with a high level of accomplishment in terms of gender equality in science are less prone to be highly active regarding gender equality policies and action plans at the institutional level. This might partly be seen as a 'no problem – no need for

action' situation in countries in which the historical labour market trajectories have been more conducive to gender equality in science.

- The third and smallest cluster includes Spain, Portugal and Romania, and is characterised by high scores on just about every second dimension and fairly low scores on the other half. On one dimension, 'PE in assessment', this cluster is doing particularly well. Member States within this cluster also on average score very highly on both gender equality status and open access status, while in the other dimensions they score very low.

- The fourth and final cluster includes Belgium, Germany, France, Denmark, Italy, the Netherlands, Finland, Sweden, and the United Kingdom. The cluster is generally performing above average. Exceptions include the dimensions of 'GE status' and 'OA status', where the average score of the Member States in this cluster is low. When it comes to PE participation and SLSE culture, countries within this cluster are particularly committed to these areas.

The results demonstrate that there is **significant diversity in the European RRI landscape**. Attention, efforts and priorities across the 11 sub-dimensions differ across Member States. The roots of diversity may require a subtle understanding of historical trajectories in the relationship between science and society, and R&I policy approaches, as well as political and civic culture.

These different patterns are not set in stone but change occurs slowly. The learning could be enriched for example through a European hub for RRI, which collects and shares learning from such activities.

To do: Make use of the MoRRI indicators as a learning platform and to foster exchange; for example by integrating them in existing RRI platforms.

Creative data collection and linking strategy needed

Given the efforts required to collect primary data (survey fatigue, reluctance to provide information, etc.), more thinking is needed to develop a *creative data collection and linking strategy* that draws on existing data sources.

In order to include various perspectives, this could include relevant Eurobarometer results from different survey waves to capture public opinion, Eurostat data, data collected though the SHE Figures series, but also to explore data mining techniques of institutional websites and repositories and assess the usefulness of this approach.

Moreover, a potential wealth of information could be mined using the *proposal and monitoring data* from Framework Programme participation. Questions on ethics, gender and open access are included in the reporting requirements by each (potential) participant. Thus, a thorough analysis of this data opens up significant insights on a very large number of European research and innovation organisations.

To do: Develop a smart, inclusive and creative data collection and linking strategy that avoids survey fatigue and opens up detailed insights into the practice of RRI

Four areas of RRI benefits

There are two important elements that distinguish RRI benefits from being simply an extension of a 'from-inputs-to-impacts' intervention logic: RRI benefits can be attributed directly to transformations in processes that are embedded in implementation activities and to transformations with a normative character. In order to capture these benefits, impact pathways were conceptualised. These pathways can be analysed in terms of *integration*, *implementation, and contribution*. RRI benefits were initially categorised as **societal**, **democratic**, and **economic** benefits, but in the course of the work various **scientific** benefits were also identified.

While the emergence of benefits of these four different types may be attributable to a particular RRI dimension, benefits should also be thought of as driven and/or reinforced by multiple RRI dimensions.

Three observations can be made regarding the MoRRI identification of potential RRI benefits. First, the potential **metrics and indicators** of RRI benefits developed were **not evenly distributed across RRI dimension.** Second, **potential RRI benefits are not distributed evenly by type**. For example, economic benefits were less readily identifiable for the public engagement and science literacy dimensions. Democratic benefits were lacking in the ethics and open access dimensions. Third, **the character of the benefits identified varies considerably**. Many RRI benefits identified were of a very general character, which is logical when considering benefits at a societal scale. The narrower benefits identified were often focused mainly on the R&I system itself. Whilst benefits for science and for the R&I are important in themselves, these will take time, when and where applicable, to translate into benefits at a societal scale.

To do: Attribute observable benefits to the implementation of particular RRI activities or interventions; move beyond simply identifying and measuring perceptions that this is the case.

It is the organisation that matters

The MoRRI monitoring indicators focus on the national level. MoRRI has thus produced a tool that can help map and compare RRI activities at national level. The underlying data, however, comes from organisations. Our primary data collection strongly demonstrates the **crucial influence of organisational factors for implementing RRI.**

The institutional environment can positively influence the degree of RRI activities and the general attitudes towards more responsible research and innovation. Researchers working in an institutional environment that systematically supports the practice of RRI, for example, through funding incentives for public engagement, having dedicated staff in charge of RRI pillars, etc., are more active in RRI practices than researchers who cannot rely on such structures.

While country-level monitoring is useful for national policy makers to see where a country stands *vis à vis* other countries, **understanding the patterns and effects of policies requires a deeper understanding of structures and impacts at the institutional level.**

To do: Combination of quantitative and qualitative approaches in future RRI monitoring activities and a stronger focus on the meso-level.

Changes occur slowly

We have seen from the survey data as well as available Eurostat data that measurable institutional change happens rather incrementally and over a number of years. The least amount of year-to-year change can be expected for policies that depend almost entirely on the institution itself, for example, if an organisation encourages its researchers to be involved in citizen science projects or engages with the public – or not. In other cases, legally binding policies, e.g., ethics committees or gender equality plans – which have to be applied within all relevant institutions – will show no change from the point these policies are implemented. Soft-law, which can be found in open access policies, will most likely show subtler annual changes. Furthermore, one needs to also take into account that new, structurally changing R&I policies – programmes, measures or legal requirements – do not apply on a continuous basis, meaning we can expect to see rather sudden changes after several years of little change. All these factors suggest limiting monitoring to every two to three years.

To do: Limit the data collection to every 2 or 3 years.

Promote RRI

There is still a long way to go regarding the 'universe' of researchers in Europe before RRI is more broadly known and accepted. Researchers receiving funding from the EU framework programme are more familiar with the concept of RRI, and they also associate more future benefits than non-funded ones. Furthermore, the EU-funded researchers are more likely to practise activities related to the five RRI dimensions. What seems to be a hampering factor is a strong overload of tasks – this is in particular the case for younger, less- or non-established researchers. In general, the institutional environment can positively influence the degree of RRI activities and the general attitudes towards more responsible research and innovation. Researchers benefitting from a conducive environment that systematically supports the practice of RRI are more active in RRI practices than researchers who cannot rely on such structures. Overall, the most important supportive factors are personal motivation and the institutional strategy.

Researchers perceive scientific benefits from RRI in particular concerning 'visibility in the research community' and 'emergence of new research topics'. In terms of economic benefits, 'faster diffusion of knowledge' is regarded as the most important benefit, followed by the stimulation of innovations. Researchers also perceive societal benefits with an 'increasing interest in science' and the 'improvement of curricula and enlarged competences among students' were the two items that were most frequently reported benefits.

If RRI is not only confined to FP participation but truly mainstreamed in the Member States, it is important to envisage all research and innovation stakeholders – including industry, and to include the expected and experienced impacts on society. This may require a different mixed-method approach and the development of new or the use of existing proxy indicators.

To do: Further promote RRI - also including industry – through a set of measures at EU as well as national or regional levels.

1 Introduction

Research and innovation is an increasingly powerful force in shaping the future. There is enormous potential for science and technology to contribute towards tackling global challenges, such as those identified by the United Nations Sustainable Development Goals. Maximising the potential of research and innovation to make a difference while understanding and mitigating the new risks and ethical dilemmas that come from technological progress demands thoughtful governance. Technological power forces us to confront questions of responsibility. According to the European Commission's most recent definition, 'Responsible research and innovation is an approach that anticipates and assesses potential implications and societal expectations with regard to research and innovation, with the aim to foster the design of inclusive and sustainable research and innovation'.[1] The hope is that, in the Commission's words, 'societal actors (researchers, citizens, policy-makers, business, third-sector organisations, etc.) work together during the whole research and innovation process in order to better align both the process and its outcomes with the values, needs and expectations of society'.

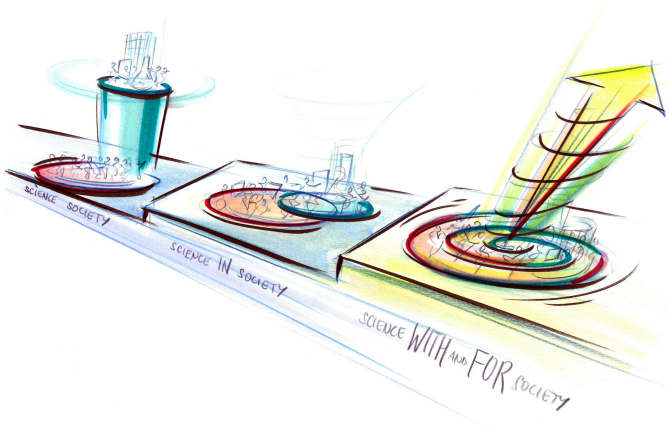
The Rome Declaration on responsible research and innovation (RRI), produced as part of the 2014 Italian presidency of the European Union, diagnosed the challenge in these terms:

> First, we cannot achieve technology acceptance by way of good marketing. Second, diversity in research and innovation as well as the gender perspective is vital for enhancing creativity and improving scientific quality. And third, early and continuous engagement of all stakeholders is essential for sustainable, desirable and acceptable innovation.[2]

The declaration called for Member States to prioritise RRI and develop ways to measure and talk about research and innovation that support more responsible practices.

Studies have shown that there are significant obstacles at both national and organisational levels to mainstreaming RRI across the European Research Area (Smallman et al., 2015; Mejlgaard and Griessler, 2016). These relate to priorities and incentive schemes, but also simply to the lack of adequate measures of and for responsibility in research and innovation. The inability to evaluate, compare and benchmark constitutes a barrier to international and organisational learning, whereas identification of useful indicators and metrics for RRI might contribute to bringing RRI from a peripheral position closer to the centre of activity.

The Monitoring the Evolution and Benefits of Responsible Research and Innovation (MoRRI) project responds and contributes to this agenda. It is concerned with the development of conceptually and empirically sound RRI indicators and takes the first steps towards identifying the impacts of responsible practices in research and innovation. It combines review activities with an extensive empirical programme to formulate and populate measures of RRI. Components of the empirical programme include the



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[1] See: https://ec.europa.eu/programmes/horizon2020/en/h2020-section/responsible-research-innovation

[2] Rome Declaration on Responsible Research and Innovation in Europe, 21 November 2014, https://ec.europa.eu/research/swafs/pdf/rome_declaration_RRI_final_21_November.pdf

collection of large-scale survey-based data from among European researchers, research-funding organisations, research-performing organisations, societal stakeholder organisations and manufacturing businesses; an extensive set of case studies addressing the benefits of RRI; the collection and analysis of databases, including bibliometric and patent data; secondary analysis of existing datasets at individual and country level; and desk research and qualitative data collection.

As the European Commission gears up towards the Ninth Framework Programme (FP9), it is more important than ever to consider the social contract that underpins its investments in science. This report seeks to support this process.

1.1 From 'science and society' to 'responsible research and innovation'

The changes in how European science relates to citizens are mapped in the terminology of European Framework Programmes.

Scientists and policy makers have come to appreciate that it is neither possible nor desirable to keep science behind closed doors. The Sixth Framework Programme funded work on 'Science *and* society'. The Seventh Framework Programme urged as a priority closer integration with 'Science *in* Society'. Horizon 2020 pushed for 'Science *with and for* Society', inviting members of the public into the processes of science as well as into discussions about its purposes.

As with the UN's Sustainable Development Goals (SDGs), aspirational agendas need to be coupled with measurable indicators.[3] The idea of 'responsible research and innovation' in the service of such global challenges is starting to spread through the European research and innovation system.[4] The impact of this idea is hard to measure in the abstract.

The Science with and for Society part of Horizon 2020 has eight lines, covering the six 'key areas' of RRI: gender equality (GE), science literacy and science education (SLSE or science education), public engagement (PE), open access (OA), and ethics (E) and governance (GOV)[5].

As science comes under growing pressure from its funders to contribute towards economic growth and to solve grand societal challenges, the need for a vibrant debate on responsibility only becomes stronger. The growth of uptake of RRI suggests a renewal of the scientific ideal of openness. The promise of 'Open science, open innovation, open to the world'[6] means making science open to new possibilities and new kinds of people. There is a public appetite for open access to scientific publications, democratic debate and science activities for citizens. Science *for* the people may in some cases involve science *by* the people.

Responsible research and innovation means changing the cultures and practices of science, business and policy. The evidence suggests that change is both possible and is already happening, but at the same time established patterns of 'how things are done' in research are often very difficult to overcome and resist structural changes.

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[3] In the case of the SDGs, 17 goals are supported by 230 agreed indicators.

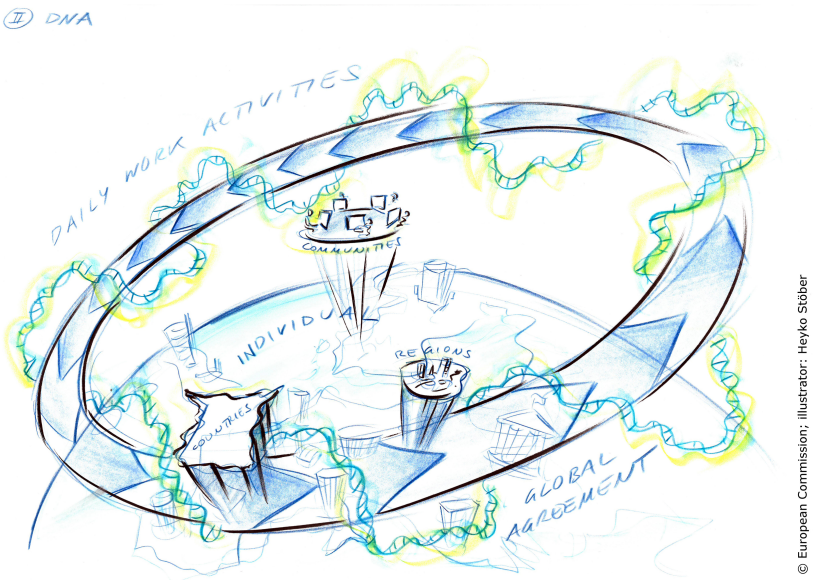
[4] Data in MoRRI indicator report, 2017.

[5] The lines of SwafS that are not RRI key areas are science careers, science communication, and due and proportionate precaution (though there are of course obvious conceptual links between them and RRI).

[6] Open innovation, open science, open to the world – A vision for Europe, Directorate-General for Research and Innovation, 2016.

1.2 RRI in action

The stated aim of the European Commission's work on Science with and for society is 'to build effective cooperation between science and society, to recruit new talent for science and to pair scientific excellence with social awareness and responsibility'. In recent years, there has been a growing focus, among both policy makers and researchers, on ideas of responsible research and innovation as a way to ensure that the mistakes of past technologies are not repeated and new sources of public value are captured.



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The question therefore becomes how research and innovation can become more responsive to these while taking into account and mitigating the unanticipated, unintended and undesirable consequences of emerging science and innovation. Responsible research and innovation draws on previous activities such as anticipatory governance (Karinen and Guston, 2010), constructive, real time and other forms of technology assessment (Rip et al., 1995; Guston and Sarewitz, 2002; Grin and Grunwald, 2000), upstream engagement (Wilsdon and Willis, 2004), value-sensitive design (Friedman, 1996) and socio-technical integration (Fisher et al., 2006). In the British context, RRI is imagined as having four dimensions, summarised by the United Kingdom's Engineering and Physical Sciences Research Council (the largest British government funder of scientific research) as 'Anticipate, reflect, engage, act'[7].

RRI is a cross-cutting issue of Horizon 2020, working across the priorities of the programme. The European Commission brings together different issues under the RRI umbrella. Each of these brings its own policy specifics, but they can rightly be grouped together as a common agenda to do with shaping the processes, purposes and products of research and innovation towards social needs and aspirations.

1.3 Visions of RRI

RRI will inevitably mean different things to different people, and demand different forms of engagement in different countries, cultures and scientific disciplines. As with any agenda that proposes changes to cultures and practices, RRI activities will encounter resistance. RRI, if it is to succeed, should be seen as a set of activities that are done *with* and *by* the research and innovation community rather than *to* it. With this in mind, our project's visioning workshop looked for desirable futures that could be a basis for ongoing dialogue between research and innovation communities, stakeholders and the generic public. These visions were articulated with respect to RRI in general, as well as its constituent policy agendas.[8]

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[7] See EPSRC's framework for responsible innovation, drawing on Stilgoe's research, http://www.epsrc.ac.uk/research/framework/Pages/framework.aspx

[8] 19 research and innovation (R&I) actors from 15 European countries representing the core R&I actor groups (academia, research and technology organisations, policy and industry), and five colleagues from different units of the European Commission participated in the visioning workshop (September 21 to 22, 2015). The

The following visions and perspectives on RRI emerged:

- RRI is in your DNA, embedded in daily activity across all actors.
- There is a multiple and diverse understanding of excellence in research and innovation.
- There is a merit and incentive structure to support RRI at all levels.
- RRI is a creative activity or opportunity rather than a burden.
- Society is actively involved in all steps of the research process – agenda setting, evaluation, implementation.

The vision, jointly developed by the participants, provided both initial substantive and normative orientation for the project's ensuing research process of developing an improved understanding of the benefits of RRI and possible indicators for their measurement.

1.4 About this report

This is the final report of the MoRRI (Monitoring the evolution and benefits of responsible research and innovation) study contract.[9] The study identified and measured the scope and the benefits or responsible research and innovation for Europe by:

- developing and operationalising a sound conceptual framework and associated methodology, while at the same time
- testing the potential of this methodology to allow monitoring the current state and short-term evolution of responsible research and innovation and its socio-economic and democratic impacts.

This final report presents findings from the development and operationalisation of the concept, while the results on individual indicators and the monitoring of developments are integrated in the complementary report *The evolution of Responsible Research and Innovation in Europe: The MoRRI indicators report* (2018). In this final report, we aim to highlight some methodological aspects and focus particularly on conceptual and empirical findings – including identification of benefits.

Following the introduction (section 2.1), we focus on the individual RRI dimensions by presenting short overviews and highlighting some of the empirical results (section 2.2). The data were then tested and two main findings emerged: 11 sub-areas for the RRI dimensions and dedicated country clusters. These are presented in section 2.3. Section 3 then focuses on the benefits of RRI. Following the definition (section 3.1) and identification (section 3.2) of benefits, we present the results from a large selection of case studies (section 3.3) and a dedicated researchers' survey (section 3.4). A reflection of impact pathways (section 3.5) and alternative benefit indicators (section 3.6) are followed by a critical reflection and looking at future developments (section 3.7). The final section (4) is more forward looking, providing some learning and, based on this, suggesting ways forward.

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vision was developed through a visioning process starting from individual visions of the participants that were then synthesised in ever-larger group compositions until finally an agreement on five key elements was reached. For more details, see D5.1 (www.morri-project.eu).

[9] Contract number RTD-B6-PP-00964-2013, Duration 09/2013-03/2018.

2 Emerging patterns of RRI

2.1 Introduction

While issues of responsibility in research and innovation will always be situated in particular social, geographical and policy contexts, it can be useful to think about broad themes that may help to establish the field of interest.

Each of the six key areas of RRI reflect lines of thinking in policy, practice and scholarship about the interrelatedness of science and society, and are informed by variants of technology assessment, risk assessments, foresight, anticipatory governance, value-sensitive design, research ethics, upstream engagement and scientific citizenship. One of the strengths of the six-keys approach to RRI is its ability to integrate and build on decades of efforts related to understanding and improving the interaction of science and society.

Any attempt to measure and monitor RRI, even if confined to the operational six-keys definition, is challenging, not least because of the complexity and subtleness ingrained in each of these areas. Just as in music, a 'key' is indeed an umbrella for multiple scales and chords that go together well. Gender equality, for example, is more than equal representation of men and women in academia; it also concerns structural changes in academic institutions to promote diversity and giving priority to gender issues in the contents of research. In this sense, conceptual and empirical clarification of the relevant issues under each thematic key is a prerequisite for monitoring.

In the MoRRI project, several steps were taken in the process towards being able to measure and monitor RRI. First, a comprehensive review of literature and previous research projects was carried out for each key area. Six analytical reports[10] conveyed the results, which included a conceptualisation of the respective key areas. These conceptual outlines informed a subsequent review of existing indicators and metrics potentially qualified to populate the six areas, a mapping of the limitations of primary data, and development of supplementary indicators requiring primary data collection across the six areas. After several iterations, a set of 36 indicators was selected for the purposes of the MoRRI monitoring study.[11]

In section 2.2 below, the 36 RRI indicators are listed and following this, the key areas are briefly presented. We also show the patterns across countries on a selection of indicators. In section 2.3 we explain what we did to identify statistically robust indicators. We then examine the empirical interrelatedness of individual indicators in section 2.4, and analyse the broader similarities and differences across clusters of countries.

2.2 RRI indicators

The MoRRI project has been worked from an intervention logic, which in principle encompasses a need for understanding the inputs in terms of responsible practices and the immediate outputs of these, as well as the longer-term impacts. It recognises that benefits are being generated both in relation to the immediate processes and to the later consequences of responsible practices in research and innovation. When it comes to the RRI indicators, these provide only a limited view of such processes and lack the dynamic view of how practices within the key RRI areas have developed over time.

In compliance with the aims of MoRRI, all indicators target the country level, even though most of them are based on data aggregated from the level of institutions or individuals.

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[10] The six analytical reports (D2.1, D2.2, D2.3, D2.4, D2.4.1, D2.4.2) can be found on www.morri-project.eu or http://www.technopolis-group.com/morri/

[11] The process of identifying and selecting indicators of RRI is described in reports D3.1 and D3.2. see www.morri-project.eu. The initial list of 36 indicators can be found in D3.2.

MoRRI has compiled a significant body of data at the micro and meso-level, which may later be used to examine patterns at the level of organisations, researchers or citizens. The project has sought to capture RRI through indicators that are both relevant, robust and can be collected across all EU Member States. The data collection included primary data through surveys to research-performing organisations, research-funding organisations, other science actors, and industry[12]. Secondary data was generated for bibliometric and patent indicators. Qualitative information was collected through secondary information and transformed to quantitative data where useful and possible . Table 1 below provides an overview of the 36 indicators, or to be more precise, we should say 36+ indicators, since several of the indicators actually cover several individual measures[13].

Table 1 36+ RRI indicators

RRI dimension	Indicator code	Indicator title	Year(s)	Source
Gender equality	GE1	Share of research-performing organisations with gender equality plans	2014-2016	HEI, PRO surveys
	GE2	Share of female researchers by sector	2007, 2014	Eurostat
	- GE2.1	Share of female researchers – all sectors	2007, 2014	Eurostat
	- GE2.2	Share of female researchers – business enterprise sector	2007, 2014	Eurostat
	- GE2.3	Share of female researchers – government sector	2007, 2014	Eurostat
	- GE2.4	Share of female researchers – higher education sector	2007, 2014	Eurostat
	GE3	Share of research-funding organisations (RFOs) promoting gender content in research	2014-2016	RFO survey
	GE4	Dissimilarity index	2009, 2012	SHE Figures, 2012, 2015
	- GE4.1	Dissimilarity index: higher education sector	2009, 2012	SHE Figures 2012, 2015
	- GE4.2	Dissimilarity index: government sector	2009, 2012	SHE Figures 2012, 2015
	GE5	Share of research-performing organisations (RPOs) with policies to promote gender in research content	2014-2016	HEI, PRO surveys
	GE6	Glass ceiling index	2010, 2013	SHE Figures, 2015
	GE7	Gender wage gap	2010, 2014	Eurostat
	- GE7.1	Gender wage gap – academic professions	2010, 2014	Eurostat
	- GE7.2	Gender wage gap – technicians and associate professionals	2010, 2014	Eurostat
	GE8	Share of female heads of research-performing organisations	2014-2016	HEI, PRO surveys
	GE9	Share of gender-balanced recruitment committees at research-performing organisations	2014-2016	HEI, PRO surveys

[12] Industry data was collected in in the context of the European Manufacturing Survey (EMS).

