D6.3 Synthesis report: ON-MERRIT findings, including disciplinary and gender case studies

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Observing and Negating Matthew Effects in Responsible Research and Innovation Transition

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This deliverable presents a synthesis of findings from the ON-MERRIT project, including on issues of relevance to the Sustainable Development Goals.

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Abbreviations

APCs - Articles Processing Charges
EC - European Commission
GDP - Gross Domestic Product
SMEs - Medium-sized Enterprises
OA - Open Access
PRT - Promotion, Review and Tenure
RRI - Responsible Research and Innovation
SNPRs - Scientific Non-Patent References
SDGs - Sustainable Development Goals
WP - Work Package

Executive summary

Equity is a key aim of both Open Science and Responsible Research and Innovation (RRI), but could these policies actually worsen existing inequalities? These practices require resources (funding, time, knowledge, skills), and the traditionally advantaged usually have more of them. Will their privilege mean that they are the ones to benefit most? Access to scientific products and processes is not made uniform simply because they are made available via the Internet. The potential for the Open Science and RRI agendas to realise these promises of "inclusive and sustainable research and innovation" depends heavily on the drivers and barriers to implementation imposed by a diverse range of institutions and individuals. Making processes open will not per se drive wide re-use or participation unless also accompanied by the right knowledge, skills, technological readiness and motivation to do so. These vary considerably across institutions, businesses and populations. Differences are further intensified by other factors like geographic location, language abilities, technological skills, educational levels and access to basic equipment (e.g., Internet access). Those in possession of such capacities are advantaged, with the effect that RRI's agenda of inclusivity is potentially put at risk by conditions of "cumulative advantage" (the so-called "Matthew effect").

Identifying and avoiding such dynamics has been the aim of the project ON-MERRIT (Observing and Negating Matthew Effects in Responsible Research & Innovation Transition), investigating implementation of OS and RRI across a range of stakeholder categories, and in particular for those at the peripheries, to ask whether RRI interventions might actually deepen socioeconomic inequalities (such as the digital divide) and conflict with the sustainable development goals. How do geographical, socio-economic, cultural and structural conditions lead to peripheral configurations in the European knowledge landscape? What factors are at play and what can be done (at a policy level) to foster absorptive capacity and enhance OS/RRI uptake and contributions to scientific production across regions?

To answer these questions, we have investigated the impact of Open Science and RRI practices in academia, industry, and policy. We particularly focused on institutions and individuals working in the areas of agriculture, climate and health (key pillars of the UN Sustainable Development Goals). In addition, we examined the role of gender across all investigated questions. Our multidisciplinary team used a combination of qualitative and computational methods, complemented by stakeholder engagement and co-creation in order to examine the advantages and disadvantages in responsible and open research practices. ON-MERRIT had several research strands studying the role of Open Science and RRI in academia and its interfaces with industry and policy. This report synthesises findings from across the project (documented in these deliverables), highlighting key findings relating to ON-MERRIT's cross-cutting issues (SDGs 2, 5, 3, and 13).

1. Introduction

Scientific knowledge is a key resource for achieving societal and economic goals. Responsible Research and Innovation (RRI), and especially Open Science, public participation, and gender equality, promise to fundamentally transform scholarship to make scientific endeavours more inclusive, participatory, accessible and re-usable beyond the ivory towers of universities and research institutions, and to increase the academic, economic and societal impact of research outputs. These aims form a cross-cutting agenda that stands to contribute to most of the UN's Sustainable Development Goals (SDGs) that cover a range of pressing issues, such as eradicating poverty and hunger, ensuring access to clean water, quality education, establishing good health and well-being, as well as gender equality, and combating the intensifying climate crisis, among others. Given the fundamental role of science in today's societies (Drori et al. 2003), research and innovation are expected to make a substantial contribution in meeting these challenges (see also Bautista-Puig et al. 2021).

Equity is a key aim of both Open Science and Responsible Research and Innovation (RRI), but could these policies actually worsen existing inequalities? These practices require resources (funding, time, knowledge, skills), and the traditionally advantaged usually have more of them. Will their privilege mean that they are the ones to benefit most? Access to scientific products and processes is not made uniform simply because they are made available via the Internet. The potential for the Open Science and RRI agendas to realise these promises of "inclusive and sustainable research and innovation" depends heavily on the drivers and barriers to implementation imposed by a diverse range of institutions and individuals. Making processes open will not per se drive wide re-use or participation unless also accompanied by the right knowledge, skills, technological readiness and motivation to do so. These vary considerably across institutions, businesses and populations. Differences are further intensified by other factors like geographic location, language abilities, technological skills, educational levels and access to basic equipment (e.g., Internet access). Those in possession of such capacities are advantaged, with the effect that RRI's agenda of inclusivity is potentially put at risk by conditions of "cumulative advantage" (the so-called "Matthew effect").

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ON-MERRIT investigated all these questions broadly across three domains of interest. These were agriculture, climate, and health, and have been chosen for their tangible relevance for the achievement of the UN's sustainable development goals. By undertaking research into barriers to participation in and exploitation of open scientific outputs, ON-MERRIT sought to directly address SDG 2 (Zero Hunger), SDG 3 (Good Health and Well-Being), and SDG 13 (Climate Action), in addition to investigating gender as a cross-cutting issue.

The project synthesised this evidence to reveal the extent to which Open Science and RRI (including public engagement and gender equality), despite their key aims of inclusivity, are subject to the "rich get richer" logic of the Matthew effect. ON-MERRIT's analysis of public engagement in evidence-based policy-making helped enhance the understanding of conditions that determine which societal actors are able to make their voices heard in some of today's most important societal challenges and techno-scientific developments. This will aid in identifying barriers and excluded groups and assist in understanding how the public engages with scientific issues, including those relating to key sustainable development goals, with the intention of increasing the public's engagement with reliable and compelling science and consequently extending equality in the public participation in science. Throughout ON-MERRIT, gender was a key cross-cutting issue in each analysis. A focus on the motives and practises exhibited by economic actors in interacting with scientific developments and outputs in the age of Open Science further informs understanding of the interaction of science and society in the broadest sense.

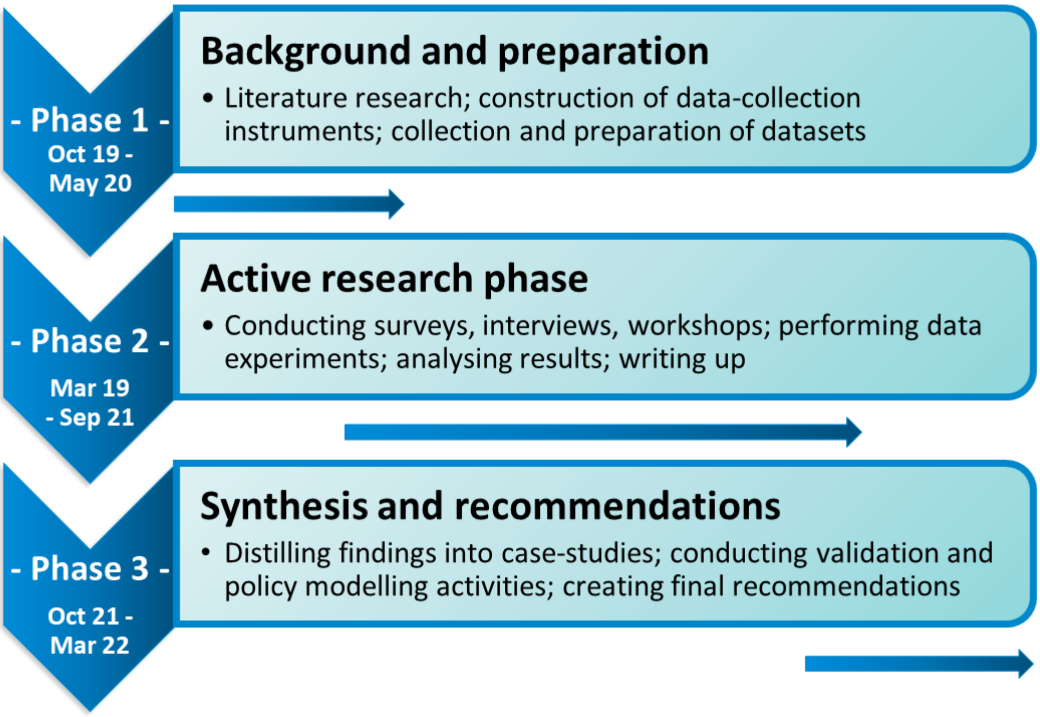

Figure 1. ON-MERRIT project timeline

The results summarised below are intended to enable Open Science policy to move beyond the current state-of-the-art to better incorporate self-reflexive critique of the consequences of policy interventions and to reveal gaps and deficiencies in current policy measures. This the project hopes to achieve by making evidence-based policy recommendations on how stakeholders (Research Performing Organisations, Research Funders, and other stakeholders) should amend indicators and reward/incentive schemes to address and/or mitigate these factors, thus breaking new ground for equitable Responsible Research and Innovation.