[13] For an extensive introduction to every indicator, please consult MoRRI report D4.3, see http://www.technopolis-group.com/morri/ or the Annex of the *MoRRI indicators report* (2018). While it is envisaged that the indicators developed in MoRRI will pave the way for sustained data collection, at this current stage the indicators serve mainly to provide a detailed snapshot of activities, status and actions to promote RRI during the period of 2014 to 2016. When it comes to some of the indicators based on secondary data, the reference year is further back.

RRI dimension	Indicator code	Indicator title	Year(s)	Source
	GE10	Share of female inventors and authors	2005-2016	Patstat, Scopus
	- GE10.1	Share of female authors	2005-2016	Scopus
	- GE10.2	Share of female inventors	2005-2016	Patstat
Science literacy and science education	SLSE1	Importance of societal aspects of science in science curricula for 15 to 18-year-old students	2016	Desk research and interviews
	SLSE2	RRI-related training at higher education institutions	2014-2016	HEI survey
	SLSE3	Science communication culture	2012	MASIS
	SLSE4	Citizen science activities in research-performing organisations	2015, 2016	ECSA, Scopus
	- SLSE4.1	Organisational memberships in ECSA	2015, 2016	ESCA
	- SLSE4.2	Citizen science publications	2015, 2016	Scopus
Public engagement	PE1	Models of public involvement in science and technology decision-making	2012	MASIS
	PE2	Policy-oriented engagement with science	2010	Eurobarometer
	PE3	Citizen preferences for active participation in science and technology decision-making	2013	Eurobarometer
	PE4	Active information search about controversial technologies	2010	Eurobarometer
	PE5	Public engagement performance mechanisms at the level of research-performing organisations	2014-2016	HEI, PRO surveys
	PE6	Dedicated resources for public engagement		Indicator dropped - results from HEI and PRO surveys on resources for PE are inconsistent.
	PE7	Embedment of public engagement activities in the funding structure of key public research-funding agencies	2014-2016	RFO survey
	PE8	Public engagement elements as evaluative criteria in research proposal evaluations	2014-2016	RFO survey
	PE9	Research and innovation democratisation index	2016	SiS survey
	PE10	National infrastructure for involvement of citizens and societal actors in research and innovation	2016	SiS survey
Open access	OA1	Open access literature	2010, 2016	DOAJ list, PMC, the ROAD list, CrossRef, and OpenAIRE
	- OA1.1	Share of open access publications	2010, 2016	DOAJ list, PMC, the ROAD list, CrossRef, and OpenAIRE
	- OA1.2	Citation scores for OA publications	2010-2014	DOAJ list, PMC, the ROAD list, CrossRef, and OpenAIRE
	OA2	Data publications and citations		Indicator dropped - Underlying data inconsistent and erratic.
	OA3	Social media outreach/take-up of open access literature	2012-2015	WoS and Altmetric.com

RRI dimension	Indicator code	Indicator title	Year(s)	Source
	- OA3.1	Ratio of OA and non-OA publications used on Twitter	2012-2015	WoS and Altmetric.com Limited to publications
	- OA3.2	Ratio of OA and non-OA publications used on Wikipedia	2012-2015	WoS and Altmetric.com Limited to publications
	OA4	Public perception of open access	2013	Eurobarometer
	OA5	Funder mandates	2011	DG-RTD
	OA6	Research-performing organisations' support structures for researchers as regards incentives and barriers for data sharing	2014-2016	HEI, PRO surveys
Ethics	E1a	Ethics at the level of research-performing organisations	2014-2016	HEI, PRO surveys
	E1b	Ethics at the level of research-performing organisations (composite indicator)	2014-2016	HEI, PRO surveys
	E2	National ethics committees' index	2012	EPOCH
	E3a	Research-funding organisations' index	2014-2016	RFO survey
	E3b	Research-funding organisations' index (composite indicator)	2014-2016	RFO survey
Governance	GOV1	Use of science in policymaking	2012	MASIS
	GOV2	RRI-related governance mechanisms within research-funding and performing organisations	2014-2016	RFO, HEI, PRO surveys
	GOV3	RRI-related governance mechanisms within research-funding and performing organisations – composite index	2014-2016	RFO, HEI, PRO surveys

As referred in the "source" column of table 1, the data collection efforts conducted by the project team included four surveys that were launched since 2016, collecting data for the years 2014 to 2016, namely:

- Science in society stakeholders survey (SiS survey);
- Research-funding organisations survey (RFO survey);
- Higher education institutions survey (HEI survey) and;
- Public research organisations (PRO survey).

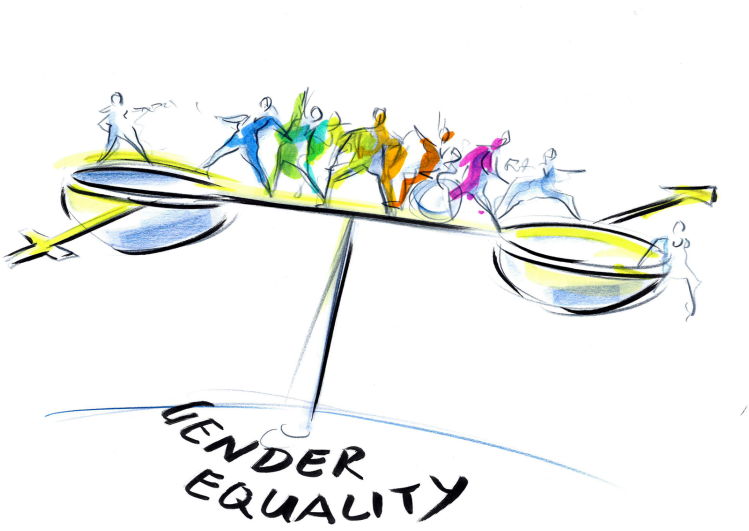
Table 2 provides information on the sample sizes, response rates (overall) and where the questionnaires can be accessed. More information about the survey results and the produced indicators can be found in the MoRRI indicators report[14].

[14] Peter, V., Woolley, R., Spaini, C. and Maier, F. (2018). The MoRRI indicators report (D4.3), February 2018. Peter, V., Woolley, R., Spaini, C. and Maier, F. (2018): The MoRRI indicators report (Annex) (D4.3), February 2018.

Table 2 MoRRI surveys

Survey	Sample size[15]	Overall response rate	Questionnaire
SiS survey	686	48%	MoRRI indicators report - Annex 3.1
RFO survey	275	44%	MoRRI indicators report - Annex 3.2
HEI survey	1479	18%	MoRRI indicators report - Annex 3.3
PRO survey	1486	14%	MoRRI indicators report - Annex 3.4

The following sections provide a brief glimpse into the key areas and some of the indicators included. It is not meant to cover all indicators – this is provided in the previously mentioned monitoring report – but to provide an overview of the rather complex key areas.



Gender equality

The dimension of gender equality was conceptually expected to be shaped by three sub-dimensions. The first concerns the **representation of women in research and innovation** with the objective to reduce gender segregation. Four indicators investigate national variations in the horizontal and vertical gender segregation of researchers.

GE2: **Share of female researchers by sector** accounts for the gender distribution of researchers across sectors (i.e. higher education, government and non-profit sectors), hereby providing basic information on sectorial variations with respect to women's opportunities and barriers. GE4: **Dissimilarity index** comprises information on the horizontal gender segregation of researchers in the higher education and government sectors. GE6: **Glass ceiling index** addresses the issue of vertical segregation, by measuring women's chances of reaching the highest academic ranks relative to men's. GE7: **Gender pay gap** measures gender variations with respect to annual earnings, and is used as a proxy for gender equality in the non-academic research sector. GE10: **Number and share of female inventors and authors** illuminates developments in women's representation across fields and sectors over time, on the basis of bibliometric data and patent counts.

The second sub-dimension concerns actions **to promote gender equality**, the structural and organisational changes in research institutions with the aim to break down structural

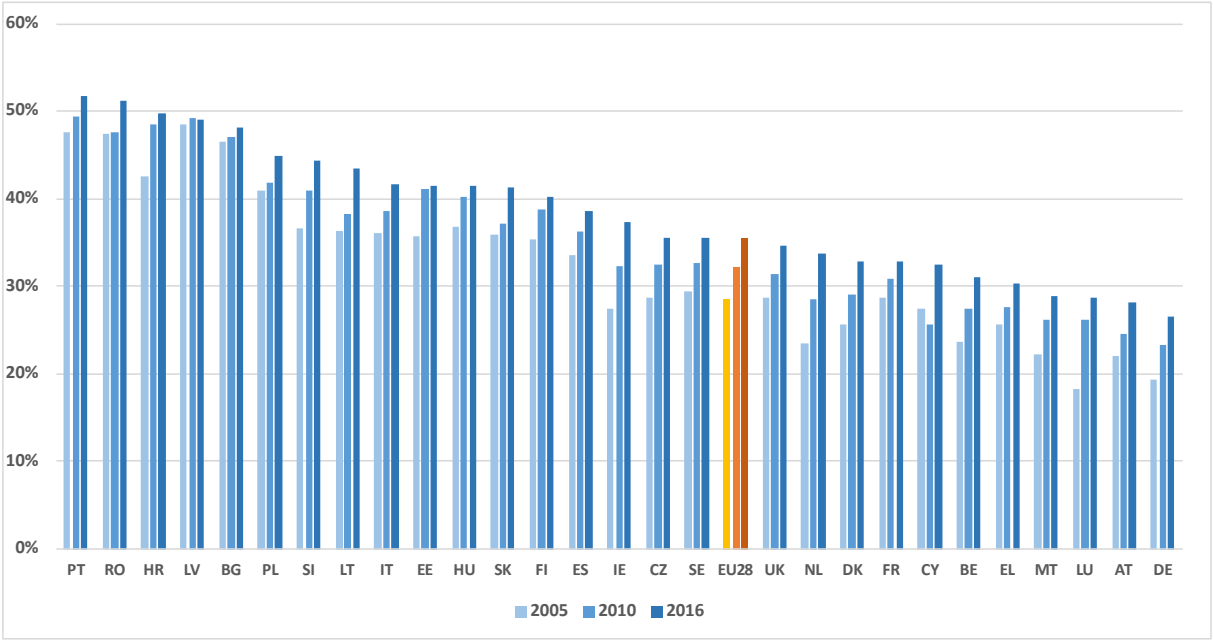
[15] Number of contacts does not necessarily correspond to number of organisations. In some cases, several contacts per organisation were identified, in order to maximize chances of obtaining a response

gender barriers by means of action plans and gender budgeting, among other actions. GE8: **Share of female heads of RPOs** and GE9: **Share of gender-balanced recruitment committees at RPOs** monitor female participation in key gatekeeping positions that involve decision-making for strategy and employment. GE1: **Share of RPOs with gender equality plans** measures institutional engagement in gender equality work.

The third sub-dimension concerns action to promote the **inclusion of gender in R&I content**. GE3: **Share of RFOs promoting gender content in research** and GE5: **Share of RPOs with policies to promote gender in research content** investigate the extent to which RPOs and RFOs take actions to ensure the integration of the gender dimension in research content.

The indicators show a number of patterns across countries. First, and as is already well known from the statistics of Eurostat and She Figures, gender balance in terms of researcher employment is highest among eastern European countries. This pattern also transfers through to research productivity where again gender balance is highest for eastern European countries. Figure 1 shows the results of indicator GE10 for the share of female authors in journal articles.

Figure 1 Share of female authors in journal articles (2005, 2010, 2016)

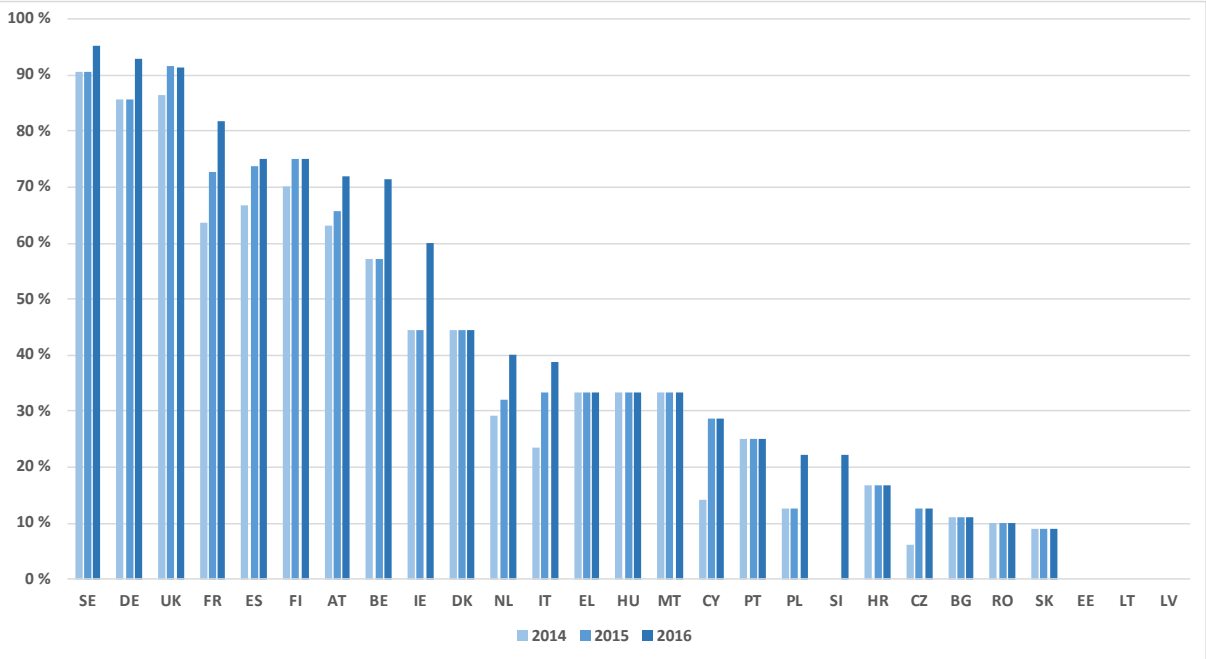


Source: *MoRRI Monitoring report* (2018).
Data: Patstat, Scopus. Calculations: Fraunhofer ISI.

Country patterns are less clear when examining wage gaps for researchers (GE7) or shares of women in gatekeeping positions (GE8 and GE9), where results are more mixed across EU-15 and EU-13 Member States.

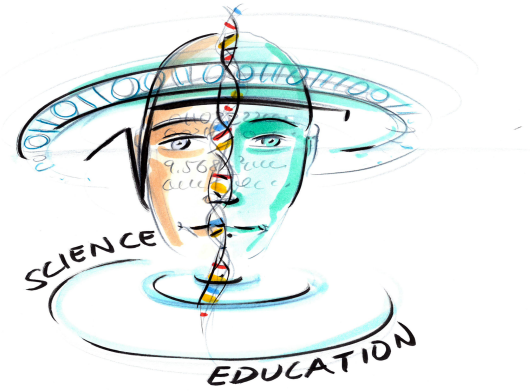
A second noteworthy pattern is for actions to promote gender equality, including in relation to gender balance in employment. Western, and in particular northern, European Member States appear to have a much greater focus on the promotion of gender equality. Figure 2 shows the results for GE1, the share of higher education institutions (HEIs) and public research organisations (PROs) that have gender equality plans.

Figure 2 Share of HEIs and PROs with gender equality plans



Source: *MoRRI Monitoring report* (2018).
Data: HEI and PRO surveys, MoRRI 2017.
Note: Insufficient number of responses for LU.

It is difficult to discern the possible explanations for this negative relationship between gender balance in employment and action to promote gender equality. Its current status is significantly influenced by longer-term, country-specific factors. Hence, in looking at the evidence of impacts of actions to promote gender equality, one should give attention to individual country changes over time. It will be interesting to see how the relationship between measures of the status of gender equality and actions to promote it evolve over time.



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A thorough expert discussion on the gender equality indicators suggested that all 10 (and their sub-indicators) are useful and provide information on different aspects. In fact, there are blind spots that are not yet covered by an indicator, namely on 'Gender in curricula' and 'Gender in research content at project level'. The latter is thus an example of useful meso-/ micro-level indicators (see section 0).

There remains a difficulty in interpreting the findings, in particular when taking into account the relationships between the three gender sub-dimensions. Often there is a positive development in one dimension that can probably be associated with stagnation or negative developments in another dimension.

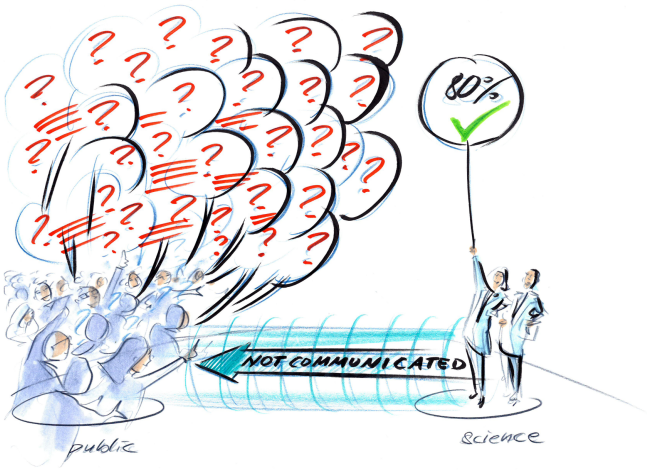
Also, an increasing share of women in R&I is partly due to an increase in part-time positions. Obviously whether this is good or bad is a value judgement, but having a basket of individually useful GE indicators still requires more qualitative information in order to interpret the findings.

Science literacy and science education

Science literacy and science education was defined in the conceptual phase as being generated through activities that aim to provide citizens with a deeper understanding of

science, to shape their attitudes towards science, and to develop their abilities to contribute to science and science-related policy making. The definition includes three aspects, which are based on the main mechanisms through which the science literacy and science education abilities are built: science education, science communication and the co-production of knowledge. All four indicators seek to cover what are quite different aspects concerning this dimension.

SLSE1: **Science curricula** captures controversial science topics and their coverage in the curricula of 15 to 18-year-old students (ISCED3). This was further broken down, asking for societal, environmental and ethical aspects. While a number of countries were found to cover all aspects at least to some degree, no country was found to cover all these societal aspects substantially. Austria, Italy, Luxembourg, the Netherlands and Romania do not cover these items officially in their curricula.



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SLSE2: **RRI-related training** provides information on whether and to what extent RRI-related aspects, i.e. ethical, economic, environmental, legal and social aspects (EEELSA), are included in the training of young researchers. Almost all countries have some examples of RRI-related training of young researchers at their HEIs, though in the majority of countries, the share of HEIs with RRI-related training is less than half.

SLSE3: **Science communication culture** places countries in one of three categories: consolidated science communication culture, developing science communication culture, and fragile science communication culture. This indicator shows an East-West divide in science communication, where most western EU Member States have a consolidated culture and most eastern EU Member States have a developing culture.

SLSE4: **Citizen science activities** captures whether research-performing organisations are engaged in citizen science in projects or through scientific publications on the subject. Measurement of citizen science is still in its very early stages, and given this, it is somewhat difficult to interpret indicators. However, both the measures of citizen science activities and citizen science publications indicate that work with citizen science spans the majority of EU countries and appears to show increases in the 2 years measured, though from fairly low levels.

While SLSE indicators capture the present situation, they point to future capabilities of a country and are thus particularly interesting as regards policy making.

Two of the four indicators chosen capture training of pupils (ISCED 3) and PhDs (ISCED 8). It would be useful to close the blind spot regarding bachelor and master students (ISCED 6 and 7).

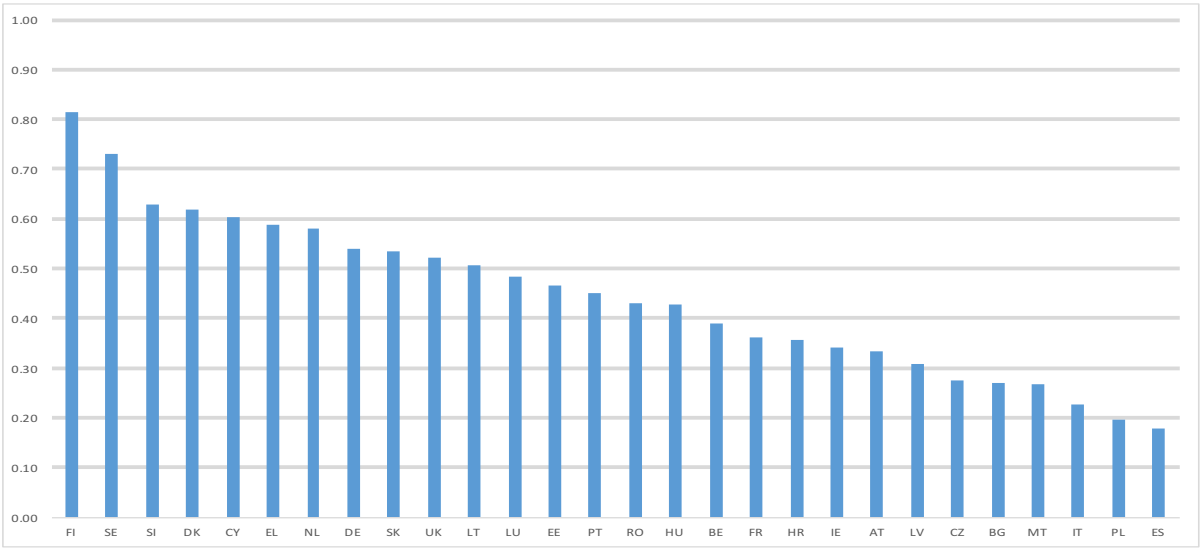
Public engagement

Public engagement was conceptually defined through activities where there is a distinct role for citizens and/or societal actors in research and innovation processes. A defining characteristic is the complexity of objectives for public engagement and the variation in mechanisms for engagement. Public engagement includes the engagement of other actors in science, in order to inform and/or educate citizens, to inform decision makers and create awareness in order to influence decision-making processes, to facilitate interaction and dialogue, and to involve citizens in decision making. There are thus a number of aspects

of public engagement concerning **participation, facilitation and actions to promote engagement**.

PE9: **R&I democratisation index**, and PE10: **National infrastructure for involvement of citizens and societal actors in research and innovation** are also focused on participation, from the viewpoint of key stakeholders. PE9 measures both the degree of involvement of citizens and civil society and their degree of influence on decision making.

Figure 3 R&I democratisation index 2016

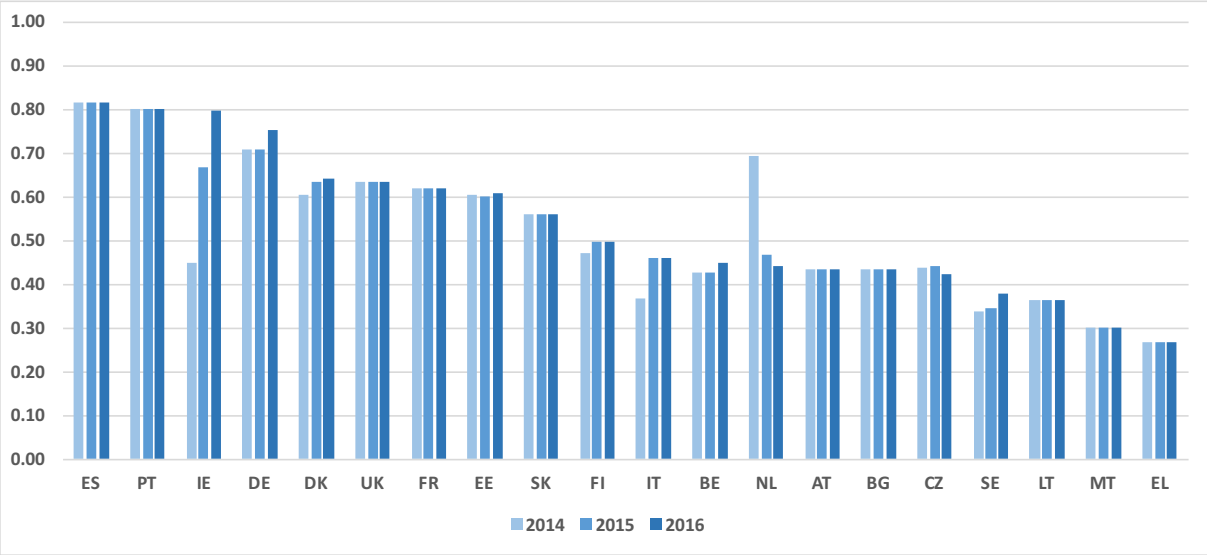


Source: *MoRRI Monitoring Report* (2018).
Data: SiS survey, MoRRI 2017.

The remaining indicators, PE5: **Public engagement performance mechanisms** at the level of research institutions, PE7: **Embedment of public engagement activities in the funding structure of key public research funding agencies**, and PE8: **Public engagement elements as evaluative criteria in research proposal evaluations** focus on the activities of public research organisations and public funding, both on public engagement activities themselves and on actions to promote engagement.

Figure 4 shows results for PE7 at the degree to which public engagement is embedded in funding activities. Interestingly, there is a number of country differences in terms of public engagement by public research organisations compared to its promotion by funding agencies.

Figure 4 Embedding of public engagement activities in the funding structure of key public research funding agencies (2014-2016)

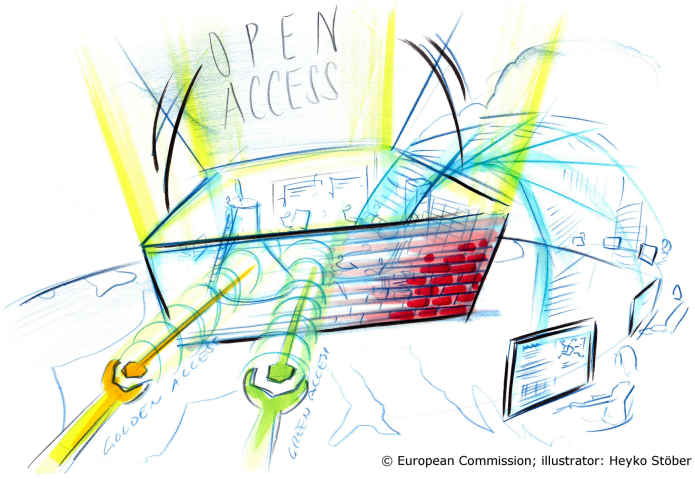


Source: *MoRRI Monitoring Report* (2018).
Data: RFO survey, MoRRI 2017.
Note: Missing LU, RO.

Open access

Open access is the idea of making research results freely available to anyone that wants to access and re-use them. One of the main drivers of open access is to make publicly funded research accessible to the general public. In the academic sense, the term 'open access' referred originally to the provision of free access to peer-reviewed academic publications. Open access is separated into 'gold' and 'green' where gold indicates open access journals and green indicates open access through self-archiving.

Open access includes both the open availability of research results and also of the research data that underpins publications or research projects, also referred on its own as open research data. Open research data is a relatively new and emerging field of scholarship, and systematised data sources are still fairly scarce compared to the data available on issues related to open access publications. Research on open research data and data sharing have mainly been conducted as case studies, but growing efforts are made to systematise such sources with the objective of developing data metrics (Meijer et al., 2015; D2.4: p35-36).



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Data sharing and open data are topics where benefits, controversies and challenges are described repeatedly (e.g. Costas et al., 2013). Benefits are likely to occur with greater emphasis and practice of what is known as open science, a higher efficiency in the use (and reuse) of scientific resources, and generally better science through the possibilities of verifying, refuting or refining scientific results.

The reality in scientific practice is that rewards and incentives for scientists to share their data are limited, standardisation of curation and findability are still under development,

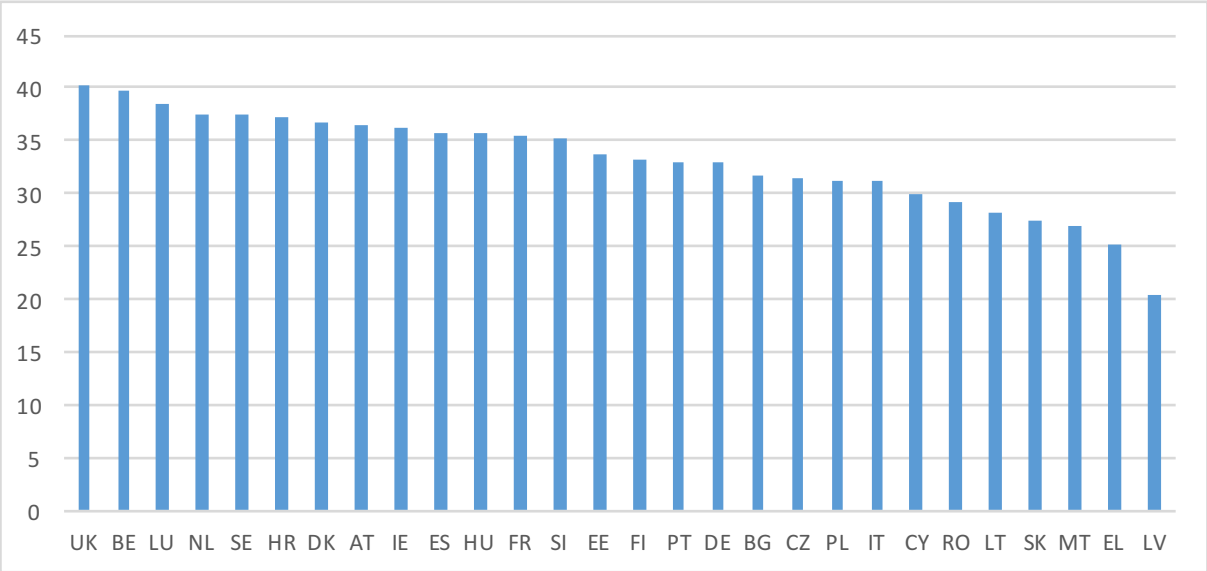
and that perceptions and the culture around data sharing differ largely between fields (Berghmans et al. 2017).

OA2, the **open data** indicator, aimed to analyse practices by assessing the number of data sets in repositories. Unfortunately, due to data source issues, this proved to be an invalid indicator for the time being. DataCite, which is currently the most reliable source to analyse repositories across the world, shows that the distribution of repositories is uneven. Whether this reflects an actual situation or an analytical bias is currently still unclear (Robinson-Garcia et. al., 2017). Although the source is considered the most promising, more research and development is needed in order to be able to provide reliable indicators on open data production. Therefore, OA2 is not taken into account in the monitoring.

OA1: **open access literature** measures the share of publications that are either gold or green open access[16], while OA3: **Social media outreach/take-up of open access literature** measures the take-up of open access vs. non-open access literature in social media outlets such as Twitter and Wikipedia. OA4: **Public perception of open access** covers citizen views on whether publicly funded research should be openly available to all, while OA5: **Funder mandates** measures the number of national funding mandates that are disposed to open access publishing. Finally, OA6: **Research performing organisations' support structures for open access** measures the extent to which countries have support structures in place for open data and open data sharing.

Shares of open access publications vary greatly across countries, from 20 to 40 % over the period 2012-2015, with the highest shares in the United Kingdom and Belgium. A general trend across all countries is that shares with open access appear to be increasing over time[17]. The average annual EU-28 growth rate of the shares for 2012-2015 was 26 %

Figure 5 Share of open access publications (2012-2015)



Source: *MoRRI Monitoring Report* (2018).
Data: altmetric.com Calculations: CWTS.

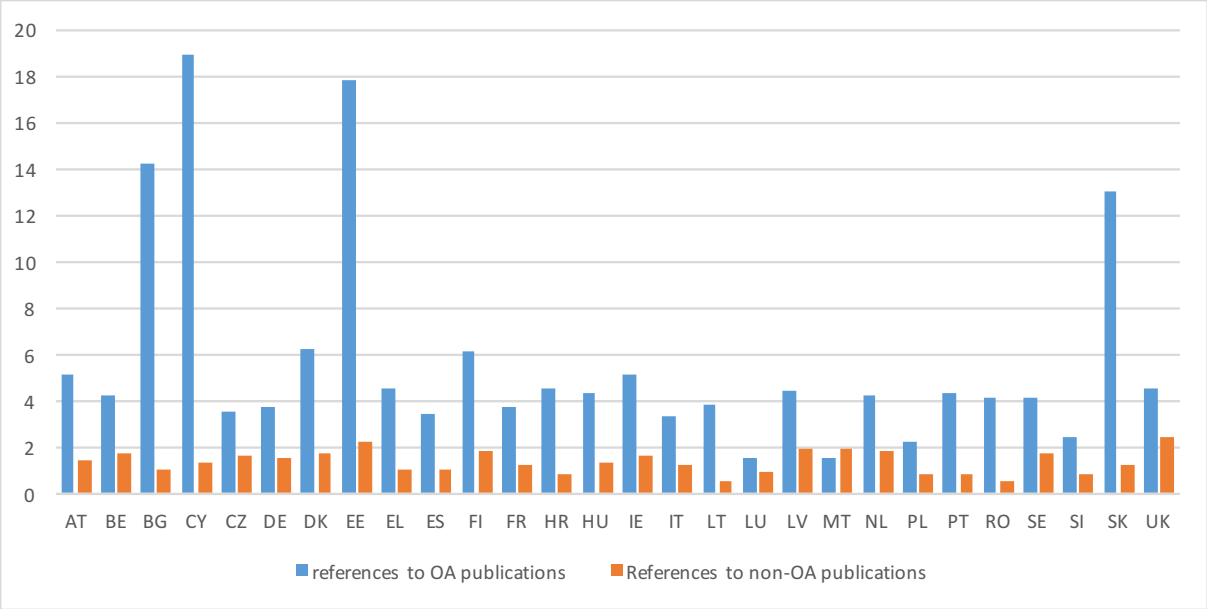
Another pattern that holds across all countries, though to differing degrees, is that open access publications are more likely to be disseminated through social media channels than

[16] Gold open access is defined by the appearance of a journal on the Directory of Open Access Journals (DOAJ) or ROAD (Directory of Open Access Scholarly Resources) journal list. Green open access is defined by the presence of publications in CrossRef, PubMedCentral or OpenAIRE.

[17] Current calculations for 2016 are lower in a number of countries, but this likely reflects lags in the archiving of green open access publications.

non-open access publications. Figure 6 illustrates this result for publications used in Wikipedia. In all Member States, the share of open access publications that are used in Wikipedia is much higher than shares of non-open access publications.

Figure 6 Share of open access and non-open access publications used in Wikipedia (2012-2015)



Source: *MoRRI Monitoring Report* (2018).
Data: altmetric.com. Calculations: CWTS, MoRRI 2017.

Ethics

The MoRRI project defines ethics in the following way: *Ethics as a scientific discipline is concerned with normative rules for everybody. In the context of research and innovation, ethics is a common platform for deliberation and discussion of values in society, that are based on perceptions of right and wrong, influenced by cultural norms, and aiming at informing policy making*.

Ethics is measured both for public research organisations and funding organisations and concerns to what degree ethics or research integrity committees are in place, and the strength and breadth of their influence on research activities. Strong ethics committees can be characterised where the submission of applications to the committee is obligatory, all disciplines are covered and where decisions are binding.

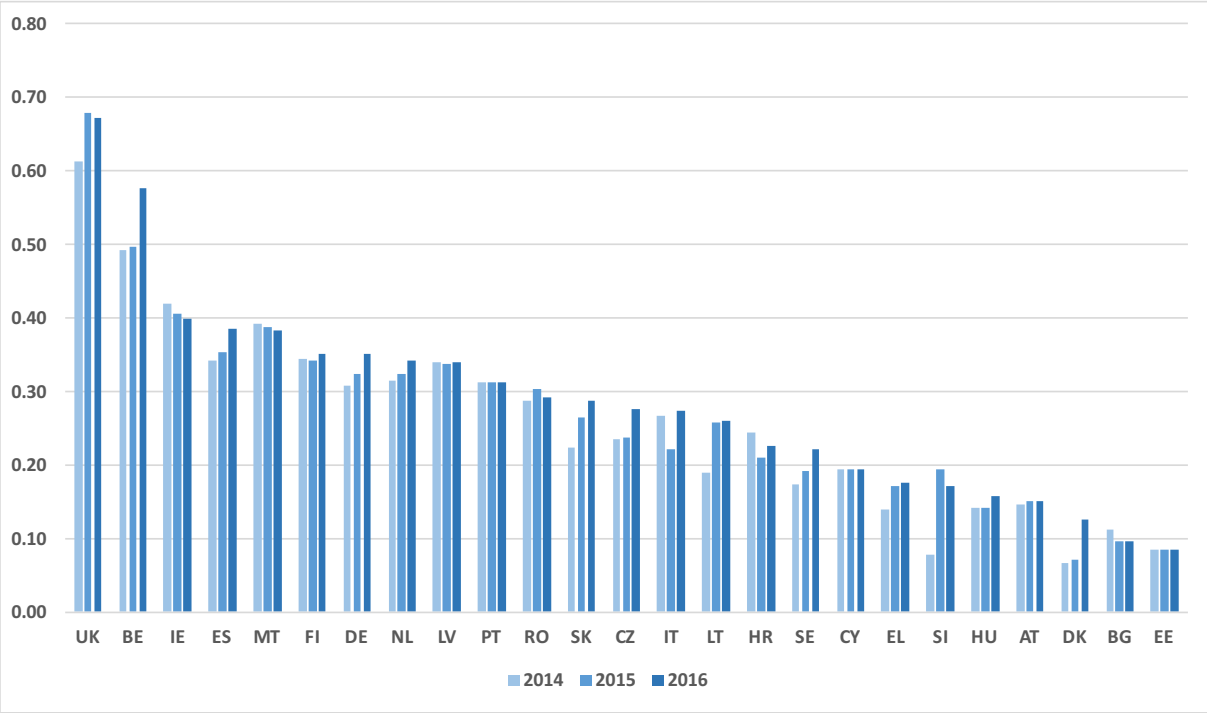
E1: **Ethics at the level of research performing institutions** consists of two measures. E1a is a measure of the share of higher education institutions and public research organisations with a research ethics committee or a research integrity office. E1b is an index measure designed to provide information on the level of mechanisms that should safeguard the observance of ethical standards in research ethics and research integrity implemented within higher education institutions at the country level.

E2: **National Ethics Committees** is a composite measure of the existence, output, impact and quality of national ethics committees across EU-28 Member States.

E3: **Research-funding organisations' ethics index** covers mechanisms dealing with ethics and societal implications in public and private RFOs.

There is a wide variation in the prevalence of research ethics committees across Member States, where they are very commonplace among universities in some such as the United Kingdom, Malta and Portugal, and only exist at a minority of universities in others, such as Sweden, Austria, Estonia and Bulgaria. The availability of ethics committees and research integrity offices also varies greatly, as can be seen in Figure 7.

Figure 7 Composite index of ethics/research integrity at universities



Source: *MoRRI Monitoring Report* (2018).
Data: HEI Survey, MoRRI 2017. No data for LU. Too low response for FR, PL.

Governance

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In order to meet the ambitious objectives of RRI, the European Commission has defined five key thematic elements or key dimensions (public engagement, open access, gender, ethics and science education) that need to be deeply embedded in research and innovation activities. With the aim of ensuring that these actions are implemented in an integrated manner and unfold in a mutually reinforcing way, the cross-cutting or overarching dimension of 'governance' was introduced alongside the thematic dimensions. The governance dimension supports the implementation of the RRI 'package' by fostering institutional transformations, developing conducive framework conditions for RRI, and supporting changing cultures and practices of research and innovation actors.

The European Commission's operationalisation of RRI governance is highly compatible with the definition of governance applied in MoRRI to develop suitable indicators for the governance dimension. We defined governance as a way in which societal and state actors intentionally interact in order to transform ST&I systems, by regulating issues of societal concern, defining processes and direction of how technological artefacts and innovations are produced, and shaping how these are introduced, absorbed, diffused and used within society and economy. (Borrás/Edler, 2014: 14).

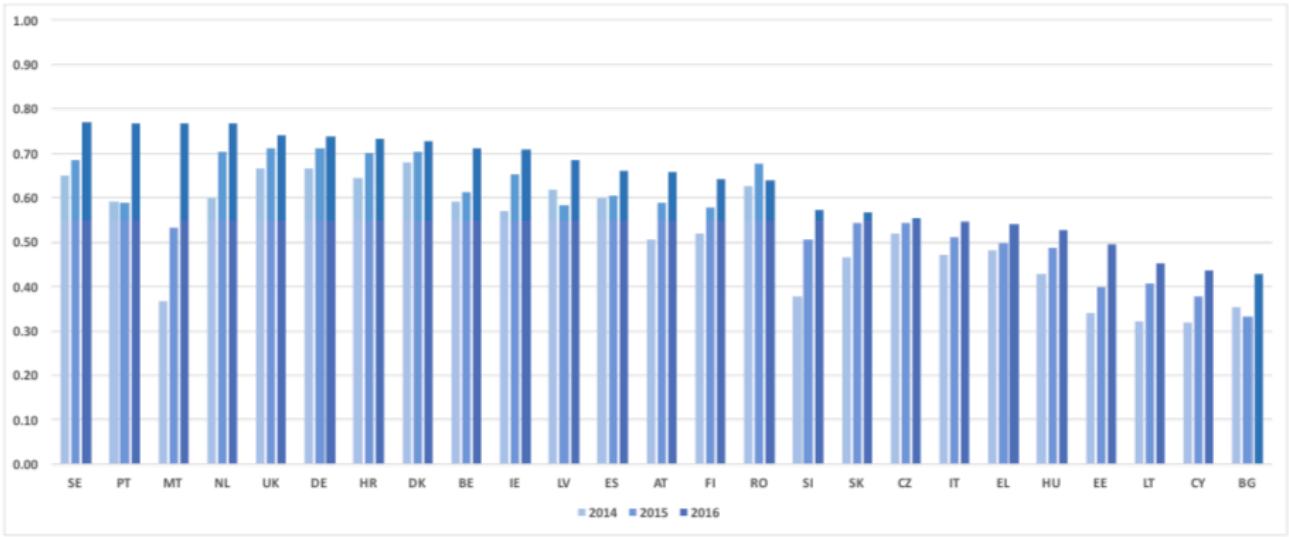
GOV1: **Use of science in policymaking** is based on two dimensions relating to the use of science-based knowledge in decision-making: the extent to which a formalised structure for feeding science-based knowledge into decision-making is in place, e.g. in terms of institutional sites dealing with these processes; and the extent to which science-based knowledge and advice have a real impact on decisions.

GOV2: **RRI-related governance mechanisms** examines whether research-funding and performing organisations have established processes for managing the key areas of RRI.

GOV3: **RRI-related governance mechanisms** captures how actively these organisations have promoted RRI.

Shares of research-performing and funding organisations with RRI-related governance mechanisms in place range from 43 % to 79 %, with 10 countries above 70 %. Within the short period examined (2014-2016), almost all countries experienced an increase in the share of organisations with RRI-related governance mechanisms.

Figure 8 RRI-related governance mechanisms within research-funding and research-performing organisations



Source: *MoRRI Monitoring Report* (2018).
Data: HEI, PRO and RFO surveys, MoRRI 2017. No data for LU. Too low response rate for FR and PL

2.3 Core indicators and country clusters

As described above, the identification of indicators in the MoRRI project revolve around the six key areas outlined by the European Commission in its pursuit of an operational definition of RRI.

There is, however, no automatic alignment between the intended conceptual qualities of the selected indicators and the empirical structure of their interrelatedness. It is, in other words, crucial to examine how they actually relate to each other and the latent variables one would expect them to be indicators for. In the context of the MoRRI project, such an examination is difficult for two main reasons.

1. We have a limited number of observations. The EU-28 Member States are covered by the project, and while the underlying datasets arguably are comprehensive with extensive coverage of both individuals and organisations, the indicators are all tailored to the aggregated level of countries. The implication is that there are in fact more indicators (36+) than observations (28), which reduces the range of relevant statistical analyses. This limitation is of course a consequence of the nature of the study, similar to many other cross-country comparative studies.

2. The majority of indicators have a few missing cases (countries for which no observed value has been obtained or for which the data collected was inadequate). This presents a challenge to any integrated statistical models drawing on multiple indicators since the number of missing values will tend to grow with the inclusion of more indicators.

For the examination of the empirical patterns of the indicators, these limitations have been accommodated by

- imputing data points to replace missing values, and
- applying factor analyses to subsets of indicators rather than the full set of 36+ indicators.

Specifically, a predictive model incorporating all the information embedded in the existing data was employed to estimate values for each missing item across indicators with a maximum of four missing values. Indicators with more missing values were discarded. Factor analyses were conducted for each key area separately; this means, for example, that the 10 gender equality indicators were considered together, but not in combination with public engagement indicators.

Interestingly, the parallel principal component analyses revealed two distinct and interpretable factors for all dimensions except governance, for which only one factor was retained. In Table 3 below, the 11 retained factors – or what could be called empirically founded dimensions of RRI – are presented, along with the indicators most highly loaded to the respective factors.