This deliverable is structured as follows:

- Section 2 presents a systematic Scoping Review of current evidence on ON-MERRIT's major focus of dynamics of cumulative advantage and threats to equity in Open Science, with reference to related factors in RRI.
- Section 3 presents an overview of the findings from ON-MERRIT's research into research cultures, support and incentives (deriving mainly from Work Package 3), including reference to specific findings of relevance to ON-MERRIT's target Sustainable Development Goals.
- Section 4 presents an overview of the findings from ON-MERRIT's research into Innovation and industry (Work Package 4), including reference to specific findings of relevance to ON-MERRIT's target SDGs.
- Section 5 presents an overview of the findings from ON-MERRIT's research into Policy-making and societal actors (Work Package 5), including reference to specific findings of relevance to ON-MERRIT's target SDGs.
- Section 6 presents findings from across the project on issues related to gender equity and the transition to Open Science and RRI.
- Section 7 concludes by reviewing key findings and relating this to the final tasks of ON-MERRIT to create policy recommendations.

2. Scoping Review of relevant literature

A first task within ON-MERRIT was to systematically scope the literature about the ways in which dynamics and structures of inequality could persist or be exacerbated in the transition to Open Science, across disciplines, regions and demographics. With this chapter, we describe these findings.[1] Aiming to synthesise findings, identify gaps in the literature, and inform future research and policy, our results identify threats to equity associated with all aspects of Open Science, including Open Access, Open/FAIR Data, Open Methods, Open Evaluation, Citizen Science, as well as its interfaces with society, industry and policy. The text situates these findings within the broader RRI landscape, especially the elements of public engagement, gender equity, science communication and governance. Key threats include: stratifications of publishing due to the exclusionary nature of the author-pays model of Open Access; potential widening of the digital divide due to the infrastructure-dependent, highly situated nature of open data practices; risks of diminishing qualitative methodologies as "reproducibility" becomes synonymous with quality; new risks of bias and exclusion in means of transparent evaluation; and crucial asymmetries in the Open Science relationships with industry and the public, which privileges the former and fails to fully include the latter.

2.1. Introduction

Academia remains critically inequitable. The Global North dominates authorship and collaborative research networks, pushing the Global South to the periphery (Cash-Gibson et al. 2018; Monroe-White and Woodson 2016). Even within richer regions, a fetish for the poorly defined goal of "excellence" (Moore et al. 2017) breeds cumulative advantage in funding allocation for the highest-funded institutions (Noble et al. 2020). At the level of individuals, early success shapes future success (Bol, Vaan, and Rijt 2018). Women occupy relatively fewer higher positions, tend to achieve senior positions at a later age, are awarded less grant funding and have fewer "high-impact publications" (Brown et al. 2020; Poczatková and Křibíková 2017; Cech and Blair-Loy 2010; Penner 2015). Lack of equity has been found to shut out participation in the scientific conversation and potentially reduce motivation, happiness and willingness to work, even amongst those who actually benefit (Gesiarz, de Neve, and Sharot 2020). These inequalities undoubtedly testify to broader societal imbalances but, as observed since the 1960s (Zuckerman 1988), dynamics of social mobility play out in academia in specific ways (cf. Bourdieu 1975).

Open Science[2] has been proposed at least in part as a corrective for some of these issues. Open Science has been defined as "transparent and accessible knowledge that is shared and developed through collaborative networks" (Vicente-Saez and Martinez-Fuentes 2018). It is a varied movement to reform research through more transparent and participatory practices including Open Access to publications, research data sharing, opening research methods and processes, new means of transparent research evaluation, and the re-

[1] This chapter was recently published as: Ross-Hellauer Tony, Reichmann Stefan, Cole Nicki Lisa, Fessl Angela, Klebel Thomas and Pontika Nancy (2022). Dynamics of cumulative advantage and threats to equity in open science: a scoping review. *Royal Society Open Science.* http://doi.org/10.1098/rsos.211032

[2] In English, the word "science" is taken to exclude the arts and humanities. Hence the term "Open Science" is often taken to be exclusionary of these domains, and more inclusive terms like "open scholarship" or "open research" can be preferred by some. We here use the more common term "Open Science", but this should be read as referring to research from all academic disciplines.

orientation of research to be more inclusive of and responsive to the needs of society and industry (Pontika et al. 2015). Its motivations are diverse. Fernández Pinto (2020) argues that Open Science can be variously seen, *inter alia*, as a culture, a goal, a movement, a set of policies, a project and a research strategy. Fecher and Friesike's (2014) definition of Open Science is as an "umbrella term encompassing a multitude of assumptions". They identify five distinct "schools of thought" reflecting the diverse motivations underpinning Open Science:

- *Infrastructure School:* Aims to create open platforms, tools and services to enable efficient and collaborative research
- *Public School:* Aims to make science accessible to citizens and others beyond academia
- *Measurement School:* Aims to develop alternative assessment systems for research
- *Democratic School:* Aims to make knowledge freely available to everyone
- *Pragmatic School:* Aims to make scientific processes more efficient, collaborative and open

Social and epistemic justice are central to at least two of these motivations ("Democratic" and "Public" Schools), but important drivers of all. Equity has been a key aim of Open Science since its inception. The stirring language of the foundational 2002 Budapest Open Access Initiative, for example, claimed Open Access could share learning between rich and poor and "lay the foundation for uniting humanity in a common intellectual conversation and quest for knowledge" (Chan et al. 2002). Nielsen's seminal "Reinventing Discovery" devotes a chapter to the ways in which networked Open Science is "democratising" research (Nielsen 2013). More recently, "increased equity" was listed as a "key success factor" for Open Science by a stakeholder-driven study (Ali-Khan et al. 2018). As Grahe et al. (2020) say, "Open science principles of openness and transparency provide opportunities to advance diversity, justice, and sustainability by promoting diverse, just, and sustainable outcomes".

However, equity is one aim of Open Science amongst others, including increasing research quality and efficiency. Depending on definitions and priorities, these overlapping aims may conflict. What is more, these aims are necessarily refracted through the competing motivations of a myriad of actors (including researchers, research institutions, funders, governments, publishers). The equivocal nature of Open Science hence leaves room for interpretative flexibility in adoption and implementation, while its heavy political and economic implications mean that diverse and potentially conflicting motives are at play. Disconnects between expressed ideals and eventual policies and practices should be expected.