Table 3 RRI dimensions and core indicators

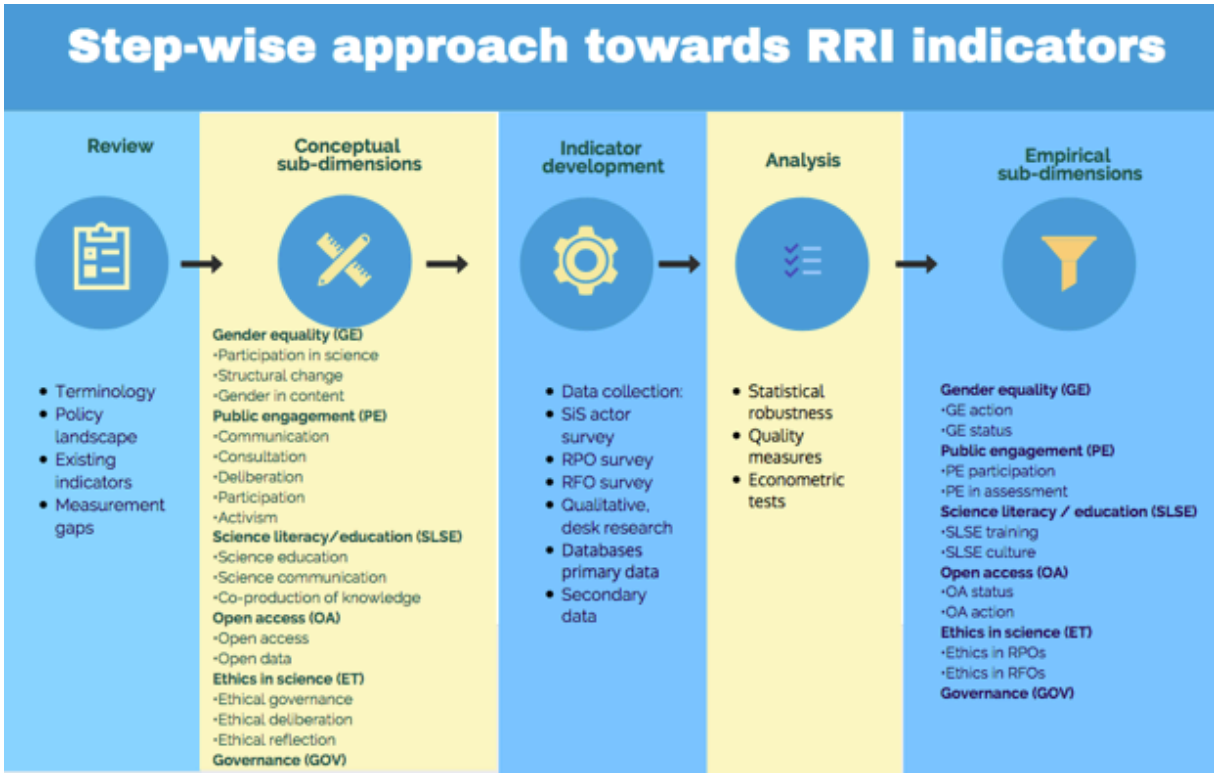
Dimension	Core indicators
GE action	GE1, GE5
GE status	GE2.3, GE10.1
SLSE training	SLSE1, SLSE2
SLSE culture	SLSE3, SLSE4
PE participation	PE1, PE4, PE9
PE in assessment	PE7, PE8
Ethics in RPOs	E1a, E1b
Ethics in RFOs	E3a, E3b
OA status	OA1.1, OA1.2
OA action	OA3, OA4, OA6
Governance	GOV1, GOV2, GOV3

Calculation: Aarhus University.

Figure 9 below summarises the approach and the various steps taken, allowing us to develop a longer set of indicators (the '36+' ones) and the narrowing down and identification of sub-dimensions (see Table 3).

The first dimension that materialises from the principal component analyses can be labelled **GE actions**. GE1, which measures the share of RPOs with gender equality plans, and GE5, measuring the share of RPOs with policies promoting gender content in research, are both strongly loaded to 'GE actions'. Both of these tap into the level of action concerning gender equality policies at the level of organisations. The second latent dimension is strongly interrelated with GE2.3 and GE10.1 and can be labelled **GE status**. These measure the share of female researchers in the higher education sector and the share of female authors of scientific papers, respectively. In this sense, this sub-dimension is not about policies to promote gender equality but rather about the actual status achieved concerning female representation in science.

Figure 9 Summary of the step-wise methodological approach



Science literacy and science education is also empirically divided into two dimensions. One relates to formal training activities around issues of responsibility in secondary education (SLSE1) and in higher education institutions (SLSE2) and can be called **SLSE training**. The other is rather about the broader national science culture, indicated by SLSE3 capturing aspects of science communication culture and SLSE4 signalling the importance of citizen science activities in RPOs (thus, **SLSE culture**).

When it comes to public engagement, three indicators of public involvement in science and technology decision-making (PE1), citizens' search for information about controversial technologies (PE4) and the level of democratisation of research and innovation (PE9) all relate strongly to a dimension that can be assumed to revolve around citizens' active **participation**. Another dimension concerns the extent to which public engagement is a component in **assessment** exercises. This dimension relates strongly with PE7, which measures the inclusion of public engagement activities in the activities of RFOs, and PE8, which is about the extent to which public engagement is used as evaluation criteria in the assessment of research proposals.

The ethics key also appears to have two dimensions. The first is concerned with the **existence** (E1a) and degree of importance attributed to (E1b) research ethics committees and research integrity offices at higher education institutions and other public research-performing organisations. The second dimension is similar but concerned with research-funding organisations. It is informed by two indicators relating to the use of an ethics **assessment** or ethics review in relation to funding decisions (E3a), and a composite indicator based on a set of questions relating to the importance of such assessment for funding decisions (E3b).

The area of open access is similar to gender equality, in the sense that it divides into a dimension concerning the **state of play** and a dimension concerning activities promoting open access (**actions**). Indicators OA1.1 and OA1.2 measure the share of open access publications and so-called gold open access publications respectively as proportions of all publications in a country, and these both relate to what can be called open access status. On the other hand, OA3 on social media outreach or uptake of open access literature, OA4 on public support for open access to scientific information, and OA6 on support structures promoting data sharing within research-performing organisations all relate to 'open access

activities', which could be expected to push a Member State towards higher levels of open access.

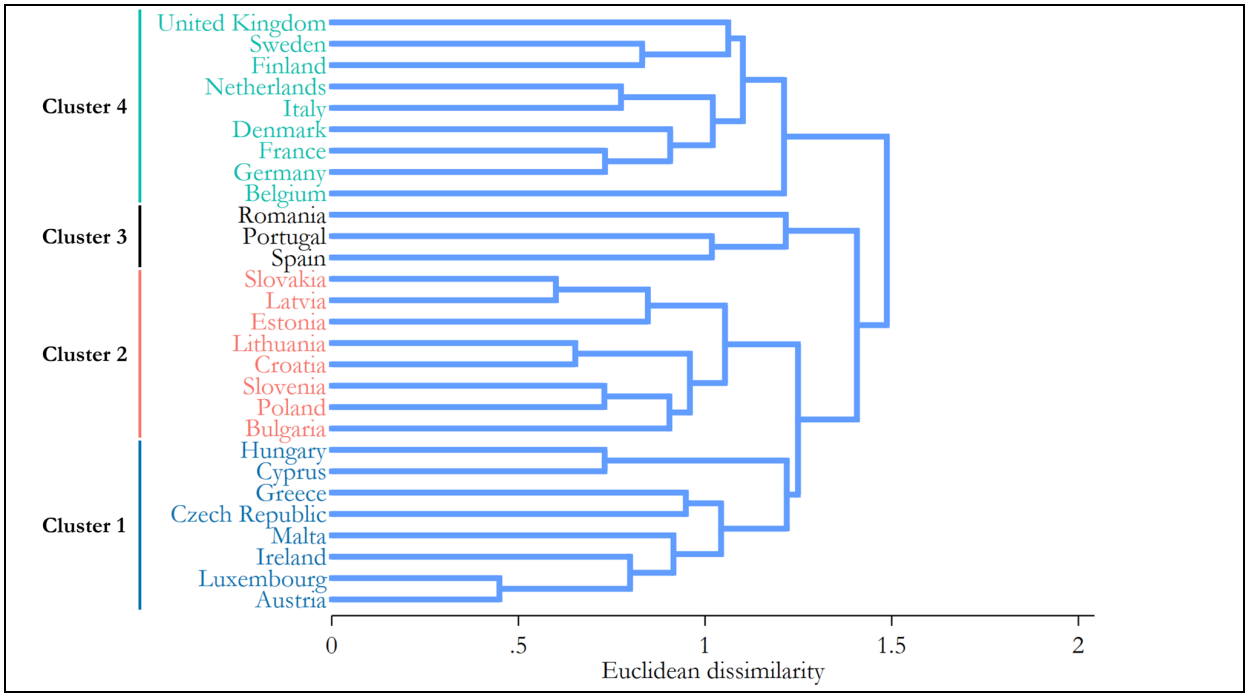
Finally, the three indicators in the governance set all load strongly to one, single factor. GOV1 concerns the use of science in policymaking at the national level, while GOV2 captures RRI-related formal governance mechanisms within RPOs and RFOS, and GOV3 is a composite measure of institutional encouragement of RRI among employees within these organisations. The empirical structure of the governance indicators thus supports the retaining of only one RRI governance dimension.

In total, **11 RRI dimensions materialised empirically**, and **25** out of the basket of 36+ **indicators turned out to be particularly strong** indicators for the 11 dimensions.

On the basis of those 25 indicators, a 0-1 normalised index was subsequently built for each dimension. In turn, the 11 indexes were used to **characterise individual countries, but also to explore similarities and differences between and within clusters of countries**. There are different approaches to cluster analyses depending on the size of the data matrix and the measurement level of the variables. Given that our set included only 28 observations and that all variables are metric, we opted for a hierarchical, weighted average linkage, cluster analysis.

A graphical representation of the agglomerative constitution of clusters is based on country scores on the 11 indices is provided in Figure 10 below. Looking horizontally from left to right, each Member State initially forms its own cluster, but progressively Member States cluster together based on the average linkage algorithm, resulting in continuously fewer clusters.

Figure 10 Dendrogram of country clustering



Calculation: Aarhus University.

The analysis reveals a **distinct four-class solution**. Looking from the bottom up, Austria, Luxembourg, Ireland, Malta, the Czech Republic, Greece, Cyprus and Hungary form a first cluster (country names in blue). This means that their individual country profiles are fairly alike, and that they as a group are distinct from the other groups. The second group (country names in red) includes Bulgaria, Poland, Slovenia, Croatia, Lithuania, Estonia, Latvia and Slovakia. The third and smallest group (country names in black) includes Spain, Portugal and Romania. The fourth and final group (country names in green) includes

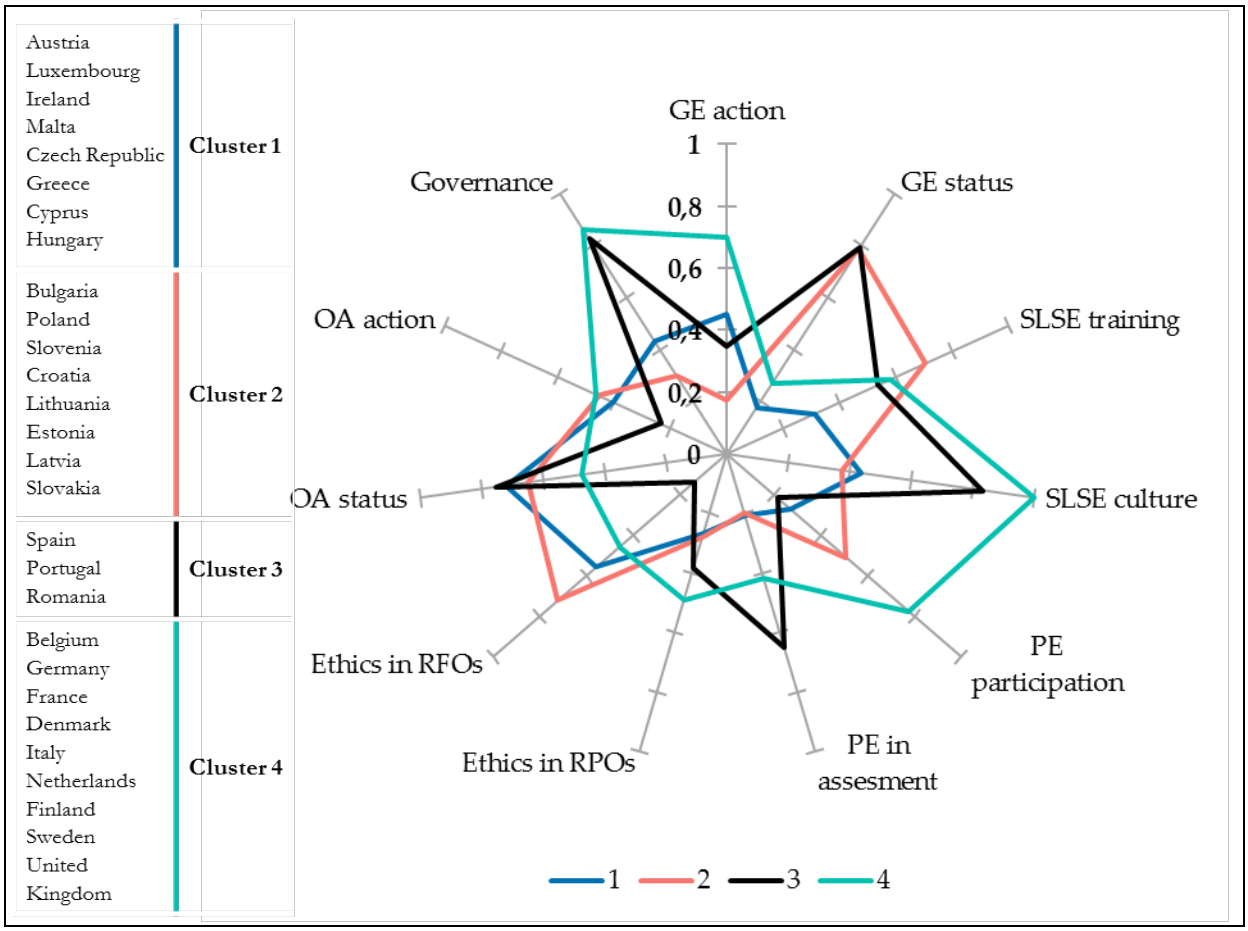
Belgium, Germany, France, Denmark, Italy, the Netherlands, Finland, Sweden and the United Kingdom.

In Figure 11, the characteristics of the four clusters are portrayed. The radar plot shows how well each cluster of Member States embraces the 11 RRI dimensions. Each of the 11 sub-dimensions are normalised to a 0-1 score, capturing the range from minimum to maximum possible effort / attention / performance within the respective areas.

The first cluster of Member States (blue) is characterised by having below-average scores on most of the 11 RRI dimensions apart from 'OA status' and 'ethics in RFOs', where this cluster is performing well. Within this cluster, then, there is a rather moderate level of accomplishment overall concerning RRI

The second cluster of Member States (red) performs particularly well on 'GE status', 'Science literacy and science education', and 'ethics in RFOs', and also rather well on both sub-dimensions of open access, while the average score of countries within this cluster on 'GE action' and 'governance' is considerably lower than for the other clusters. An interesting observation for this cluster is the distance between gender equality status and action, which resonates with the broader pattern of correlations: both seem to be negatively related sub-dimensions, so that countries with a high level of accomplishment in terms of gender equality in science are less prone to be highly active regarding gender equality policies and action plans at the institutional level. This might partly be seen as a 'no problem – no need for action' situation in countries in which the historical labour market trajectories have been more conducive to gender equality in science.

Figure 11 RRI characteristics of four Member State clusters



Calculation: Aarhus University.

The third cluster (black) has almost the shape of a star, due to its fairly high scores on just about every second dimension and fairly low scores on the other half. On one dimension,

'PE in assessment', this cluster is doing particularly well, but Member States within this cluster also on average score very highly on both gender equality status and open access status.

The fourth and final (green) cluster is generally performing above average. Exceptions include the dimensions of 'GE status' and 'OA status', where the average score of Member States within the green cluster is low. When it comes to sub-dimensions related to inclusivity and co-creation of research and innovation with civil society (PE participation and SLSE culture), countries within this cluster are particularly committed to these areas.

The results of the cluster analyses demonstrate that there is significant diversity in the European RRI landscape. Attention, efforts and priority-giving across the 11 sub-dimensions are unequally distributed across Member States. The roots of diversity are not discernible from the isolated graphics, but probably require a subtle understanding of historical trajectories in the relationship between science and society, R&I policy approaches, as well as political and civic culture. Some cleavages, e.g. between the primarily north-western European cluster 4 and the primarily eastern European cluster 2 seems to be in line with earlier findings concerning science's role and responsibilities in society in the Monitoring the Policies and Activities of Science in Society (MASIS) project, and also resonates with the European Innovation Scoreboard.

It is important to note that the use of a clustering algorithm to group countries does not mean that countries within a cluster have exactly the same RRI properties. It rather means that the profile of a country within cluster X is more similar to other members of cluster X than to countries belonging to a different cluster. But there can be significant differences in profile, even within the same cluster.

In Annex 1 to this report, we report the individual country profiles using radar plots. These allow stakeholders and decision-makers to review the observed performance across the 11 sub-dimensions, and to assess and shape priorities against this backdrop. We believe that the country clustering analysis will further promote international learning by displaying patterns of similarities and differences. The clusters themselves, and the memberships of these, are obviously not stable, but will depend on future developments at the level of countries, but specifically at the level of organisations within the ecosystems of research and innovation within which responsible practices are cultivated.

3 Emerging benefits of RRI

While the previous section focused on the development of indicators of RRI, the following one draws from our work on RRI benefits. Here we explore:

- what is meant by 'RRI benefits';
- the emergence of RRI benefits by RRI key areas;
- the identification of potential RRI benefits;
- researchers' perceptions of RRI benefits;
- impact pathways and the generation of RRI benefits;
- monitoring RRI benefits.

This is followed by a critical reflection on the work done to date.

3.1 What is meant by 'RRI benefits'?

The indicators developed to monitor the emerging patterns of RRI at Member State level (Section 2) were based on a relatively conventional intervention logic:

However, the concept of RRI benefits cannot be simply read off this intervention logic as an inevitable extension of the impacts of RRI. Although RRI benefits may indeed be partly or, in some contexts, largely based on an accumulation of positive impacts of RRI, this conceptualisation is not sufficient to capture what is meant by RRI benefits.

There are two important elements that distinguish RRI benefits from being simply an extension of a from-inputs-to-impacts intervention logic:

- RRI benefits can be attributed directly to transformations in processes that are embedded in implementation activities. For example, institutionalising a public engagement mechanism that leads to the inclusion of previously disenfranchised groups in science and technology (S&T) decision-making constitutes a democratic benefit of RRI, in and of itself. This benefit occurs regardless of the substantive outcomes and further impacts of the mechanism in which the process is embedded. Importantly, such transformations in processes within research and innovation can generate RRI benefits for science itself (see sections 3.3 and 3.4.1). Monitoring RRI benefits thus goes beyond capturing evidence of the outputs, outcomes and impacts of RRI.

- RRI benefits are attributed to transformations with a normative character. This is where RRI benefits go beyond 'positive', 'net positive' or 'accumulated' impacts, to include an assessment of the direction of those impacts, including in societal, democratic and economic terms. This is the principle that RRI benefits signal the alignment of research and innovation with the expectations, needs and values of society. The challenge then is to design appropriate ways to monitor benefits as they refer to these normative characteristics, which inevitably means that being sensitive to context is of crucial importance.

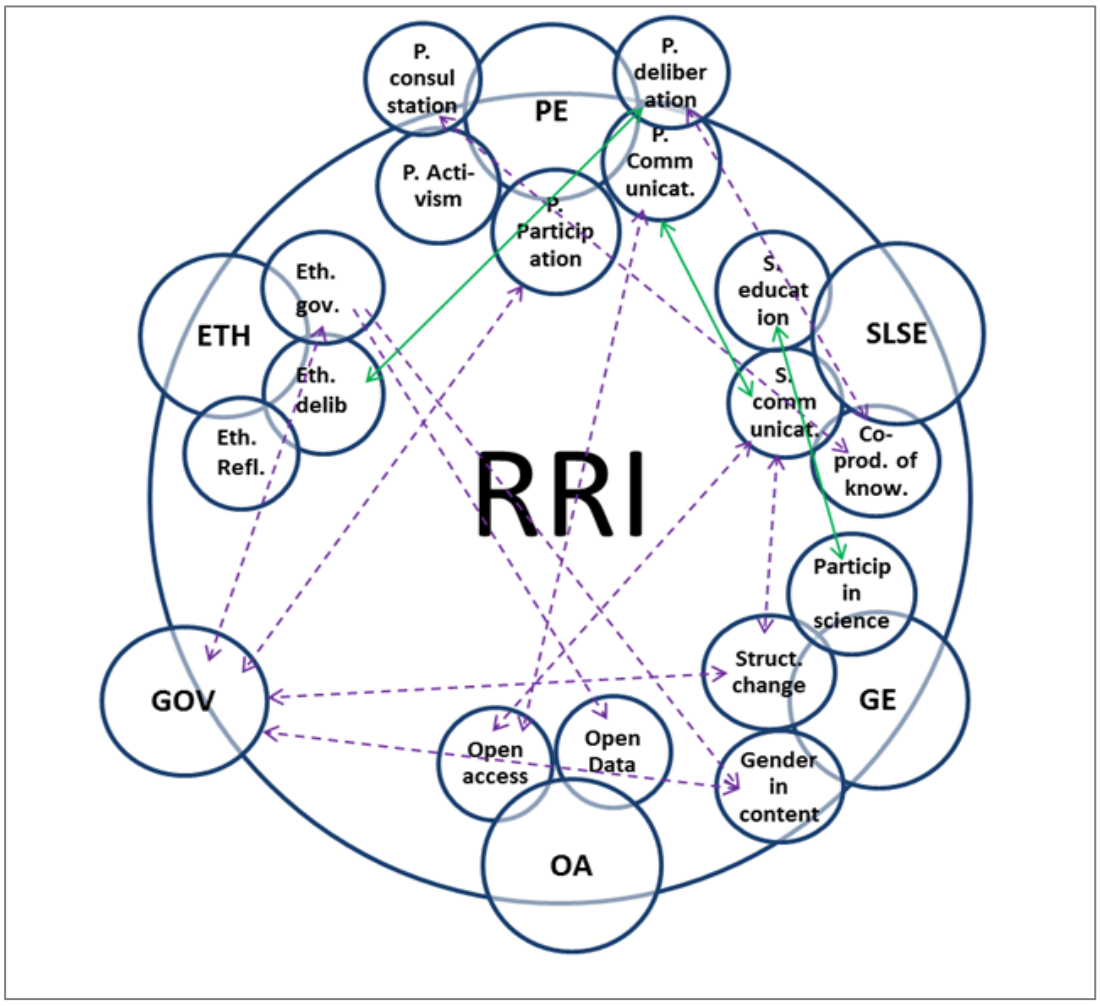
For these reasons, RRI benefits cannot be sensibly interpreted, or systematically monitored, in the absence of a framework that guides expectations about the (expected) qualities and (desirable) **directions of change**.

3.2 Emergence of RRI benefits by RRI key areas

RRI benefits were initially categorised as **societal**, **democratic** and **economic** benefits. However, various **scientific** benefits of RRI were also identified in the course of the work (section 3.3).

While the emergence of benefits of these four different types may be attributable to a particular RRI dimension, benefits should also be thought of as driven and/or reinforced by multiple RRI dimensions. For example, the public engagement and science literacy and science education dimensions are very likely to play mutually reinforcing roles in generating benefits from citizens' participation in S&T decision-making. Indeed, we can generally expect intersections between RRI dimensions and sub-dimensions to be influential in the emergence of RRI benefits, as summarised in Figure 12.

Figure 12 Existing and potential interlinkages between RRI dimensions/sub-dimensions



Source: (European Commission 2015a) *MoRRI Progress Report*, D3.2.

The nature of the benefits emerging from RRI dimensions will be shaped by the way actors are integrated and RRI activities are implemented. From a RRI benefits perspective, public engagement can be considered a complex dimension characterised by:

- the opening up of information flows between different actors and sectors of the research and innovation system, and between these R&I actors, citizens groups and the general public;
- processes of sharing perspectives and developing mutual understanding of other stakeholders in the research and innovation system and their constituents in wider society; and

- democratisation of decision-making processes regarding research and innovation regulation and policy.

Key mechanisms for the generation of RRI benefits are thus networks of actors integrated at different levels of organising research and innovation and related activities. Institutionalising processes of interaction builds awareness of the interdependence of actors and their interests. Individual actors cease to advocate or act solely based on self-interest, generating benefits for democracy. Such transformations can be expected to lead to economic benefits deriving from improved coordination.

Continuous reflexive attention to the implementation of engagement activities is also required, to ensure these activities do not function simply to enrol actors to the perspective of powerful groups (Stirling, 2008). Openness and transparency are important safeguards in this respect.

There are some linkages between public engagement and science literacy, and science education in the generation of RRI benefits. From a RRI benefits perspective, the latter can be expected to:

- deepen the quality and comprehensibility of information flows among actors in the R&I system and among citizens;

- promote a positive socio-cultural climate toward learning about science and participating in research; and

- strengthen the capabilities of citizens to assess the relevance and appropriateness of the products of R&I.

Information can thus be seen as an intrinsic ingredient in the generation of a broad range of societal, democratic, and economic benefits that can be attributed in part to science education. The potential link to public engagement activities as vehicles for the realisation of such benefits is also apparent.

Gender equality, or **the elimination of gender bias, is a democratic benefit** in itself. The societal benefits that flow from the elimination of gender bias are linked to this enhancement of democracy and can take numerous substantive forms. For example, elimination of bias enhances the intellectual and creative methods that can be brought to bear on economic problems and societal challenges. Increased diversity in workplaces is also associated with improved motivation and satisfaction levels. It can be assumed that these context-specific benefits may flow on and contribute to more general benefits in terms of health and quality of life.

From an RRI benefits perspective, the ethics dimension can be thought of as contributing to the creation of a thoughtful climate and procedural guidance to ensure that the R&I system evolves in ways that are not prejudicial to the interests of society. These elements have **direct benefits for the conduct of science** itself, for example in reducing the costs of misconduct. Economic and societal benefits can be foreseen where ethical considerations contribute to a reduction in inappropriate S&T outputs, such as those that contribute to degrading the natural environment, which may be costly to redress or unwind.

RRI benefits of open access arise from the construction of a space in which the processes and products of (publicly funded) research are accessible, whether as inputs to future research (benefit for science) or as knowledge relevant and useful to other types of end-users (societal or economic benefits). From a benefits perspective, open access is a more efficient way to utilise valuable resources, both for upstream and downstream objectives. For example, accelerating the process of diffusion of scientific knowledge through the reduction of institutionalised barriers to knowledge outputs (open access) can lead to societal benefit in terms of a more responsive R&I system, as was seen in relation to the rapid scientific reaction to the Ebola and Zika viruses for example. Creating relatively frictionless access to scientific data (open data) can also stimulate innovation by reducing

(or eliminating) the cost to the private sector of creating or replicating the essential data they need, as the example of the European Molecular Biology Laboratory-European Bioinformatics Institute bioscience data repository shows.[18]

3.3 Identification of potential RRI benefits

In order to identify and analyse the benefits of activities and measures to promote RRI, a variety of case studies was conducted.[19]

3.3.1 Methodological approach

The selection of the cases was guided by several criteria. For example, an eligible case had to comprise a concrete and already implemented measure or activity that aimed to promote more responsible ways of doing R&I. It was not essential that activities were explicitly presented as measures to promote RRI, but they had to correspond to the RRI concept used in MoRRI. We tried to find cases that covered a wide range of R&I-related activities concerning an individual RRI key area or cases where more than one RRI key area was promoted (e.g. public engagement together with open access).

In identifying RRI activities and measures for case studies, different levels of implementation were systematically considered. RRI activities were selected that addressed individual actors or certain stakeholder groups (e.g. researchers or PhD students), organisations (e.g. universities or private companies), or broader societal sub-systems (e.g. science in general or research funding).

Explorative case study research was carried out in a recursive process that consisted of three successive waves. The first wave revisited data and results of existing research, especially of projects funded within the European Commission's Sixth and Seventh Framework Programmes (FP6 and FP7). Screening and analysis of these projects showed severe limitations of secondary analysis. Only, four out of 67 FP6 and FP7 projects could be reviewed and re-analysed as case studies. In the second and third round, original case studies were conducted, enabling us to include empirical evidence from different national contexts.

The case studies combined various methods of data collection and analysis such as desk research and a review of documents and interviews with relevant actors, stakeholders or experts.

[18] See *MoRRI Project Report* D5.2 case studies for more detail (morri-project.eu).

[19] Ibid.

Box 1 Inclusive methods to empower workers

Bridging the gap between science, stakeholders and policy-makers: Integration of evidence-based knowledge and its application to science and the management of fisheries and the marine environment.

The case involved different stakeholder groups – particularly fishermen – in research processes in 11 countries. They became engaged in research planning, data collection, co-production and discussion of research results.

Inclusive methods comprised mutual mobilisation and learning activities, stakeholder workshops and debates, focus groups, networking events, cognitive maps, joint field observations, participatory sampling, surveys and other research activities (Raicevich et al., 2013).

Involving fishermen in research related to their work **should empower and inform** them, enabling them to profit from the knowledge and insights gained. Research results should inform governance and political decision-making about the management of fisheries and empower fishermen in these processes.

In some cases, new policymaking processes were implemented that were **developed together** with the fishermen taking part. Through participatory research activities and the inclusion in decision-making processes, fishermen became part of the relevant networks and acquired new competences (e.g. data collection methods) that probably strengthened their position in negotiations about fishery management. Furthermore, the **participatory approach** also involved fishermen in the evaluation of fishery management; the decision making also took into account their traditional knowledge.

The case showed the democratic benefits of RRI, but also the economic benefits. It had, at first, (short-term) negative economic effects due to a ban during the winter on shrimp fishing that the researchers and stakeholders had developed together. However, these short-term costs contributed to a positive impact in the end since sustainable fish production was secured (see Wuketich et al., 2016; MoRRI D5.2)

3.3.2 Highlights of the benefits identified in the case studies

Democratic, societal and economic benefits of RRI were identified along with an additional group of benefits that has been absent in the literature so far, namely the benefits of RRI for science, research and innovation. [20]

RRI activities had a number of **democratic benefits**. Public engagement empowered citizens by involving them in research that was meaningful to them and engaged them in public debates. In some cases this in turn contributed to better decision making and strengthened the democratic system. Science education activities helped better-informed decision making as well. Activities that addressed ethics and governance had positive effects on decision making by providing reliable and trustworthy information. One case study suggested that the potential of RRI activities for informing decision making could not materialise due to a lack of basic funding for such activities.

As regards the **societal benefits** of RRI, public engagement and gender equality activities led to research questions and findings that were better aligned with societal needs; gender equality and science education contributed to more equality and social justice; public engagement activities helped society to participate more fully, and to learn from science. Tennant and colleagues (2016: 11) report a societal benefit of open access as 'a general media advantage with open access (…) which can be used as a proxy or pathway to indicated greater societal impact'.

[20] The notion of scientific impact did not exist at the beginning of this study but emerged during research as an important benefit of RRI.

Box 2 Economic benefits in the manufacturing industry

Reaching out beyond research institutions and publicly funded research and innovation: Exploration of responsible innovation processes in the manufacturing industry in six European countries

In addition to public institutions and private non-profit organisations, the private business sector is a major investor in research and innovation. Around two-thirds of R&D investments come from the business sector. Among them, manufacturing companies are the major contributors, e.g. in Germany, 85 % of the private sector R&D investments come from manufacturing industries.

Therefore, an explorative analysis of data of approximately 2 700 manufacturing companies from six European countries (DE, AT, CH, HR, SI, RS) has been conducted to assess the dissemination of *de facto* RRI practices in the manufacturing sector. The data was generated in the context of the European Manufacturing Survey 2015 (EMS 2015). EMS contains random samples of manufacturing firms and represents the main structure of the manufacturing sector. Moreover, it covers different innovation areas from technological process innovations, to organisational innovation processes to information about product innovations.

The analysis shows that roughly **15 %** of those manufacturing companies **consider the social and environmental impact when assessing their own performance**. Around **6 % indicated a further commitment by implementing certifications** such as Cradle-to-cradle certificates, the EU Ecolabel, or ISO-14020. These certificates indicate that these firms follow procedures to assess environmental and human health impacts of products along all phases of the product life cycle, and that they generate innovation processes reflecting higher levels of responsibility. In conclusion, the analyses reveal that responsible innovation processes, understood as an overall concept by considering several innovation areas, are currently implemented in companies to a rather low degree. Less than 10 % of manufacturing firms are active in more than one of the dimensions of *de facto* RRI activities. Further descriptive analyses reveal differences between sectors, countries or firm characteristics. Thus, it can be concluded that opportunities and challenges regarding responsible innovation processes as defined by the RRI concept are to a great extent determined by the available resources of firms, reflecting individual structural characteristics.

With regard to the economic impact of responsible innovation, the results clearly show that **firms actively engaged in responsible manufacturing practices are more innovative**. A higher share of these firms is able to launch new products successfully, thereby generating higher turnover with product innovations. Additionally, these firms have a higher chance of introducing new services at the market. Moreover, the analyses show that these manufacturers are not economically disadvantaged. On the contrary, these firms even indicate higher levels of labour productivity. However, this advantage is based mainly on structural differences (Jäger et al., 2017; MoRRI D9.2).

RRI was found to have a number of **economic benefits**. In several cases, public engagement activities leading to more inclusiveness in research helped to create better solutions. Public engagement also increased trust in business: it increased firms' anticipatory capacities and helped them to participate in the shaping of public discourse. In addition, recognising gender equality and using open access led to better organisation performance; public engagement helped to collect data more cost effectively; addressing issues of research ethics and integrity could help to avoid litigation costs and produce reputational gains; taking RRI issues into account led to new business and funding opportunities.

RRI had also a number of **scientific benefits**. Public engagement activities and addressing gender equality in research framed research questions that took into consideration societal needs and local knowledge. This again led to new insights and helped to improve research, providing researchers with access to new data. RRI also contributed to changes in the science culture. For example, shifting science, curricula and the R&I workforce towards more inclusiveness and diversity provides opportunities for previously untapped human resources and can increase the numbers of students/researchers from different socio-economic backgrounds. Public engagement helped researchers to acquire new skills and to communicate and work with non-experts in research groups. If was found that more

diverse research groups performed better than homogenous groups, and activities in science education, public engagement and ethics can increase society's knowledge about and trust in science.

Box 3 Societal benefits due to gendered medical research

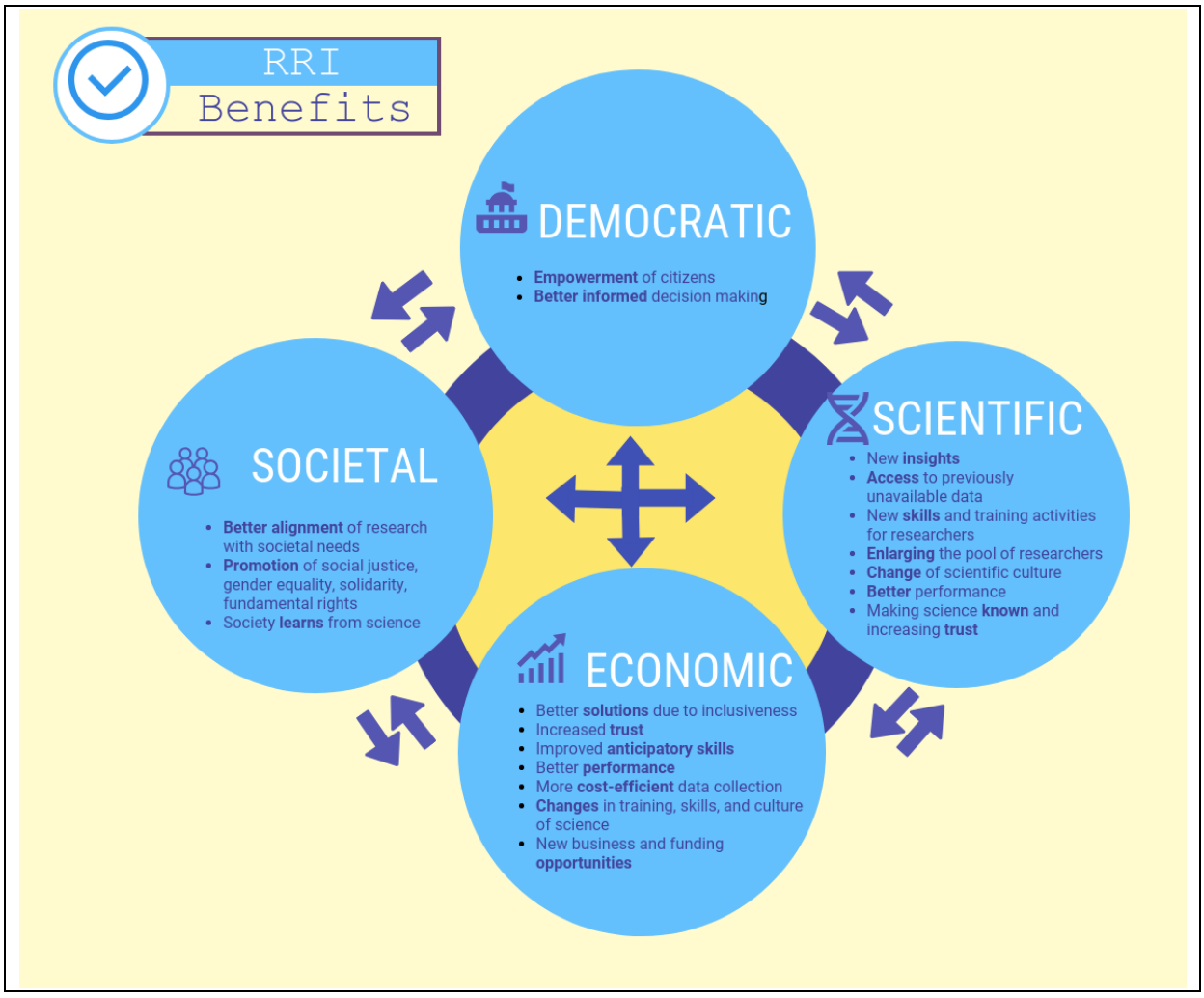
Institute of Gender in Medicine at the Medical University Berlin - Charité

The Institute of Gender in Medicine systematically researches and integrates gender aspects in the research of cardiovascular diseases. By doing so, it contributes to a better understanding of cardiovascular diseases, and improves scientific theories, methods, models and evidence-based therapies. It also contributes to new gender-sensitive curricula in teaching medicine at universities (scientific benefit).

The **societal benefit of gender medicine** is evident, since women – i.e. half of the population – receive more attention for their needs when developing and introducing new pharmaceuticals, diagnostics and therapies. This will improve human health and quality of life, and increase life expectancy. The case also provides an example that limited funding can curtail the potential democratic impact of RRI-relevant activities. Indeed, a lack of basic, institutional funding, prevents the institute from accepting invitations to participate in policy-related expert groups and to transfer its expertise to the political arena (see Wuketich et al., 2016; MoRRI D5.2).

The case study programme also found that the societal, democratic, economic and scientific benefits of RRI are closely interlinked, as illustrated in Figure 13.

Figure 13 Societal, democratic, economic and scientific benefits of RRI



Source: adapted from MoRRI 2016, D5.2.

The identification of potential benefits of RRI suggested a rich set of societal, democratic, economic and scientific effects. The case study programme indicates that these different types of benefits of RRI are interlinked, as illustrated in Figure 13. Emerging awareness of the mutually reinforcing relationships between the RRI keys thus appears likely to be an important consideration in the future development of the monitoring system for RRI benefits.

3.4 Researchers' perceptions of RRI benefits

It is not easy to attribute the benefits to particular activities or interventions directly. Nevertheless, actors within the R&I system and in society more broadly will have expectations about the kinds of benefits a more responsible R&I system can bring. Researchers are key actors in this regard, as they are likely to have a vision of the kinds of future impacts and benefits that might extend from their scientific outputs and societal engagement activities. Researchers' visions of how responsible research and innovation may benefit both science and society are thus likely to be insightful.

In order to learn more about perceptions of benefits associated with RRI and its five key areas, two large-scale surveys among European researchers were launched. The first approached researchers who had previously received EU funding. The second addressed researchers with similar structural characteristics (by discipline, gender) but who had not received EU funding (the control group).[21] In order to obtain a picture of researchers' perceptions of RRI benefits, we asked the respondents: (1) whether they have already observed any benefits when conducting an activity in the areas of gender equality, science education, open access, public engagement or ethics; (2) whether they expect respective benefits in the future or (3) whether they do not expect any benefits.

These perceptions were linked to the four types of benefits. In addition, the respondents were asked about their awareness of the RRI concept, concrete activities along the RRI keys (e.g. gender equality, public engagement, etc.), the main drivers for conducting the respective activities, and also the supporting and hindering factors for the implementation of RRI.

The analysis of the two groups of researchers, one receiving funding from the EU and the other not, showed that the framework programme designed by the European Commission makes a difference to the practice of responsible research and innovation. Not only are EU-funded researchers more familiar with the concept of RRI, they also associate more benefits and supporting factors with it than do researchers from the control group. Furthermore, the EU-funded researchers are more likely to practise activities related to the five main pillars of RRI, i.e. open access, gender equality, science education, public engagement and ethics. Presumably this is a direct effect of learning through EU-related policies and requirements, as RRI was developed and implemented first by the EU and is not yet – at least not as an acronym – fully known within national research and innovation systems. Furthermore, we can assume that European research and innovation funding typically attracts researchers who engage (more) in applied, problem-solving and challenge-oriented research, which, as shown by this analysis, is more open towards RRI than pure curiosity-oriented research.

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[21] The survey among EU-funded researchers was launched in November 2016. In total, 22 947 persons were contacted by e-mail; 673 could not be reached. Of the remaining 22 274 persons, 3 117 responded, (response rate of 14 %); 2 755 participants completed the survey (completion rate: 12.4 %). The survey to the control group was launched in March 2017: 25 968 identified researchers were contacted by e-mail; 8 245 persons could not be reached due to absence, retirement or an invalid/outdated email address, resulting in a net sample of 17 723 persons; 1 264 researchers responded to the survey request, constituting a gross response rate of 7.1 %. Of these, 945 participants answered at least half the questions in the survey, a net response rate of 5.3 %. In total, 723 participants completed the survey (completion rate: 4.1 %). For more details see Bührer et al., 2017; Bührer & Younes, 2017.

However, the control group's results also show that there is still a long way to go regarding the 'universe' of researchers in Europe before RRI is more broadly known and accepted. In this regard, moves to develop policies should bear in mind the fact that the most important barrier, from the point of view of the respondents, is a strong overload of tasks. This might be overcome by adopted institutional incentives, more staff in research organisations and reduced reporting duties. Lack of knowledge also acts as a barrier, but this could be overcome by intensified communication of RRI as a concept and particularly the communication of good practice examples. Good practice examples are, for instance, illustrations of the advantage of gendered innovations[22] or the good practice examples collected by the EU-funded RRI tools project (Kupper et al., 2015).

The survey results confirm the impression that the institutional environment can positively influence the degree of RRI activities and the general attitudes towards more responsible research and innovation. Researchers working in an institutional environment that systematically supports the practice of RRI, for example through funding incentives, dedicated staff in charge of RRI pillars, etc., are more active in RRI practices than researchers who cannot rely on such structures. Thus, from the point of view of policy-makers, active support of institutional changes might help the dissemination of RRI. As we saw from the survey results, the definition of success and/or eligibility criteria for research funding is a further mechanism that encourages a positive attitude towards RRI.

Further factors that influence the practice of RRI and its perceived benefits are the research experience and the scientific discipline of the respondents. Especially for medicine, but in most cases also for the social sciences and the humanities, RRI issues are more important than for the natural and physical sciences.

Another important result is that the longer the period spent working in research, the more the respondents are inclined to conduct a respective RRI activity. We assume that more experienced researchers have more opportunities than the less experienced to invest in such kinds of activities because they are typically already established within the science system, while younger, less established researchers still have to focus on their research and the advancement of their academic/professional careers. One might consider changes within the national systems of performance-oriented resource allocation. For example, if public engagement or science education activities were also recognised by the respective key performance indicators (and not only the number of publications and citations, etc.), this could support younger, not yet fully established researchers to address RRI issues without endangering their scientific careers.

A gender effect can be observed primarily within the gender equality pillar. Women support female colleagues and also consider gender aspects in their research design more frequently than men. The use of gender-sensitive language shows no significant differences between men and women.

Generally, the respondents report numerous benefits that have already been observed, particularly scientific and economic benefits. Even if concrete benefits have not yet been observed, the respondents are still quite optimistic that these benefits will occur in the future. This attitude also applies to the control group.

Overall, we ascertain that respondents perceive more supportive factors than hindering barriers. Whereas more than half the respondents mention supportive factors, only slightly more than one-third mention barriers. From the respondents' viewpoint, the most important supportive factors are personal motivation and the institutional strategy, which can play a decisive role.

[22] http://ec.europa.eu/research/swafs/gendered-innovations/index_en.cfm?pg=home

3.4.1 Researchers' perceptions of scientific benefits of RRI

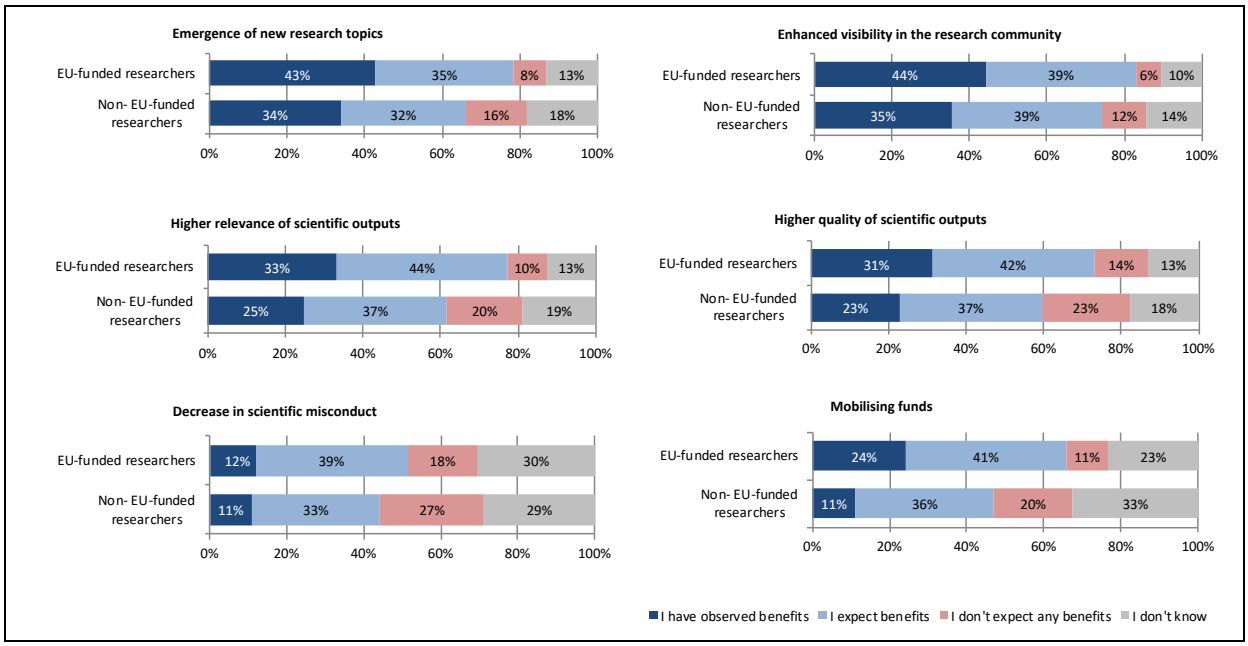
If we look first at the scientific benefits, Figure 14 shows that of the six specific scientific benefit items we asked about, enhanced visibility in the research community and the emergence of new research topics were the most important for both survey groups. Approximately one-third of the EU-funded researchers and a quarter of the control group indicate having already observed a positive effect of RRI on both the relevance and quality of their scientific outputs. The effect of RRI activities on reducing scientific misconduct was less strong and the share of the respondents who don't expect any benefits was highest for this item.