This is especially so since academia seems perniciously vulnerable to logics of "cumulative advantage", as has been recognised at least since Merton proposed the existence of the "Matthew effect", whereby already successful scientists tend to receive disproportionately high recognition or rewards (e.g., reputation, resources, access to infrastructure) in comparison to their less-famous counterparts (Merton 1968; 1973; 1988). For Merton, "systems of reward, allocation of resources, and other elements of social selection thus operate to create and to maintain a class structure in science by providing a stratified distribution of chances among scientists for significant scientific work" (Merton 1988). Subsequent research identified the Matthew effect at work in research at the level of article citations (Wang 2014), journals (Larivière and Gingras 2010), institutions (Langfeldt et al. 2015), departments (Weakliem, Gauchat, and Wright 2012), and countries (Bonitz, Bruckner, and Scharnhorst 1999), and along persistent fault lines of inequality like race (Hofmänner 2011) and gender (Rossiter 1993). It is at work across a range of scientific activities, including peer review (Squazzoni and Gandelli 2012), public engagement (Woods 2015), and funding acquisition (Zhi and Meng 2016). Although for Merton the Matthew effect was potentially detrimental in clustering resources and stifling innovation, he also saw it as a functional element aiding assessment of the credibility of sources, allocation of attention, and recognising outstanding contributions (Squazzoni and Gandelli 2012). But while the Matthew effect in its various forms might be functional at a system level, it no doubt has the effect of advantaging and disadvantaging the contributions of individuals, as well as the individuals themselves, based on secondary attributes. Given the equity aim of Open Science, this is problematic *per se*.

Merton later broadened his thought to identify the Matthew effect as an example of cumulative advantage, whereby “comparative advantages of trained capacity make for successive increments of structural location, and available resources make for advantage such that the gaps between the haves and the have-nots in science (as in other domains of social life) widen until dampened by countervailing processes” (Merton 1988). The lines delineating the Matthew effect and cumulative advantage are often blurred.[3] For our purposes, and to avoid confusion, in what follows we will prefer the broader term cumulative advantage and define it along with DiPrete and Eirich (2006) as “a general mechanism for inequality across any temporal process … in which a favorable relative position becomes a resource that produces further relative gains.” These mechanisms are also closely related to what is referred to as preferential attachment in network theory, where power-law distributions are a result of the positionality and individual attributes of specific agents as nodes in a network shape possibilities for future accrual of resources within that network, such as larger nodes having more possibility for connection (Barabási and Albert 1999).

We hence understand Open Science as a diverse agenda to increase transparency, accessibility and participation in research, where equity is a commonly stated aim. We also, however, understand that various aspects of academia are particularly vulnerable to logics of cumulative advantage. Bringing these threads together, we are led to ask whether Open Science is itself affected by such mechanisms, and whether they endanger the equity aim of Open Science.

As argued by Albornoz et al. (2018), Open Science policies are situated within power imbalances and historical inequalities with respect to knowledge production (cf. Mirowski 2018). Uncritical narratives of openness therefore may fail to address structural barriers in knowledge production and hence perpetuate the cumulative advantage of dominant groups and the knowledge they produced. Making processes open requires capacities (in terms of knowledge, skills, financial resources, political will, technological readiness and motivation) which vary across regions, institutions and demographics. In addition, persistent structural inequalities and social and cognitive biases will not be eliminated in an Open Science world. We must therefore ask how equitable is the implementation of Open Science across a range of stakeholder categories, in particular those at the peripheries? Might interventions in some cases actually deepen inequalities or be at conflict with wider Open Science goals? How do geographical, socio-economic, cultural and structural conditions lead to peripheral configurations in the Open Science landscape? What factors are at play and what can be done (at a policy level) to enhance uptake and contribution to the production of scientific knowledge by everybody?

With this chapter, we aim to systematically scope existing research to answer the question: “What evidence and discourse exists in the literature about the ways in which dynamics and structures of inequality could persist or be exacerbated in the transition to Open Science, across disciplines, regions and demographics?”

[3] Although sociologists may identify it solely as referring to Merton’s original context of scholarly reputation and rewards, the Matthew effect has been taken up to describe phenomena of accumulation in areas as diverse as online markets (Berbeglia and Hentenryck 2017), reading and literacy (Stanovich 2009), sexual networks (Blasio, Svensson, and Liljeros 2007) and transitions to democracy (Lindenfors, Wilson, and Lindberg 2020).

Our scope includes all aspects of Open Science, including Open Access, Open Data, FAIR Data, Open Methods, Open Evaluation, Citizen Science as well as its interactions with the interfaces between science and society and industry. Results are presented according to these dimensions. This will synthesise evidence and discourse, identify gaps in the literature, and inform future research and policy. Given that the intention is to describe the general scope of the issues, no systematic quality appraisal of studies is carried out.

This study uses the PRISMA framework (Page et al. 2021) to align study selection with the research question and will follow the relevant aspects of the PRISMA Extension for Scoping Reviews to ensure thorough mapping, reporting and analysis of the literature. As Tricco et al. state, scoping reviews are useful to "examine the extent (that is, size), range (variety), and nature (characteristics) of the evidence on a topic or question; determine the value of undertaking a systematic review; summarize findings from a body of knowledge that is heterogeneous in methods or discipline; or identify gaps in the literature to aid the planning and commissioning of future research".

Since the many potential benefits of Open Science have been well-argued elsewhere (McKiernan et al. 2016; Munafò, Nosek, Bishop, Button, Chambers, Sert, et al. 2017; Fell 2019; Tennant et al. 2016), our presentation here necessarily focuses in greater depth on those areas where Open Science implementation potentially endangers the aim of greater equity in science. This emphasis should not be interpreted as signalling that the authors believe that the negatives outweigh the positives. Yet Open Science has now undoubtedly come of age, as mainstream policy in many regions and institutions, and must itself be open to critical and continued reflection upon the ways in which implementation may run counter to ideals. We believe such critique should be welcomed – above all by Open Science advocates – in order to re-orient implementation strategies and optimise outcomes wherever possible and desirable.

2.2. Methods

Methodologically, following identification of the above research question, the work has been structured according to the following four steps: Identify relevant studies, Select eligible studies, Chart the data, Collate and summarize the results.

2.2.1. Identifying relevant studies

A search was conducted for published and grey literature on the research area from January 2000 to the present, published in English. The authors first conducted a search of electronic databases (Scopus and Web of Science) on 23rd December 2020 for citations and literature using the below queries.

Web of Science (All Databases) - 1627 results

TOPIC: (("open science" OR "science 2.0" OR "Open Access" OR "open peer review" OR "altmetric*" OR "alternative metric*" OR "open data" OR "reproducib*" OR "FAIR Data" OR "open innovation" OR "citizen science") AND ("matthew effect*" OR "cumulative advantage" OR "inequ*" OR "*justice"))

Timespan: 2000-2020. Databases: WOS, BCI, BIOSIS, CCC, DIIDW, KJD, MEDLINE, RSCI, SCIELO.

Search language=English

Scopus - 1543 results

TITLE-ABS-KEY (("open science" OR "science 2.0" OR "Open Access" OR "open peer review" OR "altmetric*" OR "alternative metric*" OR "open data" OR "reproducib*" OR "FAIR Data" OR "open innovation" OR "citizen science") AND ("matthew effect*" OR "cumulative advantage" OR "inequ*")) PUBYEAR > 1999 AND (LIMIT-TO (LANGUAGE , "English"))

2.2.2. Selecting eligible studies

Searches yielded 3170 total results. Following manual deduplication, 2661 results remained for title/abstract screening, which was guided by the PRISMA framework, with specific eligibility criteria applied to ensure relevance for the study and its research questions. The selection process followed the recommendations in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) checklist and mapped using the PRISMA-P chart (Figure 1). Web search-engines and other sources were used to identify strongly relevant grey-literature from bodies likely to have produced relevant grey literature reports such as research funders, research-performing organisations, academic publishers, student coalitions, OECD and UN. Finally, this was augmented by hand-searching references of the included studies and references ("snow-balling"). The following inclusion criteria were applied:

- Articles on potential effects in Open Science as they relate to the propagation of cumulative advantage
- Conducted internationally or nationally
- Published from 1 January 2000 until current
- Available in English
- Full text could be obtained
- Study is a review article, commentary article, editorial, conference paper, or other peer-reviewed article
- Study is a grey-literature report from a recognised stakeholder
- All types of methodology (quantitative, qualitative, mixed, etc.) are eligible

Based on these criteria, two reviewers[4] then separately assessed eligibility via screening of titles and abstracts. Where at least one reviewer perceived the study eligible, it was included (50% necessary percentage agreement). In total, 239 articles were judged relevant by at least one reviewer. Full texts were retrieved on 2nd February 2021. All reasonable attempts were made to obtain full-text copies of selected articles (if not openly accessible, then first via institutional access privileges, and if that failed via inter-library loans or contacting the authors directly), whereupon a further 31 articles were removed as their full-text was in a language other than English or the full-text could not be obtained. Following this, 208 articles were carried forward to the next stage.