Although the ranking of the scientific benefit categories is almost the same for both groups of surveyed researchers, it is worth mentioning that 'mobilising funds' is much more frequently reported by the EU-funded researchers than by the control group.

However, the multivariate analysis confirms that the majority of the 'scientific benefit' items differ significantly between the EU-funded researchers and the control group. Five out of six items were perceived differently (all but 'decrease in scientific misconduct'), underlining that – unsurprisingly – EU-funded researchers have had more concrete experiences of, and hold higher expectations about, future benefits.

In terms of disciplines, researchers from the humanities indicate scientific benefits more often than respondents from other scientific disciplines (see Bührer et al., 2017). In contrast to the results for all respondents, medical researchers think that the most important contribution of RRI is to decrease scientific misconduct. However, these differences between scientific disciplines are, however, not statistically significant. Instead, the number of years of research experience has a strong impact on the perception of scientific benefits: the more years of research experience, the more observed benefits. Another differentiation can be found by the type of research: researchers who describe their research as challenge-driven report more benefits than curiosity-driven researchers.

Figure 14 Scientific benefits



Source: MoRRI 2017, Researchers' survey.

The results of the researcher survey provide strong support for a category of scientific benefits of RRI, which initially emerged from the MoRRI case study programme (section 3.3). Responses indicate that researchers do perceive RRI as generating benefits for science, research and innovation. This was particularly the case where researchers had

worked on EU-funded projects and were therefore more likely to have encountered RRI concepts.

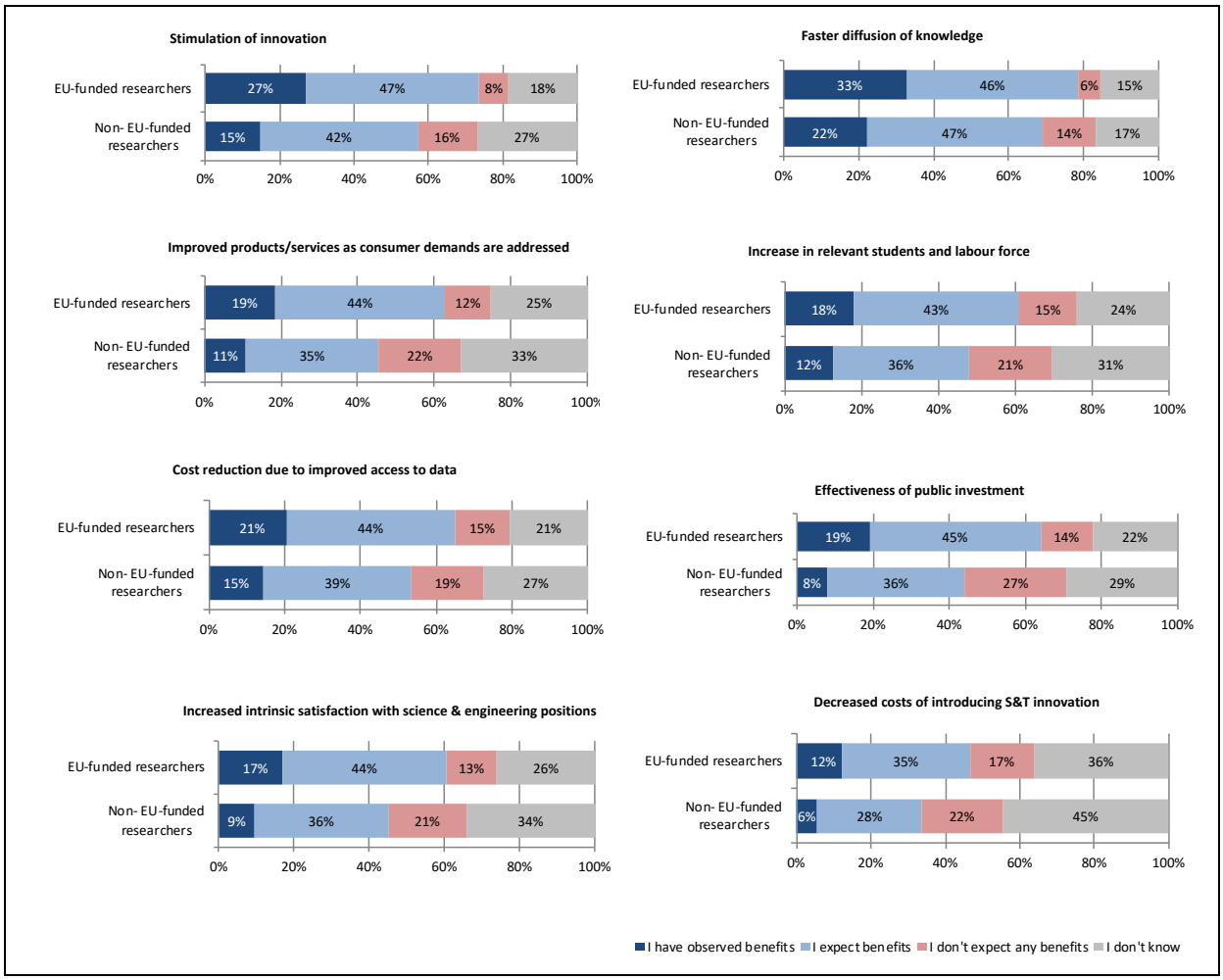
3.4.2 Researchers' perceptions of economic benefits of RRI

Turning to the economic benefits of RRI, Figure 15 shows that of the eight specific economic benefit items we asked about, faster diffusion of knowledge is regarded as the most important among the EU-funded researchers, but also more than one-fifth of the control group respondents reported observing this benefit. Stimulation of innovations is also observed or expected by the majority of respondents in both survey groups, with EU-funded respondents reporting having observed this benefit significantly more often than the control group.

Four other economic benefit items had been observed by around one-fifth of the EU-funded researchers: cost reduction, more effective public investment, improved products and services, and an increase in the relevant labour force. The control group respondents were considerably less likely to report having observed these four economic benefits of RRI than those who had received funding under a Framework Programme. Nevertheless, more than one-third of the control group respondents retained expectations that such a benefit occurs in the future.

The economic benefit items that were least frequently reported by both survey groups were increased intrinsic job satisfaction and decreased costs of introducing S&T innovation. The relatively high rate of 'don't know' responses suggests that links between these benefits and RRI may be unclear for many researchers.

Figure 15 Economic benefits



Source: MoRRI 2017, Researchers' survey.

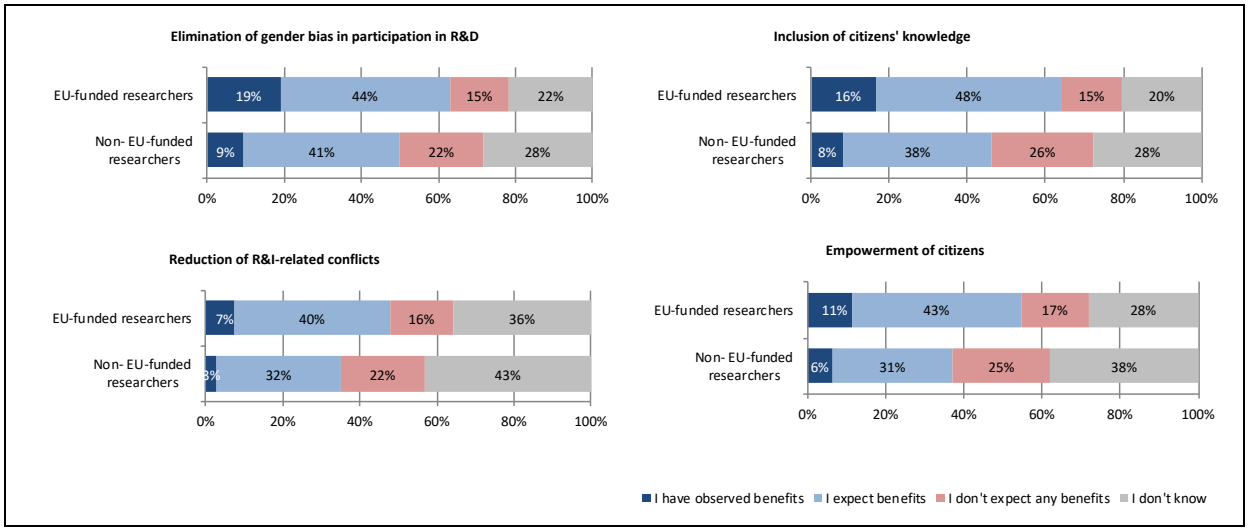
For six of the eight economic benefit items, responses differ significantly between the EU-funded researchers and the control group. Only for 'cost reduction due to improved access to data' and 'increase in relevant students and workforce' was there no statistical difference between the responses of the two groups.

3.4.3 Researchers' perceptions of democratic benefits of RRI

Respondents generally observed democratic benefits less frequently than they did either scientific or economic benefits. Among the most important democratic benefits are the elimination of gender bias in R&D participation, and the empowerment of citizens. However, even where a benefit had not yet been observed, almost half the respondents expected the respective benefit in the future.

The responses of the two survey groups are significantly different for all four democratic benefit items, with EU-funded researchers more inclined to report the respective benefit than researchers in the control group. Looking at scientific disciplines, researchers from the humanities and medicine are more likely to have observed, or to expect, democratic benefits from RRI.

Figure 16 Democratic benefits



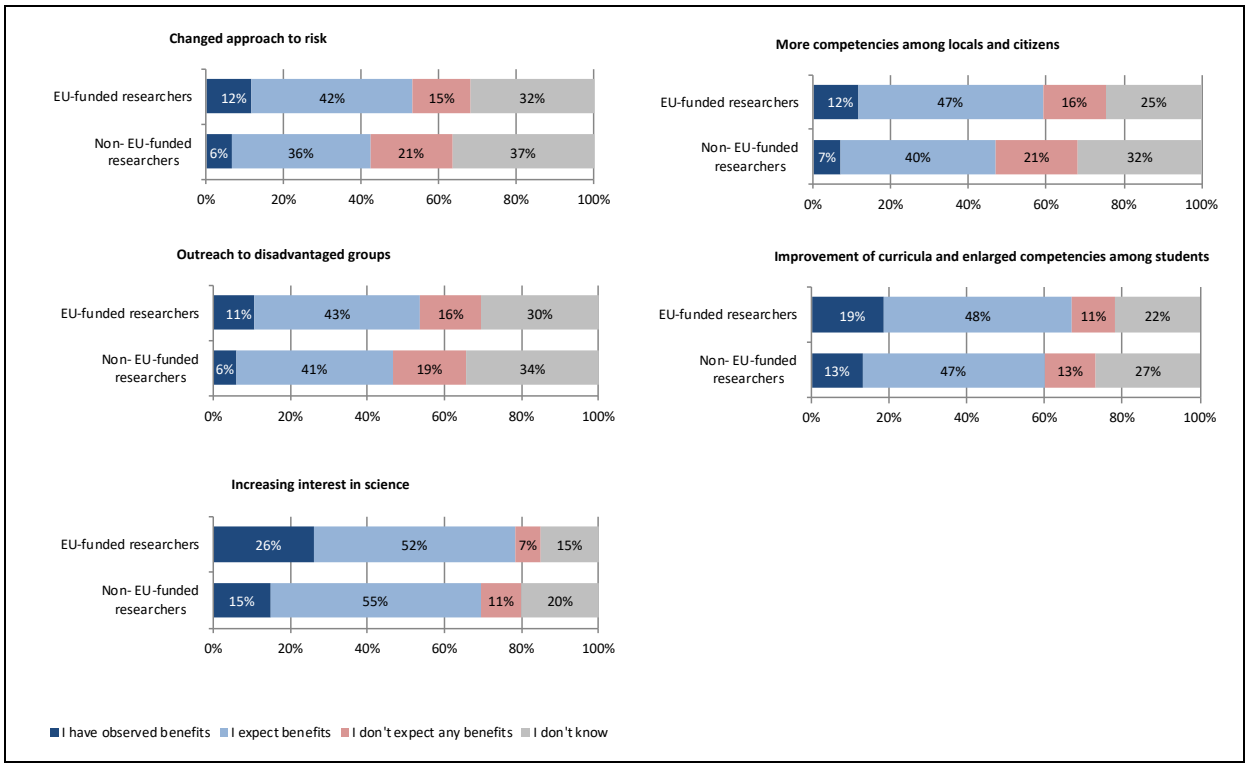
Source: MoRRI 2017, Researchers' survey.

3.4.4 Researchers' perceptions of societal benefits of RRI

Of the five societal benefit items we asked researchers about, an 'increasing interest in science' and the 'improvement of curricula and enlarged competences among students' were the two items that were most frequently reported to have been observed by respondents. There were significant differences between the responses of EU-funded researchers and those of the control group for three of the five societal benefit items (changed approach to risk; outreach to disadvantaged groups; increasing interest in science). EU-funded researchers were more likely to report having observed each of these three items.

In terms of scientific disciplines, societal benefits are most frequently observed or expected by researchers from medicine, the humanities, the social sciences and economics. However, natural scientists and medical researchers were more likely to observe an increased interest in science.

Figure 17 Societal benefits



Source: MoRRI 2017, Researchers' survey.

3.4.5 Researchers' perceptions and the monitoring of RRI benefits

This analysis has focused on comparing perceptions of the benefits of RRI between two groups of researchers: those who have been recipients of EU funding and those who have not.

The analyses demonstrate that the framework programme designed by the European Commission makes a difference to perceptions of benefits flowing from responsible research. EU-funded researchers are more likely to associate scientific, societal, democratic or economic benefits with responsible research than are researchers from a control group. We assume that the incentive provided by the prospect of an improved access to research funding motivates the researchers to reflect the concept and practice of RRI.

Other factors that influence perceived benefits of RRI are the researchers' years of experience and their scientific discipline. RRI issues are considered much more important for researchers from medicine, most of the social sciences and for the humanities, than for researchers in the natural and physical sciences. This does not mean that RRI is intrinsically less important for these disciplines, just that it is considered relatively less so by researchers in certain disciplines.

Of course, it is also important to consider whether researchers who have a favourable perception of RRI and actively engage in RRI activities are more likely to apply for framework programme funding. If so, there could be a selection bias effecting the results of the researchers' perceptions survey in that researchers who value RRI may be more likely to be framework programme participants.

Organisation-level effects may also condition researchers' perceptions of RRI. For example, organisations that promote RRI (including potentially as a consequence of receiving framework programme funding) will boost the researchers' awareness of RRI. This may increase the likelihood of researchers applying to relevant framework programme funding calls. Whether individual self-selection or such organisation-level factors influence researchers' perceptions of RRI benefits would therefore be an interesting question for further research.

Another important result is that the longer a researcher or scientist does research, the more he or she is inclined to conduct an RRI activity. We assume (though lack data to support this) that more experienced researchers have more opportunities than the less experienced ones to invest in these activities, since they are typically already established within the science system. In comparison, early career researchers still have to focus more narrowly on career advancement.

To overcome this, changes within national systems of performance-based resource allocation might be considered. For example, if public engagement or science education activities were also recognised as key performance indicators (and not only the number of publications and citations, etc.), this could support early career researchers to address RRI issues, without perceiving this as an activity potentially endangering their scientific careers.

The MoRRI Research Survey thus provides important information on particular benefits that researchers perceive as arising from RRI. Perceptions of scientific benefits specifically capture observed and expected effects of RRI on the science, research and innovation system. Researchers' perceptions of societal, democratic and economic benefits capture observed and expected effects of RRI on the well-being of citizens and the socio-cultural sphere in general.

The development of perception-based metrics and intermediate/foresight indicators, potentially drawing on a large periodic survey of researchers, could conceivably become part of a monitoring system for the evolution and benefits of RRI. Such indicators could track the emergence of expected RRI benefits, for example. However, whilst it is highly advantageous to understand researchers' perceptions of RRI benefits, perhaps the more interesting question is whether, and to what extent, these perceptions line up with those of their fellow citizens.

Ideally, a bank of indicators based on researchers' perceptions would be matched by a bank of indicators of citizens' perceptions. Citizens' perceptions would most likely need to be drawn from a comprehensive, periodic public barometer. Such a barometer would also need to control meaningfully for variation in socio-cultural contexts. 'Matching' researchers' and citizens' perceptions could then underpin periodic assessments of the degree of alignment between researchers' and citizens' perceptions. As a way of assessing the contours of the alignment of R&I with societal needs, expectations and values, this would seem an essential component of a comprehensive monitoring system for RRI.

Of course, whilst perceptions of RRI benefits are important and could potentially provide valuable metrics and indicators for a monitoring system for RRI, these should complement other types of evidence and indicators. More has to be done to attribute observable benefits to the implementation of particular RRI activities or interventions than simply identify and measure perceptions that this is the case. The next section discusses the attribution of societal, democratic and economic benefits to RRI activities or interventions in more detail.

3.5 Impact pathways and the generation of RRI benefits

Establishing a framework for monitoring the emergence and evolution of RRI benefits implies being able to plausibly identify benefits attributable to RRI, and to develop valid and reliable empirical tools for assessing this benefit, preferably at regular intervals. This presents numerous important challenges, including:

- defining particular benefits as precisely as possible;
- attributing benefits to RRI activities or interventions in a meaningful way; and
- designing appropriate and responsible metrics to support assessments of RRI benefits.

It is evident that these challenges are novel and require considerable further research and experimentation to be convincingly developed. This section summarises progress on the second of these challenges.

3.5.1 Conceptualising impact pathways

Standard linear intervention logic is of limited usefulness in seeking to monitor RRI benefits. The RRI indicators proposed in MoRRI do not, as yet, go beyond input, output and outcome measures. Difficulties associated with developing impact indicators for RRI are those commonly understood in evaluation practice as a) the problem of attribution of effects to specific antecedent events, and b) the compounding effect of the significant time-lag that often exists between the 'causal' events and the emergence of impacts.

Establishing a systematic approach to the linkages between RRI and benefits at the societal scale thus requires a straightforward conceptual framework. The framework proposed posits a set of relations through which the outputs, outcomes and impacts achieved by RRI measures can be said to promote broader benefits. The concept at the core of the MoRRI model for generating RRI benefits is the impact pathway (or interchangeably, pathway to impact).

This model draws on elements of existing state-of-the-art impact assessment frameworks. The Payback Framework (Donovan and Hanney, 2011) highlights the necessary stages of knowledge production and use that progressively and cumulatively move toward benefits in health. The SIAMPI model rests on the existence of 'productive interactions' between researchers and external stakeholders as the condition of impact creation (Molas-Gallart and Tang 2011; Spaapen and Van Drooge 2011). The ASIRPA approach to assessing the societal impact of public sector research organisations defines research impact as:

1. multi-dimensional;
2. based on the involvement of networks of actors;
3. at different stages and playing a variety of roles; and
4. over a non-linear impact pathway (Joly et al., 2015).

The emergence, institutionalisation and evolution of impact pathways are understood to produce broad aggregate effects, including societal, democratic and economic benefits as well as benefits for science, research and innovation. Impact pathways thus focus on the processes by which activities and interventions create the conditions for benefits to emerge or stimulate the expansion of perceived benefits accruing at the societal level.

Impact pathways that characterise each of the RRI dimensions are treated as independent, due to the specific normative assumptions that underlie each dimension. Nevertheless, these impact pathways are commonly conceived as resting on 'productive interactions', the 'exchanges between researchers and stakeholders in which knowledge is produced and valued that is both scientifically robust and socially relevant', with the productive dimension implying 'efforts by stakeholders to somehow use or apply research results or practical information or experiences' (Spaapen and Van Drooge, 2011: 212). Impact pathways are more likely to lead to societal-level benefits when the number and diversity of stakeholders that are committed to such efforts, including researchers, is relatively high.

Impact pathways for each RRI dimension can be analysed in terms of:

- *integration* – the forms of organising productive interactions among relevant stakeholders;
- *implementation* – the processes embedded in sets of RRI activities which create the conditions for benefits to emerge and/or expand; and
- *contribution* – the inputs of stakeholders to these sets RRI activities.

Focusing on the contribution of stakeholders to the emergence and consolidation of impact pathways has the added advantage of encouraging a reflexive or self-evaluative approach on the behalf of stakeholders. This can help in disseminating a common understanding of the direction of impact pathways and the emergence of complementarities between stakeholders' approaches and contributions that are mutually reinforcing.

Productive interactions among stakeholders provide the mechanism for mutual learning at the level of R&I system actors (researchers, individuals, groups, organisations). In this sense, an impact pathway is also a vehicle for shared involvement in (negotiated) system transformations. The intervention logics associated with RRI dimensions seek to propel such change in certain directions. These directions are normatively shaped by visions of what constitutes a better R&I system and desirable S&T outputs and impacts. Altering the normative substrate of science, research and innovation activities, and influencing the direction of the R&I system overall, depends on the capacity to effect systemic changes.

Impact pathways can be considered to generate systemic change through three modalities[23]:

- *cognitive transformations* refer to changes in thinking and attitudes;
- *procedural transformations* refer to changes in the ways things are done; and
- *competence transformations* refer to systemic changes that effect all relevant actors.

Although these modalities can be separated analytically, they are interwoven in the emergence, institutionalisation and evolution of impact pathways.

To take one example, impact pathways toward gender equality induce changes that will lead to benefits for the R&I system (and science itself) and for society/the world at large. Within the R&I system, cognitive transformations refer to the proactive and positive attitudes and expectations that researchers and the research community as a whole have toward working in gender-mixed teams and to reducing gender bias in R&I. Procedural transformations include the reform of existing procedures, or the introduction of new procedures, to reduce and eliminate gender bias from all management and other operational contexts, such as project teams and organisational committees. Competence transformations refer to the inculcation of expectations and understandings regarding gender equality across the breadth and depth of the R&I system, such that these issues can be worked on collectively from a shared basis. The ultimate objective of these cognitive, procedural and competence transformations is an R&I system that is free of gender bias.

Impact pathways thus operate to modify attitudes and procedures across the collective of actors involved in R&I. This occurs through productive interaction between actors and the transformative processes embedded in the activities implemented collectively. The following section identifies a number of the critical processes integral to these implementation activities and describes how these are linked to RRI dimensions.

3.5.2 Interactions, transformative processes and the direction of change

There are numerous contexts, both formal and informal, in which actors come together to define objectives that link science, technology and society. Interactions between these actors are the basis for implementing the activities required to reach these objectives. A

[23] The three transformative modalities described here were developed by the MoRRI project team in 2016.

number of processes can be identified, which promote responsibility in the definition and implementation of shared objectives.

Pluralisation refers to the opening up of science, research and innovation to the widest range of actors possible. Democratic benefits emerge when these actors are involved in S&T decision-making and their ideas and arguments are considered in these decisions, ensuring representation of the diversity of values and expectations in society. Economic benefits emerge when connections between actors foster creativity, increase the number and diversity of contributors to, and users of, data, information and other knowledge resources, and introduce new demand-driven research topics and questions. Connections among an increased range of actors can improve mutual awareness and understanding of expectations and needs, enhancing the relevance of R&I to societal stakeholders. Pluralisation is particularly likely to be advanced and reinforced through public engagement, gender equality and open access initiatives.

Inclusion refers to the entry and active involvement of previously marginalised or disenfranchised actors, and associated elements such as local knowledge, into science, research and innovation. Democratic benefits emerge when inclusive activities lead to the introduction of previously excluded perspectives and knowledge sources into R&I, and to their engagement in R&I policymaking. The horizontal and vertical participation of women in R&I reduces bias against women, their inclusion constituting a democratic benefit in terms of representation. Inclusive educational activities or methods also increase the representation of minority or disadvantaged groups in science. Engagement of citizens' groups can produce economic benefits where their contributions improve the alignment of R&I with consumer demand. The inclusion of women in research design and development is a powerful example of this, which can both improve the quality of science and generate economic benefits through increased relevance of R&I outputs for women. Broad societal benefits in terms of the relevance of R&I can emerge from the inclusion of citizens' perspectives and engagement with their experience, including through citizen science and student internships, for example. Inclusion is a particularly prominent element of public engagement, science education and gender equality activities.

It should be evident that pluralisation and inclusion are complementary and mutually reinforcing processes. These processes set the interactive basis for a broader, more responsive and ultimately more efficient alignment between R&I and wider society. The emergent effect of greater openness and inclusion is an enhanced social legitimacy of the R&I system.

Legitimisation refers to the improved societal awareness, understanding and acceptance of R&I emerging from interaction, communication and critical engagement. Democratic benefits emerge when more citizens understand S&T choices and accept that the process and rationale for decision-making is legitimate. Economic benefits can extend from a reduction in the costs of market entry and consumer adoption of S&T-based products, and from increased attractiveness due to perceptions of socio-technical appropriateness. Diffused societal benefits occur when diverse stakeholder roles and contributions to R&I are understood and accepted, and young people perceive R&I as a socially and ethically attractive option for careers, including for women. Legitimisation is promoted strongly through the public engagement, science education, gender equality and ethics dimensions of RRI.

While pluralisation, inclusion and legitimisation are three particularly important processes that emerge through impact pathways, particularly in terms of the normative alignment of R&I and society, several other processes also play important facilitating roles. Diffusion refers to the movement of information through networks of actors, including the sharing of relevant information, good practices and research findings. For example, open access to scientific publications and project reports can stimulate social innovation and place-based problem solving. Adaptation refers to the way R&I institutions progressively conform to the expectations of society, for example through reformed education and training or ethical standards that benefit society. Recognition refers to a generalised understanding that S&T issues always also involve choices that will impact on society in different ways depending

on their substantive content, presenting ethical dilemmas of many different shapes and sizes.

Attributing societal, democratic, economic and/or scientific benefits to RRI activities and interventions is a difficult conceptual challenge. Linear sequences of inputs, outputs, outcomes and impacts, whilst they may often be relevant to the generation of RRI benefits, cannot be the whole story as RRI benefits also involve a normative understanding of the direction of 'responsible' transformation. This presupposes an ongoing dialogic engagement among scientific and social actors of all types that furthers the alignment of R&I and society. We conceptualised such interactive processes as 'pathways to impact' in which diverse sets of actors are drawn together and make relevant contributions to the pursuit of collectively negotiated goals and objectives. The following section considers the implications of this approach for monitoring the evolution and benefits of RRI and proposes some initial steps in this direction.

3.6 Monitoring RRI benefits

Three observations can be made regarding the MoRRI identification of potential RRI benefits. First, the potential metrics and indicators of RRI benefits developed through the visioning workshop (see section 1.3) and case study (section 3.3) phases of the project were not evenly distributed across RRI dimensions. The public engagement, gender equality and, to a lesser extent, science education dimensions contain substantial numbers of potential benefits. A relatively small number of benefits were identified for ethics and open access, whilst none were identified for governance. Second, potential RRI benefits are not distributed evenly by type. Economic benefits were less readily identifiable for the public engagement and science education dimensions. Democratic benefits were lacking in the ethics and open access dimensions. Third, the character of the benefits identified varies considerably. Many RRI benefits identified were of a very general character, which is logical when considering benefits at a societal scale. The narrower benefits identified were often focused mainly on the R&I system itself. Whilst benefits for science and for the R&I are important in themselves, these will take time to translate into benefits at a societal scale (where applicable).

The problem of attribution of very general effects to RRI processes and outcomes is a significant challenge when developing a monitoring system for RRI benefits. Lengthy time lags can occur between observed changes in the R&I system, which might be monitored through indicators of RRI outcomes and flow-on or emergent benefits to society at large. Benefits emerging from RRI interventions may not yet be evident, partially or fully, regardless of the available outcome indicators. The problems of attribution and temporal lag were foreseen in the MoRRI project design; nevertheless, assigning causal links between RRI activities and impacts and societal-scale benefits remains problematic. This is a measurement theory challenge in the field of general indicator development.

Awareness of these challenges and the need for further research, experimentation and technical development does not mean we are unable to move forward with monitoring the evolution and benefits of RRI. The initial strategy for developing metrics and indicators of RRI benefits relies on three elements:

- Intermediate indicators based on metrics of RRI outcomes that are taken as proxies for assumed future societal, democratic or economic benefits;
- Indicators developed according to an impact pathways model that interpret RRI benefits as generated through transformative processes embedded in RRI activities and interventions and as a consequence of the outcomes of these actions; and
- Network indicators focused on the alignment of R&I and society within defined sub-systems.

The rationale for this diversified approach is that whilst constraints in terms of conceptualising RRI benefits and the state of the art of impact measurement continue to

evolve, progress can be made in developing a monitoring framework for RRI benefits based on these approaches. The indicators of RRI benefits are products of a first stage of development and should be regarded as a provisional set of data/metric test cases.

Table 4 Proposed indicators of RRI benefits

Indicator type	Indicator name (tag)	Type of benefit
Intermediate	Citizens' participation in research and innovation (PE-DEM1)	Democratic
	Reduction in bias against women's participation in research and innovation (GE-DEM1)	Democratic
	Proportion of research that includes a gender dimension (GE-DEM2)	Democratic
Modelled on pathways from RRI outputs/ outcomes to benefits	Citizens' perspectives feature in research and innovation policy-making (PE-DEM2)	Democratic
	Training of researchers in public communication (PE-SOC1)	Societal
	Citizens' awareness and understanding of science and technology choices and policy decisions (SLSE-DEM1)	Democratic
	Gender relevance of research and innovation outputs (GE-ECON1)	Economic
	Image and attractiveness of research and innovation careers (ETH-SOC1)	Societal
	Access to and utilisation of open data (OA-ECON1)	Economic
Network	Degree of diversity in research and innovation networks (GOV-DEM1)	Democratic
	Degree of coherence in research and innovation networks (GOV-SOC1)	Societal

Source: *MoRRI Progress Report* D6 (2016).

A total of 11 indicators of RRI benefits are proposed. The three intermediate indicators are based on indicators of RRI outputs and all are indicators of democratic benefits. In terms of RRI dimensions, one intermediate indicator is for public engagement and two are for gender equality. It should be noted that no indicators of the scientific benefits of RRI were developed in MoRRI. This was because the identification of this category of scientific benefits occurred unexpectedly and too late for inclusion in the project task dedicated to developing indicators of RRI benefits. It can also be noted that several of the proposed indicators (particularly PE-DEM1, GE-DEM2, OA-ECON1) appear to have the potential to be re-specified as indicators of scientific benefits of RRI. However, the main work developing indicators of the scientific benefits of RRI remains a task for the future.

Three indicators are proposed based on *intermediate outcomes*:

- **PE-DEM1** is designed to capture the extent to which citizens participate in S&T decision-making processes and avail themselves of full or partial decision-making power. The metric proposed is a composite of three metrics of RRI: PE2 (policy-oriented engagement with science); PE9 (R&I democratisation index); and PE10 (national infrastructure for involvement of citizens and societal actors in research and innovation). These three metrics compile an intermediate indicator of the achievement of the democratic benefit of increasing citizen representation and decision-making in R&I and society. Data for PE2 have already been collected as part of a Eurobarometer survey and could be collected again at periodic intervals. PE9 and PE10 are new indicators, for which data will be collected via surveys as part of Task 8 of the MoRRI project. These data could be collected on an annual/bi-annual basis. Coverage across all Member States is conceivable at the national level.

- **GE-DEM1** captures progress toward the elimination of bias against women in terms of participation at all levels of the R&I system. The metric proposed is a composite of two metrics of RRI, GE2 (share of female researchers by sector) and GE6 (glass-ceiling index), and a metric for the rate of change in women's and men's employment in R&D (GE2-CAGR). These three metrics compile an intermediate indicator of the achievement of the democratic benefit of reducing bias against

women in R&I and society. Thought could be given to adding other secondary data-based metrics to this composite indicator. These could include educational participation in and completion of science courses at undergraduate and postgraduate levels. These data are readily accessible and have increasingly comprehensive and consistent coverage across Member States.

- **GE-DEM2** captures progress toward the inclusion of a gender dimension in research content. The metric proposed is a composite of two indicators: the gender dimension in research GERC1 (proportion of a country's research output integrating a gender dimension in its research content) and GERC1-CAGR (compound annual growth rate of GE-RC1). These indicators are assumed to be intermediate proxies for the achievement of the democratic benefit of including a gender dimension in research content. Thought should also be given to adding other metrics to this composite indicator. For example, this could include a metric for the percentage of research projects that include a statement or analysis on the gender content of the research proposed.

Six indicators of RRI benefit were proposed *based on modelling impact pathways from RRI activities, interventions and outputs*. These indicators are evenly divided among societal, democratic and economic types of benefit. In terms of RRI dimensions, two of these indicators are for public engagement and one each are for science education, gender equality, ethics and open access.

- **PE-DEM2** captures the inclusion of the perspectives of the citizenry in R&I policymaking. The focus of metric development for this indicator is likely to be surveys of policymaking agencies and stakeholder groups at all levels. A metric such as the percentage of agencies, which observes beneficial impacts emerging, over time, from their undertaking of certain processes or steps to incorporate public opinion and interests in decision-making, could underpin this indicator, for example. Perception questions could also be a possibility. In addition, it is desirable that qualitative research tools be utilised to ascertain the extent to which these processes are aligned with desirable principles of democratic participation, such as transparency, accessibility and responsiveness. Methodologies such as focus groups in which stakeholder opinions are available for contest and qualification could strengthen the reliability of this approach. This indicator would be reasonably labour-intensive. Nevertheless, the potential for an intermittent time-series (every 3 to 5 years, for example) could produce useful time-series information. In terms of coverage, this indicator would be contextually sensitive and could be targeted at localised (town, city), regional or national levels of analysis and focus on specific controversies or on overall perceptions of the S&T policy.

- **PE-SOC1** captures the extent to which the provision of education to science and engineering professionals also prepares them to communicate with citizens to inform and/or educate them as part of their professional communication activities. This reflects the responsiveness of the R&I training system to the interests of the citizenry in terms of the appropriateness of public communication of S&T work, impacts and knowledge. Two metrics would be combined in PE-SOC1. The first metric proposed is the percentage of HEIs that provide/have a strategy for science communication training for S&T postgraduates. A second metric proposed is the percentage of science and engineering postgraduates that receive units/hours of training in science communication and other public engagement activities, such as public seminars, science/museum days and media appearances. A survey to HEIs (research direction or department units) would be the principle data source. This would be backed by document analysis of degree course curricula and unit outlines or postgraduate professional coursework. This indicator is relatively labour-intensive and could be repeated every 3 to 5 years to produce a time-series. A voluntary method of collating the introduction of new hours/units/courses of complementary training in science communication for science and technology could

be envisaged as a mechanism to reduce the labour-intensiveness of the indicator. This indicator has the potential to be developed with full EU Member State coverage.

- **SLSE-DEM1** seeks to capture citizens' awareness and understanding of S&T issues and controversies and the democratic decisions that affect S&T trajectories at particular times. The metric proposed is a series of survey questions designed to capture the democratic benefit of educational foundations that underpin citizens' awareness of S&T issues and of the different sides of debates about these issues. The indicator will capture the percentage of citizens with exposure to S&T societal issues within educational curricula, particularly exposure to societal perspectives on scientific controversies. This is intended to provide information on the basis of citizens' capacity to consider contemporary S&T issues from a variety of scientific, social and technical perspectives. The indicator would also include metrics for the recognition of current topics of debate in S&T and the capacity to recognise different arguments within these debates. Generational differences would need to be taken into account in the survey question design. It would be preferable to back these data with qualitative information that could further explore degrees of scientific citizenship with a small sub-set of survey participants. Again, this is a relatively labour-intensive indicator, but it is somewhat more experimental as the intention would be to add significant nuance to the capture of data regarding the concept of 'understanding' – in such a way as to document the value of educational experiences within forms of attentive S&T citizenship. There would be potential to replicate this indicator in order to construct time-series information, but this would likely be quite costly. The indicator would also be strongly cultural-context dependent and might not be very useful for comparative purposes. The level of analysis/coverage of SLSE-DEM1 would be contingent on the definition of relevant contextual factors, which could range very widely from local controversies to the impact of national education or targeted literacy/awareness campaigns, for example.

- **GE-ECON1** captures the extent to which R&I is perceived to be aligned with societal expectations as expressed through consumer demand, particularly in providing outputs that are relevant to women. The proposed metric would be questions focused on perceptions of the relevance of R&I outputs for women. These questions would be targeted at relevant women's stakeholder and advocacy groups to capture their perceptions of whether R&I outputs are relevant and whether the R&I system is responsive to demands for more relevant outputs. Questions regarding perceptions of R&I investment priorities are also a possibility, although this would likely require quite specialised knowledge on the part of respondents. In particular, the perceptions of women's health and other advocacy groups would be sought, along with environmental, educational and general consumer interest organisations. Coverage and level of analysis would be contingent to some degree on the definition of relevant contextual variables, including stakeholder interests and specific community or social needs.

- **ETH-SOC1** captures the degree to which the R&I system is seen to reflect a principled and ethical image that is aligned with the expectations of young people making decisions about education and careers. The metric proposed will be based on questions posed as part of a survey to incoming science students of HEIs or students exiting secondary education. The relevant questions will seek perceptions of professional roles in science and engineering, including whether a career in this field is perceived as offering opportunities to contribute to society in a desirable and appropriate way. This indicator could be produced as a time-series, although the validity of comparisons over time would possibly be compromised by (potentially radical) shifts in the science-society relationship. Coverage of the indicator could be all Member States, although the validity of any direct comparability between Member States would need to be carefully assessed.

- **OA-ECON1** captures the number of users of public data repositories and the utilisation of open data resources. There are different possibilities for a metric to

underpin this indicator. One approach could be to use user surveys to compile estimates of the value to individual firms or other users of accessing data from open access data repositories, including the estimated cost of having to acquire the data themselves. A second approach could be to use the number of discreet users and log data to assess changes in the rate of data downloads/accesses over time, using specified values for the type/amount of data being transferred to individual users. Initially such a metric could focus on large public data repositories.

Two *network indicators* were proposed, one each for democratic and societal benefits. These two indicators are applications of network quantification indexes. They are proposed primarily as indicators of relevance to governance, although may also have relevance to public engagement.

- **GOV-DEM1** is designed to capture the diversity of networks and other sub-systems of R&I and society. The base metrics used are the Shannon entropy and the Rao-Stirling diversity measure. Other metrics of balance and disparity may be considered as additional inclusions in some contexts. Together these metrics compile an index of diversity. The indicator could be applied to large research projects or other R&I initiatives in which engagement with multiple participants, stakeholders and the public are expected or desirable. The effects of pathway processes of pluralisation and inclusions can be revealed in changes to the degree of diversity of a defined entity, for example at the commencement, in the formation and at the end of a large project.

- **GOV-SOC1** captures the degree of coherence of networks and other sub-systems of R&I and society. The metric is the index of coherence, which measures the functioning of a set of network relationships in terms of characteristics of intensity and bridging. The bridging of distances between diverse elements of a system are considered as measures of qualities such as trust and coordination, which are considered to produce societal benefits in terms of legitimisation and perceived responsiveness of R&I across a range of participating and non-participating stakeholders.

In summary, two benefit indicators are proposed for public engagement, one for science education, three for gender equality, one for ethics, one for open access and two for governance. In terms of types of benefits, there are five proposed indicators of democratic benefits, two of economic benefits and three of societal benefits. A rationale for selecting these 11 indicators was to include a mix of RRI dimensions, benefit types and indicator types, as well as variety in terms of data points and potential collection methods.

3.7 Critical reflection

This section reflects on progress in the work on RRI benefits within the MoRRI project. There are four main points that should be kept in mind from a critical perspective.

- The **conceptual basis** for the definition of RRI benefits remains a work in progress. While MoRRI has developed a working definition that has facilitated progress on developing elements for a monitoring system, further work is needed. For example, a clearer distinction between the concepts of impact and benefits, and the relationship between them, is probably required.

- The **metrics and indicators** for the developed RRI benefits are provisional and yet to be fully refined. Next steps include: a) critical reflection on the validity of the proposed metrics as indicators of the phenomena described (as has been undertaken for the indicators of RRI); and b) assessment of the practicality and cost of proposed original data collections where applicable.

- There has been no scoping work undertaken on the **suitability** of the proposed indicators of RRI benefit for designing data visualisations or user tools that allow for the interrogation of indicators and their display.

- Further work could be done on **potential RRI benefit indicators** based on perceptions, along the lines pioneered by the Expert Group on RRI indicators. Perceptions-based metrics developed from sources such as surveys could make a valuable contribution to an overall monitoring system for the evolution and benefits of RRI. However, this will need a more clearly specified conceptual rationale that links a particular hypothesis to an observable change in perceptions. Perception indicators would also require very sound footings for making comparisons between citizens of different Member States who are embedded in distinctive socio-cultural contexts. For this reason, a purpose-built replicable *Eurobarometer*-type survey that could adequately control for national science cultures would almost certainly be required.

4 Outlook

Responsible research and innovation has come to stay. Concerns about the direction and pace of research and innovation are present in all technologically advanced countries. R&I is not only expected to increase knowledge and productivity, but is also called upon to help address emerging global challenges, to mitigate foreseen risks, and to deal with the ethical dilemmas directly connected to technological progress. In this spirit, R&D governance is being reshaped – and RRI has a crucial role to play. The European Union has been a pioneer in taking initiatives to address societal challenges, not least by adopting recommendations, incentives and regulations in an effort to sensitise and encourage actors to incorporate responsible behaviour in their R&I activities.

The MoRRI project has sought to contribute to progress in this area, by developing tools to measure and monitor the implementation, evolution and benefits of RRI. It has done this through a systematic review of theoretical discussions, a visioning workshop, and methodical collection of data linked to the conception and systematic testing of selected indicators of RRI. MoRRI now concludes, having provided new academic results and relevant policy insights for a range of stakeholders and potential beneficiaries interested in the advancement of cultures and practices of RRI. The MoRRI outcomes thus contribute to the ongoing and increasingly prominent debate on the direction and pace of progress of research and innovation, and provide support to the coordinated efforts being designed to meet global challenges in appropriate ways.

The commissioned work undertaken within the MoRRI project has provided a baseline for monitoring the evolution and benefits of RRI. The indicators developed within the context of the project and the empirical data collected allow us to map European efforts across countries. The project has also led to the identification of shortcomings in the current approach and thus to the identification of potential, future modification and enrichment of the monitoring of RRI.

As described in section 2, progress in monitoring the evolution and benefits of RRI has led to the development of a set of 36+ indicators of RRI that are comparable at Member State level. The 36 indicators of RRI include 14 input indicators, 11 output indicators, 5 outcome indicators and 6 mixed indicators, but there are no RRI impact indicators. The **development of impact indicators for RRI will be an important step**, which is currently constrained and will be inevitably shaped by the moving frontier of the state of the art in developing impact indicators generally.

It can be assumed that work to develop impact indicators of RRI will be influential in relation to work on RRI benefits. Impacts are the final step in the linear intervention logic underpinning MoRRI. For reasons described above, RRI benefits cannot simply be taken as a 'cumulative' or 'net' calculation of impacts. Nevertheless, the definition of calculable metrics for the impacts of RRI will likely provide important insights to help guide the identification of emerging benefits of RRI. Likewise, some of the conceptual work on RRI benefits conducted in MoRRI may be of use to future work on impact indicators of RRI.

As described elsewhere in this report, the 36+ indicators of RRI can be processed into 11 sub-dimensions of RRI, each based on one of the five key areas.

The 11 sub-dimensions were then used as a basis to develop four country clusters of RRI performance. As the summary of the country clusters illustrates (see Table 5), the implementation of RRI is differently configured across the four country clusters identified. Logically we might expect that the RRI benefits that emerge and become consolidated in different countries will be shaped by the contours of their RRI implementation profile.

Table 5 Country cluster implementation profiles and available indicators

Cluster colour/number	Countries	RRI implementation profile	Monitoring system indicators (type)
1 (blue)	Austria, Cyprus, Czech Republic, Greece, Hungary, Ireland, Luxembourg, Malta	• OA status • Ethics in RFOs	• Outputs • Inputs, process mechanisms
2 (red)	Bulgaria, Croatia, Estonia, Latvia, Lithuania, Poland, Slovenia, Slovakia	• GE status • SLSE training • PE participation • Ethics in RFOs	• Inputs, outputs, outcomes • Inputs • Inputs, outputs • Inputs, process mechanisms
3 (black)	Portugal, Romania, Spain	• Governance • GE status • SLSE training • SLSE culture • PE in assessment • OA status	• Inputs • Inputs, outputs, outcomes • Inputs • Outputs • Inputs • Outputs
4 (green)	Belgium, Denmark, Finland, France, Germany, Italy, Netherlands, Sweden, United Kingdom	• Governance • GE action • SLSE training • SLSE culture • PE participation • Ethics in RPOs	• Inputs • Inputs, outcomes • Inputs • Outputs • Inputs, outputs • Inputs, outputs, context

In terms of the available metrics and indicators that currently populate the monitoring system, there is a reliance on upstream input indicators combined mainly with output indicators. At this stage, outcome indicators are only associated with the (relatively mature) implementation of gender equality measures. RRI implementation profiles constructed on the basis of input and output indicators are useful for highlighting where countries in the different clusters are making their strongest investments and efforts in RRI, although absent of indicators of actual impacts. These profiles can nevertheless also usefully inform our expectations about expected impacts.

Periodic assessments of the country clusters will reveal movements of Member States between clusters as their implementation of RRI progresses. Transformations within the basis for emerging benefits would logically bring about change in the generation of RRI benefits, with some time lag. In addition, country clusters may shift around should the monitoring system add indicators of impact that provide an additional information type (see Table 6).

The country clusters thus provide us with an empirical orientation for the RRI benefits we might expect to see emerging in different countries, along with insights into the types of activities and impact pathways we should seek to monitor.

Future work could also consider **more diverse modes of assessment of the benefits** of RRI. These should also be sensitive to the existing RRI implementation profiles associated with different countries. For example, these new modes could focus on developing tools for assessing the alignment of R&I with the needs, expectations and values of citizens and society. For example, more attention could be paid to priority setting in R&I funding in order to monitor whether the allocation of research grants and support for research and innovation programmes maps well onto the observed needs of stakeholders, users and citizens. Designing innovative modes of assessment of the societal

value of research would undoubtedly improve our capacity to identify and monitor the emergence and evolution of the benefits of RRI.