[4] Tony Ross-Hellauer and Stefan Reichmann.

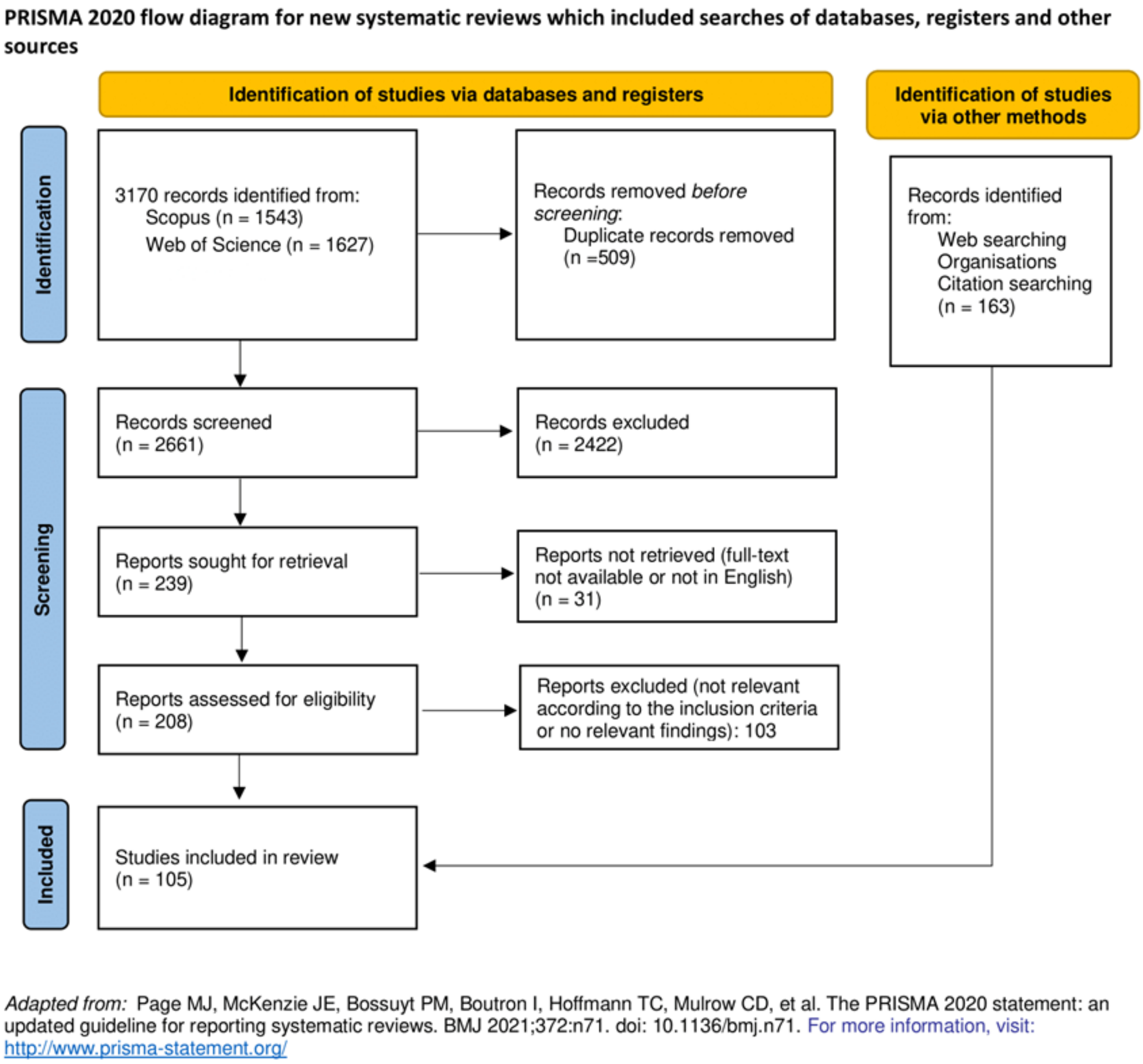

Figure 2. PRISMA diagram showing literature searching and scoping process

Full texts of the remaining articles were then examined by the first and second authors to determine to which research sub-questions the article was relevant. This literature was then delegated amongst authors according to topic.[5]

2.2.3. Charting the data and summarizing results

Each author responsible for that theme then appraised the full text to determine whether the study contained relevant evidence or discourse. Where it did (n=105), a data charting form (Table 1) was followed to electronically capture relevant information from each included study.

[5] TRH: general factors, open evaluation; SR: Open/FAIR Data, policy aspects; NP: Open Access; TK: Open Methods; NC: society aspects; AF: industry aspects.

Data chart heading	Description
Author	Name of author/s
Date	Date article sourced
Title of study	Title of the article or study
Publication year	Year that the article was published
Publication type	Journal, website, conference, etc.
DOI/URL	Unique identifier
Relevance to which study questions	Open Access, Open/FAIR Data, Open Methods, Open Evaluation, Society, Industry, Policy
Key findings, including study aims, details, design and data sources (where relevant)	Noteworthy results of the study that contribute to the scoping review question(s). Where relevant, overview of the main objectives of the study. Type of study, empirical or review, etc. Notes on methods used in study (whether qualitative or quantitative, which population demographics studied, etc.). Detail the data sources.

Table 1. Data charting form

Authors then used further snow-balling and specific keyword search using web search engines and other sources to identify further relevant peer-reviewed material as well as grey-literature, yielding a total 163 items identified by other methods, in addition to the 105 items identified via Scopus, for inclusion. All results were then exported to a single library in the Zotero open-source reference management software. Data-charting was collated in a combined CSV file. The co-author responsible for each theme then drafted an initial narrative summary of the evidence. These sections were then compiled by the lead author and revised into a full first draft, which was then shared with all co-authors, who worked collaboratively to revise the study and fill any perceived gaps in evidence and argument.

These methods were pre-registered in advance on 22nd December 2020 (https://osf.io/t6uy9/). All materials and data are available at DOI: 10.5281/zenodo.4936202. This resulting manuscript deviates slightly from the pre-registration in broadening the title and framing of the chapter from a narrow focus on the Matthew effect to dynamics of cumulative advantage and threats to equity more broadly, in order to better reflect the scope of the pre-registered search queries and the resultant chapter.

2.2.4. Results

The following sections present our synthesis of this literature. Since the many potential benefits of Open Science have been well-argued elsewhere (McKiernan et al. 2016; Munafò, Nosek, Bishop, Button, Chambers, Sert, et al. 2017; Fell 2019; Tennant et al. 2016), our presentation here necessarily focuses in greater depth on those areas where Open Science implementation potentially endangers the aim of greater equity in science. This emphasis should not be interpreted as signalling that the authors believe that the negatives outweigh the positives. The presentation of the results is in a descriptive format (narrative summary) to align with the study objectives and scope of the review, and phenomenon-oriented according to the various dimensions of Open Science: Open Access, Open Data, FAIR Data, Open Methods and Open Infrastructure, Open Evaluation, as well as Open Science's interfaces with society, industry and policy. It begins with some overarching issues which apply generally across the dimensions of Open Science.