Table 6 RRI monitoring system overview

RRI KEY AREAS	Inputs	Outputs	Outcomes	Impacts
Gender Equality	GE1 - GE2 - GE3 - GE5 - GE6 - GE8 - GE9 - GE10	GE2 - GE3 - GE4 - GE6 - GE7 - GE10	GE1 - GE2 - GE5 - GE6 - GE8	
Science Literacy Science Education	SLSE1 - SLSE2	SLSE3 - SLSE4		
Public Engagement	PE1 - PE5 - PE6 - PE7 PE8 - PE9 - PE10	PE2 - PE3 - PE4		
Ethics	E1 - E3	E1 - E2 - E3		
Open Access	OA6	OA1 - OA2 - OA4 - OA5	OA3	
Governance	GOV1 - GOV2 - GOV3			

5 Recommendations

1. We recommend making use of the MoRRI indicators as a platform for international learning. At institutional level there needs to be room for testing, setting of own goals and the use of measurements that indicate the quality of the institutional change.

The country clusters based on RRI indicators can help Member States as well as the European Commission to identify areas for intervention and improvement, and the results can help nurture ideas for prioritisation in the Framework Programme. For organisations, the 11 sub-dimensions may provide a helpful framework for reflection and strategic decision-making towards cultivating RRI. It is crucial that MoRRI indicators are used reflexively by the R&I community, and their value would be multiplied if combined with the accompanying narratives and case studies, acting as constant challenges and added value. RRI should not be just about ticking boxes to comply with minimum standards for ethics or gender representation, for example. Institutions as well as policy-makers at national and EC level should support experimentation and other innovative activities without demanding certainty about impacts. New ideas to improve gender representation, public engagement or ethical reflection, from scientists, civil society or elsewhere, should be welcomed. A European hub for RRI could collect and share learning from such activities.

2. We recommend to apply the RRI approach flexibly and according to the situation

Regardless of both the conceptual and practical challenges of measuring and monitoring RRI, all in all, the data collected and analysed during the course of the MoRRI project demonstrate that RRI has taken root across Europe. Of course, we observe marked differences between Member States with regard to their individual paths towards institutionalising RRI, reflecting different contexts and socio-economic conditions. And even those countries, currently at the forefront of aligning policies and practices with the ambitions of RRI, will need to step up their efforts if they actually want to fulfil the vision of a genuinely renewed relationship between science and society. However, this is not a message of despair – on the contrary. As RRI is being substantiated and embedded in different contexts, the approach needs to be adjusted to specific circumstances, thereby legitimately creating variety, not uniformity. At the same time, MoRRI gathered evidence that the European Framework Programmes and related efforts to mainstream RRI make a significant difference when it comes to the awareness, expectations and perceptions of the approach. These findings are an encouragement to continue further embedding RRI in research and innovation funding, while enabling experimentation and bottom-up mobilisation.

3. We recommend developing a smart, inclusive and creative data collection and linking strategy.

Another aspect related to data collection, given the efforts required to collect primary data (survey fatigue, reluctance to provide information, etc.), is that more thinking is needed on developing a *creative data collection and linking strategy* that draws on existing data sources.

This could, for example, not only include relevant Eurobarometer results from different survey waves to capture public opinion, but also to advance with *data mining* techniques of institutional websites and repositories – as suggested in our final event. Several RRI indicators provide information about structures: does an organisation have a gender

equality plan, does it have a research integrity office, etc. These structures should in principle be detectable via mining the relevant websites of research and innovation-performing organisations. Data mining can also be applied to private sector websites and thus relevant information about RRI and its wider diffusion could be identified.

A potential wealth of information could be mined using the proposal and monitoring data from FP participation. Already information or proxies on ethics, gender or open access are included in the reporting requirements by each (potential) participant. A thorough analysis of this (electronically recorded) data opens up significant insights and can be aggregated to country level – but also differences by sector can be identified with some effort. Potentially, a relevant adaptation of the reporting requirements of FP-funded projects could capture even more relevant information.

4. We recommend to further identify benefits for citizens and the private sector.

Case studies were conducted in the context of MoRRI to investigate, precisely through narrative and not only indicators, the potential benefits of RRI. Despite the large number and varieties of case studies, the evident result was that benefits are difficult to assess let alone measure. Democratic and societal benefits, as well as scientific benefits were more visible and easier to capture than economic benefits. This again does not imply fewer benefits but the need for more systematic research. The case studies did not suggest that economic benefits are absent but that they are more difficult to capture because of time lags and attribution problems. It may also be argued that different kinds of benefits are better linked to specific keys, i.e. science education, science communication and the co-production of knowledge are more likely to lead to democratic and scientific benefits, whereas open access is more likely to lead to economic benefits in the long run.

While we have identified several benefits and suggested potential new indicators that combine two RRI keys, more effort is needed in order to fully explore potential benefits. If RRI is not only confined to FP participation but truly mainstreamed in the Member States, it is important to envisage all research and innovation stakeholders, including industry, and to include the expected and experienced impacts on society. This may require a novel mixed-method approach and the development of new or the use of existing proxy indicators.

5. We recommend combining quantitative and qualitative approaches in future RRI monitoring activities and to put a stronger focus on the meso-level.

The MoRRI monitoring indicators focus primarily on the national level. MoRRI has thus produced a **tool that can help map and compare RRI activities and situations at national level**. The basis, however, is made up of aggregated meso-level information mostly coming from surveys addressing research-funding organisations, research-performing organisations, and other organisations in the broader R&I ecosystem.

Surveys addressing individual citizens and researchers also feed into the MoRRI indicator system. The researcher survey and several cases studies strongly demonstrate the crucial influence of organisational factors for implementing RRI; individual RRI projects aiming at concrete transformation show that RRI practice depends on organisations.

While the country-level monitoring is useful for national policy-makers to see where a country stands *vis à vis* other countries, **understanding the patterns and effects of policies requires a deeper understanding of structures and impacts at the institutional level**. In this respect, the case studies conducted in MoRRI proved to be

very helpful to contextualise RRI activities in concrete settings. Insights at institutional level are indispensable to explore the benefits of RRI and develop a better understanding of the interplay between policy interventions, organisational factors and individual motives. Future work should thus explore the potentials of developing indicators targeting RRI at organisational levels.

6. We recommend limiting the data collection to only every 2 or 3 years.

We have seen from the survey data that, for some indicators, the year-to-year changes were marginal. We have seen in the collected data that measurable institutional change happens rather incrementally and over a number of years. One can see differences in types of policies: policies addressing RRI keys such as ethics committees or gender equality plans – which could for example be established by law and thus should be applied within all relevant institutions – will show no change from the point these policies are implemented. Soft regulation, which can be found in open access policies, will most likely show more subtle annual changes. Furthermore, one needs to also take into account that new, structurally changing R&I policies – programmes, measures or legal requirements – are not issued on a continuous basis.

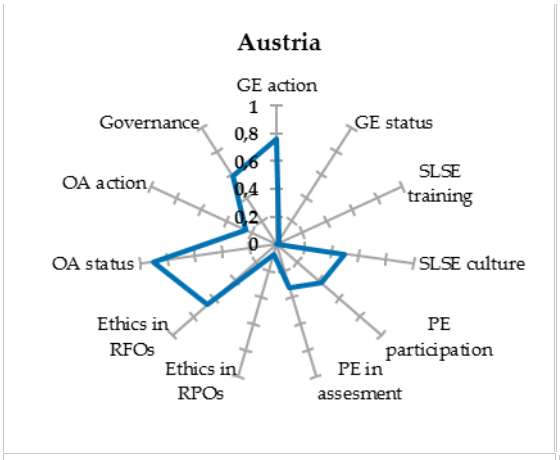
The least year-to-year change can be expected for policies that depend almost entirely on the institution itself – for example, if an organisation encourages its researchers to be involved in citizen science projects or engages with the public (or not). Wider diffusion of these RRI keys and thus a measurable change at the national level will most likely grow the slowest. Taking this into account does not favour annual monitoring.

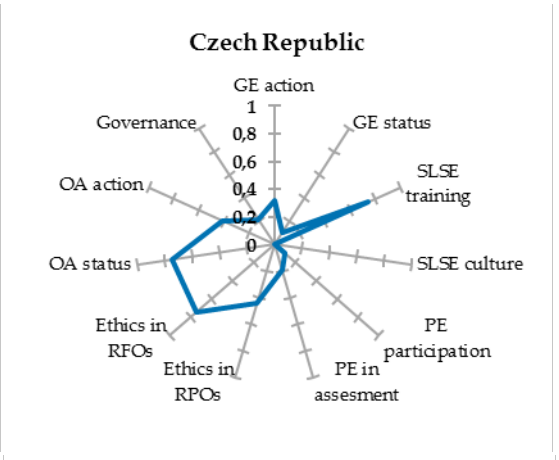
There is suitable data available that is collected through Eurostat and is available annually. Large-scale data on bibliometrics and patents can also be used on an annual basis. Other data, such as memberships of relevant organisations, can be collected without much effort.

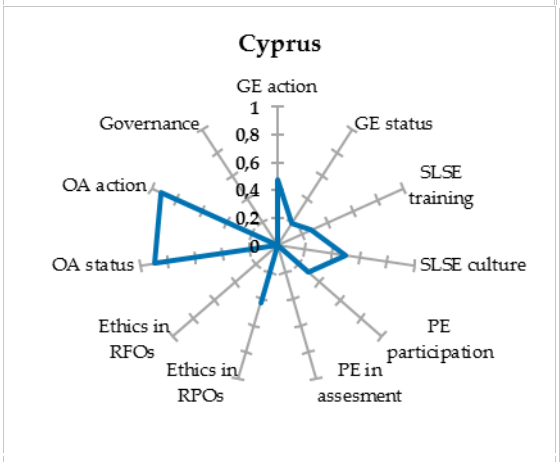
Taking into account the enormous efforts needed to collect suitable data from the institutions and the slow pace of change at institutional level, we suggest limiting the data collection effort to a 2- or 3-year period. The SHE Figures are a good example where data is collected on the basis of a 3-year period. This time frame is not only suitable concerning the collection costs but in general, measurable effects due to changes in policies or programmes are often showing with a delay and often only very gradually.

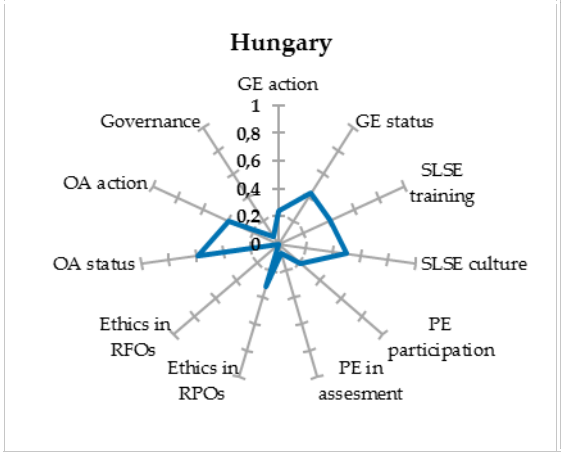
Annex 1- RRI Country profiles by cluster

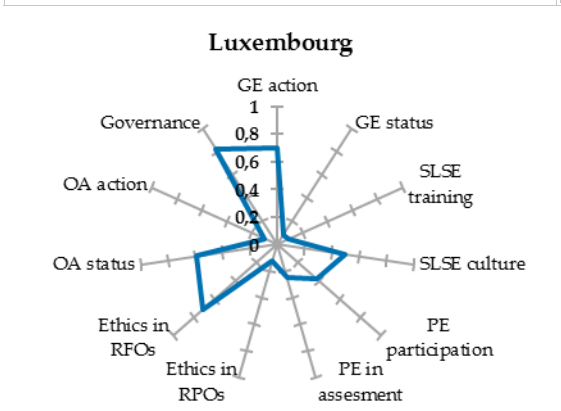
Cluster 1 (blue)

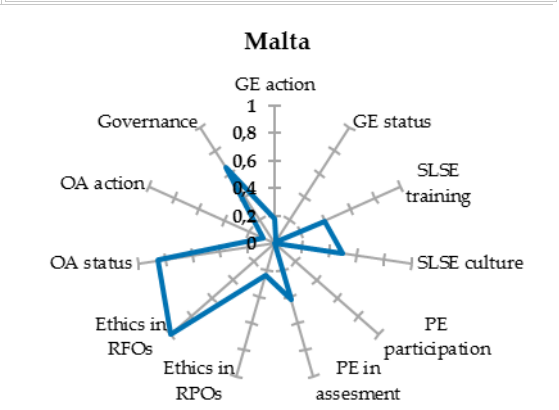












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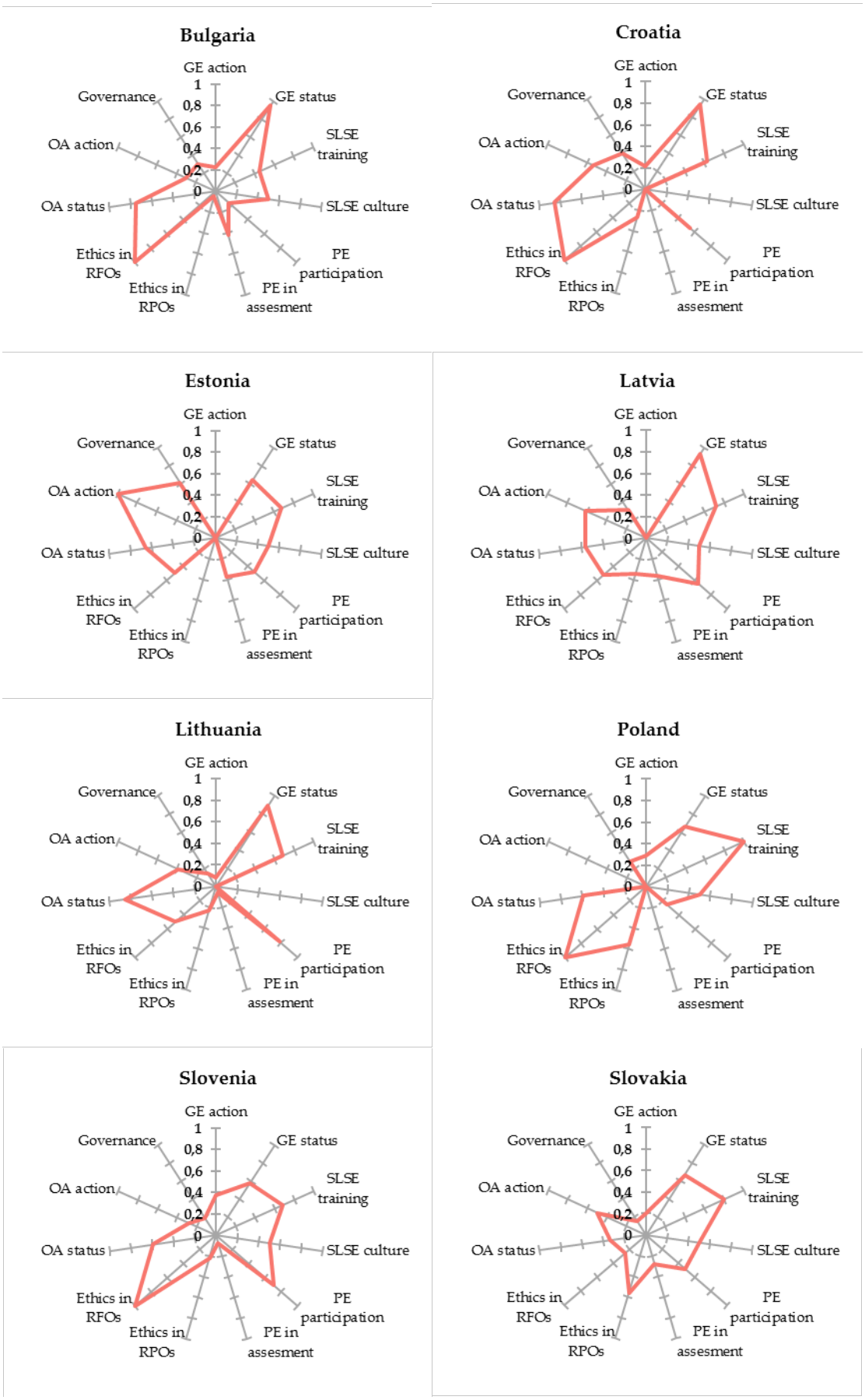
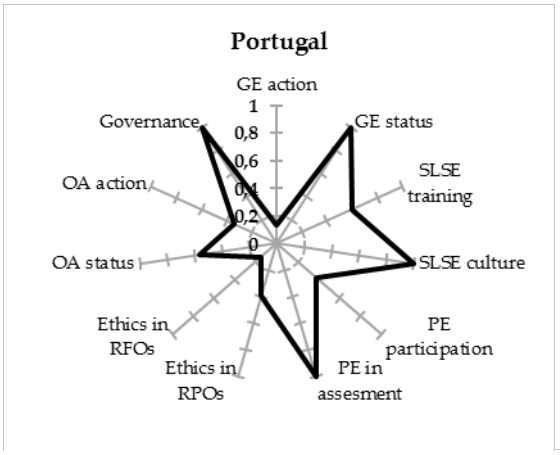
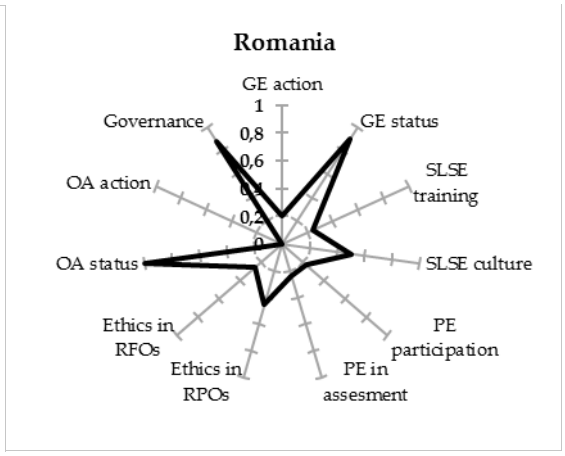
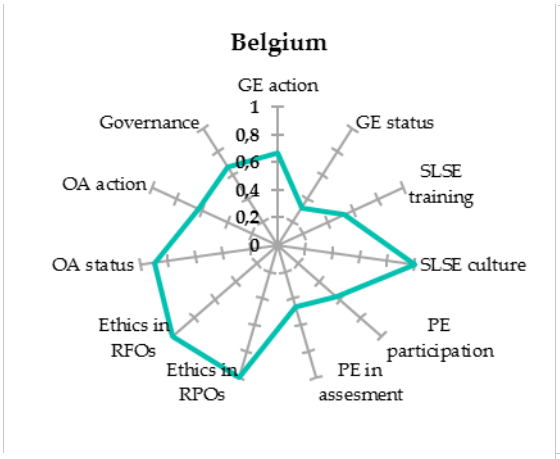


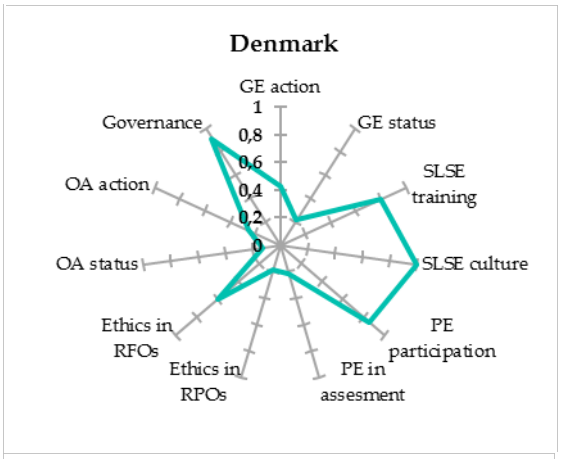
Cluster 3 (black)

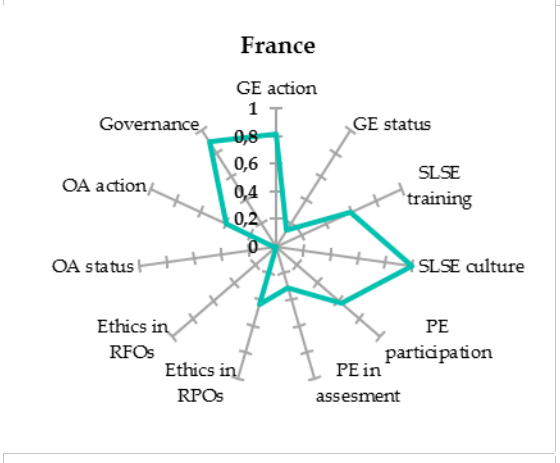


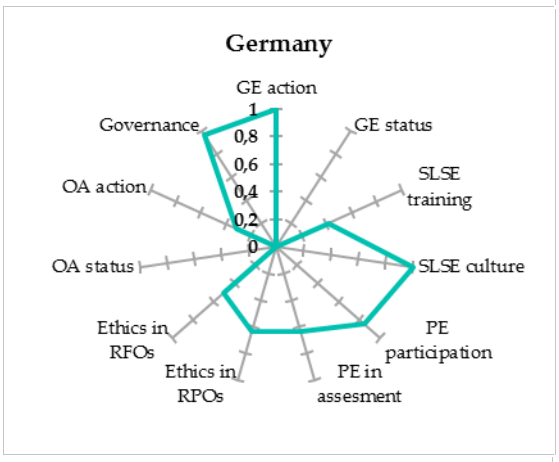


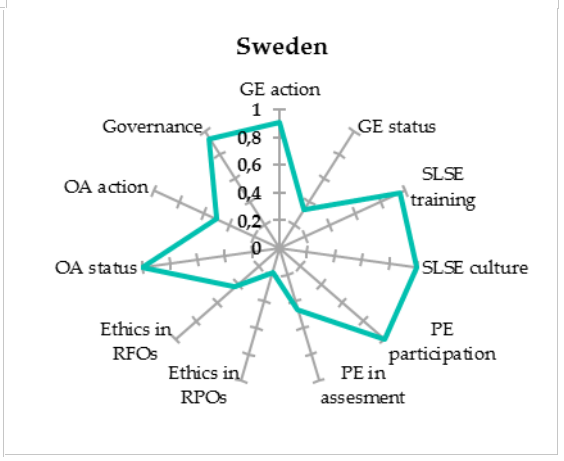
Cluster 4 (green)

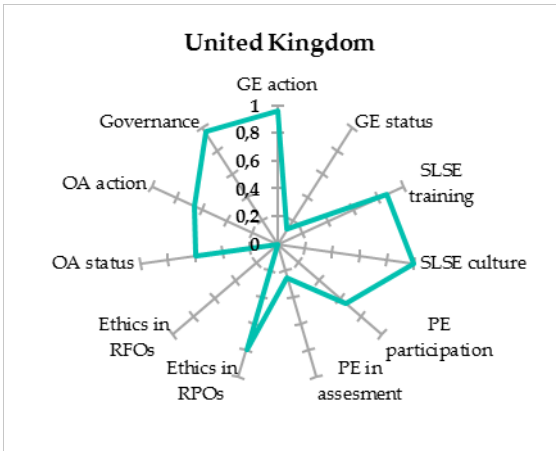











United Kingdom
GE action
GE status
SLSE training
SLSE culture
PE participation
PE in assesment
Ethics in RPOs
Ethics in RFOs
OA status
OA action
Governance
1
0,8
0,6
0,4
0,2
0

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The EU Open Data Portal (http://data.europa.eu/euodp/en/data) provides access to datasets from the EU. Data can be downloaded and reused for free, both for commercial and non-commercial purposes.

[Summary about 10 lines]

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