2.3. Overarching issues concerning inequity in Open Science

Open Science is aimed in part to counteract inequity. Opening access to publications enables readership beyond those privileged by journal subscriptions (Suber 2012; Willinsky 2009). Data-sharing and open methods allow reuse beyond the narrow networks of existing collaboration (Wilkinson et al. 2016). Greater transparency in processes of evaluation might eliminate bias in selection procedures (Wilsdon et al. 2015; Ross-Hellauer 2017). Participatory processes of Citizen Science could make scientific endeavours more inclusive and understandable for large audiences (Nielsen 2013).

But, as Chin, Ribeiro, and Rairden (2019) remind us, "transitioning to open research involves significant financial costs." Open Science relies upon local training and support, as well as infrastructure and resources. Even in well-resourced regions such as Europe (Tenopir et al. 2017; MoRRI consortium 2018) and the US (Tenopir et al. 2014), readiness-levels of training and support infrastructure amongst nations and institutions are highly diverse. These disparities are, of course, even greater in what Siriwardhana (2015) terms “resource-poor” settings. Given that Open Science practices depend on underlying digital competences (Steinhardt 2020), the continuing realities of the digital divide (Maiti, Castellacci, and Melchior 2019) have real effects on participation in an Open Science world.

Implementation of Open Science must also be supported by policy. As Prainsack and Leonelli (2018) argue, “open science is a political project to an even greater extent than it is a technological one”. In Europe the Open Science policy landscape is highly variable across nations, funding organisations and institutions (Sveinsdottir, Proudman, and Davidson 2020). Policy priorities shape incentive-structures and resource allocation, and hence drive different implementation strategies. Open Science perhaps began as a grassroots movement of scholars, but its quick uptake into national and institutional policy has seen it linked to wider goals, including economic growth. In Europe, the European Commission (EC) has been a driver of Open Science (Burgelman 2021). But as an influential 2016 EC publication makes explicit, this interest is at least partly motivated by Open Science’s perceived potential to maintain and promote Europe’s “competitive edge in global knowledge markets in the information age” (Directorate-General for Research and Innovation 2016). To which we must naturally ask, at whose expense?

In light of this, we should take seriously a strand of critique which links Open Science to broader trends to reshape the academy under neoliberal principles to emphasise market principles of competition, foregrounding its economic role in training the workforce and fostering new products and services, at the expense of the social mission to provide upward mobility for marginalised populations (Slaughter and Rhoades 2000; Maisuria and Cole 2017; Canaan and Shumar 2008; Mirowski and Sent 2002). For some critics, Open Science has the potential to merely fuel these developments. In the words of Tyfield (2013), Open Science’s legacy may be defined by its “effects on the construction of a new moral economy of knowledge production”, meaning the marketisation of science for the benefit of corporations (Tyfield 2013, 29). Similarly, for Mirowski, Open Science will result in a “platformisation” of science – for-profit firms colonising the research landscape with a host of tools, seeking to construct “the One Platform to Rule Them All”, and the research process being subject to increasing division of labour wherein smaller and smaller chunks are made objects of public scrutiny (e.g., open projects, open lab notebooks) (Mirowski 2018, 197). Such developments could see, in the words of Kansa (2014), the “cause of ‘openness’ subverted to further entrench damaging institutional structures and ideologies.”

2.4. Inequities in Open Access

The rationale for Open Access (henceforth OA, whereby scientific publications are distributed online, free of cost or other access barriers under open licensing conditions) to research publications is often centred around the democratisation of knowledge – what Kathleen Fitzpatrick (2011) calls the "ethical desire" to remedy an imbalance between information "haves and have nots" (c.f, Suber 2012; Willinsky 2009). Open Access is posited as boosting return on investment (Mayer 2013) and as a solution to in equity to information access in regions (Nwagwu and Ahmed 2009; Bawa 2020; Koutras 2020; Arunachalam 2017; Raju, Claassen, and Moll 2016; Koutras 2015) and disciplines, especially to improve public participation in conversations related to social challenges like health, education and agriculture (L. Chan, Arunachalam, and Kirsop 2009; Terry 2009; Robinson and Scherlen 2009; Scherlen and Robinson 2008; Adelle 2019; Roehrig et al. 2018). Yet, similar to Open Science more broadly, OA is also not a "movement with a coherent ideological basis" (Moore 2019). Democratisation is but one aim amongst others, including efficiency gains through speeding dissemination and potentially lowering publishing costs (Suber 2012). The diverse ethical, political and economic priorities motivating these aims in turn present a range of possible routes to OA implementation. A crucial issue in this regard has been the extent to which policies favour publishing in OA journals ("Gold OA") over author self-archiving of non-OA publications in OA repositories ("Green OA").

Gold OA can be supported via a multitude of business models, including consortial funding (also called "Diamond OA", cf. Fuchs and Sandoval 2013) or volunteer labour (Moore 2019), but many OA journals and publications are financed via Article Processing Charges (APCs). The APC-model is controversial since the benefit of OA (free readership) is offset by a new barrier to authorship at the other end of the publication pipeline. In this regard, the extent to which OA policy has been driven by richer, global North nations risks reshaping scholarly communications to enable access but still foster exclusion. As the costs of APCs are usually borne by institutions or research funders (via project funding), those with fewer resources are disadvantaged (Siriwardhana 2015; Raju et al. 2020). The UK's government's 2012 decision to clearly favour, "publication in open access or hybrid journals, funded by APCs, as the main vehicle for the publication of research" (Willetts 2012), can be seen as a watershed moment for APC Gold OA. More recently, the related funder-led initiatives OA2020 and "Plan S"[6] were initially accused of ignoring experiences and interests of developing nations and lacking support for "the advancement of non-commercial open-access initiatives" (Debat and Babini 2019). Although Plan S has arguably somewhat corrected course here (Bosman et al. 2021; Becerril et al. 2021), the overall impact of Plan S remains to be seen.

APC-based OA hence risks stratifications of publishing as well-resourced researchers can cover even the highest APCs while less well-resourced researchers cannot (Pourret et al. 2020; Boudry et al. 2019; Kyle Siler et al. 2018; Batterbury 2017; Sotudeh and Horri 2008; Gray 2020; Christian 2008; Davison et al. 2005; Ellers, Crowther, and Harvey 2017; Tennant and Lomax 2019; Monge-Nájera and Monge-Nájera 2018). Even in well-resourced areas like the UK, rising costs (Copiello 2020) of APCs is recognised as an issue which will mitigate OA's net benefits (Jubb et al. 2017). Although many publishers offer fee-waivers and discounts to authors unable to pay, restrictive terms and administrative burden, as well as the extent to which they seemingly place authors in the position of asking for "charity", mean that they are often criticised as a weak response to an urgent issue (Lawson 2015; Burchardt 2014). This may have effects on specific demographics. For instance, Niles et al. (2020) found that women tend to take cost into consideration significantly more than do men when deciding where to publish. This issue is made especially pressing by the citation advantages

[6] 'Plan S and Coalition S" - https://www.coalition-s.org/

linked to OA publishing (Tennant et al. 2016; Ottaviani 2016). Usually seen as an important driver for motivating OA, in the light of equity such an advantage may in fact merely further fuel a classic Matthew effect, privileging those actors with the resources to pay for OA in the most prominent journals.

Given the problematised (Ferrer-Sapena et al. 2016) but persistent association between journal prestige (often quantified via the journal impact factor) and publication quality, it is especially problematic, then, that publishers often charge more for high impact journal publications (Gray 2020; Tennant and Lomax 2019).[7] In addition, APC rates are highly variable across disciplines (Demeter and Istratii 2020) and regions (Pourret et al. 2020), and are especially problematic in what Martin Eve has referred to as the "dry climate" of funding in the Social Sciences and Humanities (Eve 2014).

The APC model, combined with the pressure to "publish or perish" (Génova and de la Vara 2019), has also helped give rise to what is termed "predatory" journals and publishers, who collect APCs for publishing articles with little or no editorial rigour (Grudniewicz et al. 2019). The extent of the "predatory publishing" problem has been argued as overhyped by traditional publishers eager to discredit OA (Eve and Priego 2017). Indeed, according to Shen and Björk (2015), it is "highly contained" to a few countries. Yet even if limited, there is a problem, nonetheless. Authors from developing nations or with less-developed competences in English, already known to be disadvantaged in traditional publishing (MoChridhe 2019; Ramírez-Castañeda 2020; Williams-Jones et al. 2017; Batterbury 2017; Foxall 2019) as well as early-career researchers with limited publishing experience, are known to be especially affected by predatory publishing (James 2017; Nnaji 2018; Soler and Cooper 2019; Allman 2019; Noga-Styron, Olivero, and Britto 2017; Kurt 2018). Given the stigma attached to publishing in these venues, predatory publishing therefore poses a risk to the development of early-career and developing-world researchers and potentially contributing to what Collyer terms "two separate publishing circuits, leading knowledge produced in the global South to be 'systematically marginalised, dismissed, under-valued or simply not made accessible to other researchers'" (Collyer 2018).

Such stratifications in publishing, favouring traditionally advantaged actors (including for-profit publishers), will only exacerbate historical inequalities (Garuba 2013) and undermine wider aims of Open Science. Hence, as Nyamnjoh argues, for "open access to be meaningful … questions of content and the epistemological, conceptual, methodological and contextual specificities that determine or impinge upon it are crucial" (Nyamnjoh 2010). We therefore agree with Czerniewicz (2015) who argues that such consequences are the result of too narrow a focus on achieving OA *per se*, by whichever means, without acknowledging "the inequitable global power dynamics of global knowledge production and exchange". Rather, she suggests, we must broaden our focus "from access to knowledge to full participation in knowledge creation and in scholarly communication".

2.5. Inequities in Open Data and FAIR Data

Data sharing has been linked to increased citation rates (H. A. Piwowar, Day, and Fridsma 2007), economic growth (Tennant et al. 2016), transparency (Gilmore et al. 2017), reproducibility (Toelch and Ostwald 2018), improved research quality (Fecher, Friesike, and Hebing 2015), reuse (Linek et al. 2017) and efficiency (Leonelli, Spichtinger, and Prainsack 2015). These benefits have often been dissociated from specific research contexts, however. Hence, some suggest that the Open Data movement has overestimated the homogeneity of research environments (Olmos-Peñuela, Benneworth, and Castro-Martínez 2015), resulting in a

[7] Nature even recently agreed terms to charge APCs of up to €9,500, for example (Else 2020).

generalised “assumption that all scientists will benefit from releasing data, no matter where they are based” (Rappert and Bezuidenhout 2016). Such an assumption fails to appreciate that conditions for making data available differ across disciplines (Borgman 2015) and regions (Rappert and Bezuidenhout 2016). The concept of data as decontextualized facts removable from context that underpins the idea of data sharing has come under criticism of late as scholars are beginning to appreciate that data are situated and mutable [140]. In fact, it has been suggested (Borgman 2012) that “data” is an umbrella term whose meaning changes with context: with the specificity of the research purpose, with the scope of data collection, and with the goal of the research (Borgman 2012).

Data sharing occurs for many reasons, including reproducibility of published research, enabling others to ask new questions, and making publicly funded research publicly available (Leonelli, Spichtinger, and Prainsack 2015; Borgman 2012). The situated nature of research practices means motivations vary across research contexts (Hillyer et al. 2017). Hence data-sharing is viewed more favourably in some fields than others (Leonelli 2016, 57). To date, much work on data practices has arguably been led by the (biomedical) sciences (Perrier et al. 2017), with less attention to other disciplines. For example, the FAIR principles (to make data Findable, Accessible, Interoperable, and Reusable, but importantly not open) (Wilkinson et al. 2016), were heavily inspired by life sciences research. This initial focus has carried over to the scope of empirical work on their adoption (L. M. Bezuidenhout et al. 2017). But contexts differ depending on issues like the readiness-level of data formats (Weinshall and Epstein 2020) and whether research involves human subjects (Cychosz et al. 2020; Bargh et al. 2019; Ross, Iguchi, and Panicker 2018). For these disciplinary reasons, a blanket appreciation of Open Data as inherently democratic is problematic (J. A. Johnson 2014; 2018). One-size-fits-all policies may therefore disadvantage those disciplines and actors less able to participate, and further add to the prioritisation of STEM subjects.

Data inequalities are also cumulative, shaped by individual and community characteristics, access to infrastructure, and political and economic factors (Cinnamon 2020, 218), affecting the abilities of different groups to partake in the 'gift economy' (Klump 2017) of academia. As ethnographies of (non-Western) research (L. M. Bezuidenhout et al. 2017) show, access is not enough to guarantee that Open Data can be reused effectively because reuse requires not only access, but other resources such as skills, money, and computing power (J. A. Johnson 2018). Those working in environments where these are in short supply might be put at a disadvantage (L. Bezuidenhout et al. 2017; L. M. Bezuidenhout et al. 2017; Rappert and Bezuidenhout 2016). Additionally, making use of Open Data is closely linked to data literacy, potentially marginalising those that cannot engage with data effectively (Atenas, Havemann, and Timmermann 2020; Yoon and Copeland 2019; D’Ignazio and Bhargava 2018). Edelenbos et al. (2018) argue that Open Data "are particularly accessible to research institutes with more budget". Hence, increasing evidence suggests that instead of levelling the playing field, open data might simply empower those already advantaged (Carroll, Rodriguez-Lonebear, and Martinez 2019; Cinnamon 2020; Kitchin 2013). In this way, existing inequalities moderate the positive effects of Open Data which means they might be just a further mechanism whereby the rich get richer instead of leading to the democratisation of knowledge.

In addition, effects of data-intensive research on careers should be monitored for their outcomes regarding equity. Studies of authorship contributions to publications have found a clear gender divide (Larivière, Pontille, and Sugimoto 2020). Women are more likely to contribute to the investigation, data curation or writing of the original draft, whereas men are more likely to contribute to tasks associated with seniority (supervision, funding acquisition, resources). This division of labour and capital among researchers might reinforce existing hierarchies and cumulative advantages, in that additional workload involved with Open Data is frequently proportionally carried more by women.

These barriers to participation in Open Data are made ever more pressing by the citation advantages linked to data-sharing (H. A. Piwowar, Day, and Fridsma 2007). Piwowar et al.’s results approximate the original conception of the Matthew effect through establishing a clear (not necessarily causal) connection between Open Data practices and citation advantage. Giving due attention to the various contexts within which data sharing does or does not happen is therefore paramount for meeting the goals of inclusivity and openness espoused by the Open Science agenda.

2.6. Inequities in Open Methods and Open Infrastructures

Open science and in particular open methods, which involve practices like sharing analysis code, lab notebooks or preregistering analyses, hold the promise to counter current concerns regarding integrity in reporting and the reproducibility of research (Chambers 2013; Nosek et al. 2015; Munafò, Nosek, Bishop, Button, Chambers, Percie du Sert, et al. 2017). There are a few potential impacts on equity, however. First, it seems plausible to expect that better-resourced academics could be early adopters in terms of open methods (Siler et al. 2018). Well-resourced institutions can provide the necessary setting to successfully integrate open practices into the research workflow more easily. Well-resourced and high-status actors tend to be early adopters in general (Rogers 2003) and methods such as preregistration or sharing of research notes and code need additional training, effort and access to infrastructure to be implemented correctly. To the extent that transparency in research is increasingly becoming a benchmark for quality (Leonelli 2018), these well-resourced players will potentially have an advantage.

Secondly, the meanings and limits of openness are not uniform across disciplines. Calls to increase the reproducibility of research findings originated in specific fields, most prominently biomedicine and psychology (Button et al. 2013; John, Loewenstein, and Prelec 2012). While normative calls for increased standards in reporting are diffusing to further disciplines, it must be recognised that the notion of reproducibility is not equally applicable everywhere. Methodological approaches as found in mathematics, information sciences and computer sciences are clearly better suited for reproduction, based on their reliance on statistics and their level of control over the research environment. On the other hand, qualitative approaches as found in parts of the humanities, history and social sciences are more difficult to assess in terms of reproducibility (Leonelli 2018; Penders, Holbrook, and de Rijcke 2019). In the same way that the FAIR data principles have been designed primarily for quantitative data (data that does not rely on human subjects), extending the standards of quantitative methodologies to qualitative approaches in attempts to make them more “scientific” may “obscure unavoidable interpretive work” (Freese and Peterson 2017, 159) or further devalue qualitative approaches which cannot meet such criteria. This could then also reproduce existing inequalities of race and gender, since quantitative-focused fields, in particular STEM, are known to favour white men, and academic participation among women and racial and ethnic minorities is higher within the humanities and social sciences (Li and Koedel 2017).

Finally, open methods are heavily infrastructure-dependent, reliant on networked online platforms and other e-Infrastructures. Concerns have been raised about the extent to which privately-owned platforms may frustrate the aims of Open Science (Mirowski 2018; Andrews 2020; Plantin, Lagoze, and Edwards 2018). Recent years have seen major publishing corporations like Elsevier, Wiley and Springer (via subsidiary Digital Science) rush to capture researcher workflows through a host of proprietary tools which often eschew interoperability in favour of intraoperability with their own product suites (Andrews 2020; Posada and Chen 2018). Hence, there is a growing recognition of the need for Open Science infrastructures to themselves be open source and community-governed to ensure they (and the data they generate) remain community resources responsive to community needs (Andrews 2020; Ross-Hellauer, Schmidt, and Kramer 2018; Okune et al. 2018; Thanos 2016; Bilder, Lin, and Neylon 2015). As Gary Hall has noted, the Open movement is "in danger of being outflanked, if not rendered irrelevant, as a result of our media environment changing from being content-driven to being increasingly data-driven. For the data-driven world is one in which the data centre dominates" (Hall 2015).

Yet sustainability and governance models for open infrastructures remain unclear. Funding often comes from competitive project grants whose bureaucratic funding logic often requires inflexible and shorter-term project work-plans be satisfied at the expense of longer-term planning, agile development and broader interoperability within the infrastructure ecosystem (Hasani Mavriqi et al. 2020). In addition, open infrastructures often rely on voluntary contributions from open-source communities (Ficarra et al. 2020). In this regard, we must first ask: who is building and for whom? According to Ehls (2015), open-source communities generally skew heavily young (average age 27-32) and male (91-98%). How this homogeneity of contributors may influence issues like gender-bias (Vorvoreanu et al. 2019) in design of open-source tools should be monitored. In addition, that mainly younger people may be contributing requires us to examine the ways in which contributions are rewarded. In the prestige economy of academia, open-source contributions are heavily undervalued in promotion, review and tenure procedures, where publications still dominate (Schimanski and Alperin 2018). Hence, we might say that open infrastructures are very often reliant upon the unpaid contributions of early-career researchers, whose precarious employment conditions (Herschberg, Benschop, and van den Brink 2018) mean that their time could be better invested in terms of career advancement (Hasselbring et al. 2020). Appropriate credit and recognition (e.g., during evaluations for hiring, promotion and review) of work involving open methods and open infrastructures are therefore key for attaining equitable outcomes in the uptake of open methods and development of infrastructures.

2.7. Inequities in Open Evaluation

Open evaluation identifies the ways in which Open Science principles of transparency and inclusivity can be applied to the evaluation of research and researchers via peer review or metrics.

Peer review, assessment of research outputs by external experts, is the gold standard for evaluation and selection in scholarly publishing, conferences and funding allocation, but is often criticised as inefficient, unreliable and subject to bias (Bornmann 2017). Open Peer Review applies Open Science to reform peer review in various ways, most prominently by removing reviewer anonymity or publishing review reports (Ross-Hellauer 2017). A major supposed advantage is increased review quality. Yet opponents counter that this may compromise review processes, especially considering power-imbalances, either by discouraging full and forthright opinion or opening especially early-career reviewers to potential future reprisals from aggrieved authors later on (Rooyen, Delamothe, and Evans 2010). Given that a recent study found that publishing reports does not compromise review quality, at least when allowing anonymity (Bravo et al. 2019), it seems the issue of de-anonymising reviewers is the main issue. In contrast to other elements of open peer review, opening reviewer identities is not favoured by researchers (Ross-Hellauer, Deppe, and Schmidt 2017).

Research metrics are used throughout research and researcher evaluation processes, usually based heavily on counting citations, often aggregated via mechanisms like the h-index or Journal Impact Factor. However, citations have been widely criticised for being too narrow a measure of research quality (Wilsdon et al. 2015; Hicks et al. 2015; Curry 2018). The application of particularistic standards is especially perilous for early-career researchers who have yet to build their profile. By using citation metrics to evaluate research contributions, the Matthew effect leads to the self-reinforcement of initial positive feedback (Wang 2014). Moreover, indicators such as the impact factor are highly reactive (Fleck 2013) and therefore exacerbate a quasi-monopolization of resources (prestige, recognition, money) in the hands of relatively few institutions and individual researchers.

The rise of the “social” web in the mid-2000s soon gave rise to calls for “Alternative Metrics” or “altmetrics” to be part of balanced research assessment by aggregating additional online impact measures such as tweets, likes, shares, bookmarks, blogs and press coverage (Priem et al. 2010; H. Piwowar 2013). With their intention to expand the scope of research assessment using new sources of web data, altmetrics have been associated with the move to Open Science (Wilsdon et al. 2017; Mounce 2013). Perceived advantages include the speed of data availability and ability to track outputs beyond publications (Priem et al. 2010; H. Piwowar 2013).

Given general agreement on the limitations of, and over-reliance on, citations, broadening the range of possible data sources for research evaluation is welcome. Yet altmetrics themselves have been criticised for a lack of robustness and susceptibility to ‘gaming’; disparities of social media use between disciplines and geographical regions; reliance on commercial entities for the underlying data; indicating “buzz” or controversy rather than quality; under-representation of data from languages outside English; and underrepresentation of older papers (Mingers and Leydesdorff 2015; Hogan and Winter 2017; Wilsdon et al. 2017; A. E. Williams 2017; Bornmann 2017; Momeni and Rabbat 2016; Pooladian and Borrego 2017; Ghaly, Elabd, and Mostafa 2016). Each of these could have consequences for altmetrics’ efficacy as tools of equitable research assessment and advantage some at the expense of others. In addition, the very idea of expanding the number of metrics used for assessment can be critiqued as merely perpetuating the “tyranny of metrics”. Ryan (2016), for example, argues that metrics *per se* are tools of surveillance, enclosing academic freedoms by furthering a neoliberal idea of the academic as a competitor in a game of visibility, and promulgating a negative culture of competition that is the root of much ill in the academy (c.f. Mirowski 2018; Tyfield 2013).

2.8. Inequities in Citizen Science

Strengthening the relationship between science and society is a key pillar of Open Science. Citizen Science seeks to foster inclusion in knowledge production by involving the public in scientific processes. Practises range from research where the public contribute data to scientific projects via crowdsourcing platforms, to “extreme citizen science" or “strongly participatory science,” wherein members of the public participate in all aspects of research and are able to make valuable use of the research results in ways that benefits their lives and communities (English, Richardson, and Garzon-Galvis 2018; Allen 2018). It is the latter, rooted in traditions of participatory research, that most directly and strongly challenges the dynamics of inequality within academia (Morales-Doyle and Frausto 2020; English, Richardson, and Garzon-Galvis 2018). Participatory research is directed by a self-reflexive, critical, ethics-focused approach to research design, conduct, distribution of labour (Timmermann 2019) and financial benefits (Saleh et al. 2020; Kumar 2019; Timmermann 2019), outputs and impacts (Godrie et al. 2020; Kumar 2019; O’Leary 2018; Burke and Heynen 2014; Saleh et al. 2020). Questions of equality, justice and equity are often centred (Ottinger 2017; Kumar 2019; Hendricks et al. 2018; O’Leary 2018; Raphael 2019; Allen 2018) and the knowledge produced reflects the lived experience and situated expertise of the participants and communities upon which the research is focused (Morales-Doyle and Frausto 2020; Mena et al. 2020; Holzmeyer 2019; Allen 2018). Further, those that participate in Citizen Science and participatory projects develop scientific expertise that would otherwise be unavailable to them, making them more effective democratic actors who are able to challenge policies, civic expertise, and corporate power in pursuit of justice and equality (Kimura and Kinchy 2016; O'Leary 2018; Krings, Kornberg, and Lane 2019; Allen 2018; Misonne 2020; Eymard 2020; Barzyk et al. 2018; Hendricks et al. 2018).

Nevertheless, Citizen Science may also in some circumstances perpetuate inequalities. When participants serve merely as free data collectors, those who primarily benefit are researchers (Vercammen et al. 2020; Derrien et al. 2020; Prudic et al. 2019; Burke and Heynen 2014). Where such practices bridge the global north and south, data extraction absent anything else echoes colonial exploitation (Saleh et al. 2020). Additionally, there are issues of biassed inclusion in terms of the populations that are invited to participate in traditional Citizen Science (Herschan et al. 2020; Oti et al. 2019), with the most marginalized groups likely to be left out (Derrien et al. 2020; Friedrich, Reichel, and Renkert 2020; Vercammen et al. 2020; Katapally 2019). Likewise, there is biassed participation in the crowdsourcing of information (Bright, De Sabbata, and Lee 2018). Finally, approaches taken by well-intentioned researchers may also reinforce existing inequalities, like when a paternalistic stance is taken towards participants (see the use of "provide voice" in Hendricks et al. 2018); research seeks to prove the quality and validity of citizen-generated data, thereby reifying the expertise divide between scientists and the public (Vercammen et al. 2020; Ottinger 2017; Derrien et al. 2020); or when science education is framed as a unidirectional resource coming strictly from scientists (e.g., Beattie, Hippenmeyer, and Pauler 2020). All these have implications for equity in Citizen Science relating back to our themes of how cumulative advantage can impact participation in Open Science, especially related to issues of digital divide, differential levels of resources and skills, and data equity. Again, it is non-dominant actors who are at risk. Shelley-Egan et al. (2020) criticise such instumentalisation of participants as demonstrating that in Open Science "publics operate as citizen scientists collecting or systematising data without necessarily reflecting on or critiquing the broader institutional and societal frameworks for uptake." In summary, these findings point towards a biassed inclusion of populations invited to participate in citizen science projects, which tends to perpetuate the divide between experts and publics and raises questions of representation and equity: Whose voices are represented in Citizen Science projects, and for which reasons?

2.9. Inequities at the interfaces of Open Science and society, industry and policy

The societal impact of research has been an increasing factor in policy-making throughout academia in recent years, especially in research evaluation exercises. The drive for Open Science and new forms of knowledge production has been intimately linked, at least at the policy-level, with this agenda (Albornoz et al. 2018). For instance, the EU believes Open Science "instrumental in making science more responsive to societal and economic expectations" (Directorate-General for Research and Innovation 2016). However, we can question the terms on which such responsiveness has thus far been sought. As we shall see, there are crucial asymmetries which potentially compromise, or at least restrict, Open Science's potential to fully realise equity in research.

Firstly, we must point out that achieving impact is a resourceful activity. A dominant theme in our study so far is that enabling access is not enough and this is also the case for societal impact. In policy uptake of scientific knowledge, for example, it has been suggested that Open Science will help by making scientific resources more readily available to policy-makers and other policy actors (Olesk, Kaal, and Toom 2019; Tennant et al. 2016; Willinsky 2003). However, such uncritical narratives of openness fail to address structural barriers in knowledge production. Firstly, more high-profile OA output from established actors may lead to further over-representation of knowledge produced by dominant groups (ElSabry 2017; Hillyer et al. 2017; Okune et al. 2016). Perhaps more importantly, though, in addition to access, relationships between academics and policy-makers are a main factor in policy uptake of science (Oliver, Lorenc, and Innvær 2014). Policy-makers, with limited time to make decisions and to seek advice, heuristically rely on (personal) networks of experts that have previously contributed to policymaking (Dodson, Geary, and Brownson 2015). Researchers' and intermediaries' translation skills ("elevator test") are particularly important in this regard (Gold 2009), with tailored messages a key driver of uptake (Boyko, Kothari, and Wathen 2016). Building relationships and fine-tuning messaging require time and effort and can be significantly bolstered by support structures within research-performing institutions (Abekah-Nkrumah et al. 2018). Hence, researchers with access to such support are advantaged in ensuring uptake.

Knowledge-transfer services are also vital in fostering the uptake of scientific resources in industry. Here, indicative evidence shows that Open Science might have a positive economic impact. A recent synthesis (Fell 2019) summarises the literature to find that Open Science can help industry-uptake through (1) efficiency gains through easier access to publications (Rowlands et al. 2011; Houghton, Swan, and Brown 2011; Houghton et al. 2009; Jubb 2011) and data (Beagrie and Houghton 2012; 2014; 2016), as well as reduction of transaction costs via collaborative approaches (Jones et al. 2014; McDonald and Kelly 2012) and lower labour costs or increasing productivity (Houghton, Swan, and Brown 2011; Parsons, Willis, and Holland 2011; Leeson and St-Gallay 2011; Chalmers and Glasziou 2009), and (2) enabling new products, services or collaborative possibilities (Houghton and Sheehan 2006; H. L. Williams 2013; Arshad et al. 2016). However, evidence points towards firms (particularly small and medium-sized enterprises) lacking necessary skills such as information literacy, to fully benefit from open resources (Houghton, Swan, and Brown 2011; P. A. Johnson et al. 2017; Huber, Wainwright, and Rentocchini 2020). Given the above discussion of the underlying digital competences necessary for uptake of FAIR Data, this will be especially acute for those on the wrong side of the Digital Divide. Again, the most well-resourced stand to benefit most. Ironically, this fact extends even to the demonstration of impact. As Bornmann (2017) points out, institutional societal impact is often assessed based on case-studies which are "expensive and time-consuming to prepare". This all suggests that uptake of scientific knowledge, even in an age of Open Science, remains prone to dynamics of cumulative advantage.

There are more fundamental dimensions of asymmetry. Regarding industry, Fernández Pinto (2020) argues that current Open Science policies risk perpetuating the commercialisation of science in three ways. Firstly, the focus on opening *publicly* funded research allows industry the "privileged position of adopting openness as they see fit", adopting openness where it is commercially attractive or improves public image (cf. Leonelli 2013) and ignoring it in less favourable circumstances, such as where findings may impact sales. Secondly, policy focus on Open Science's potential to spur innovation means that the science-industry connection is deepened without critical reflection on the "epistemic and social justice challenges" of private sphere research, including scandals in corporate-sponsored scientific research (c.f., McGarity and Wagner 2010; Michaels 2008; Oreskes and Conway 2010), conflicts of interest and their influence on research work (cf. Lundh et al. 2017), and the ways in which strong intellectual property regimes might inhibit or corrupt scientific research (cf. Biddle 2014). Finally, repeating the point made above, the networked and platform-dependent nature of Open Science enables commercial interests to increasingly control and commodify research processes (cf. Tyfield 2013; Mirowski 2018). For Fernández Pinto, therefore, the issue lies in the unequal terms on which Open Science engages industry, with the latter privileged. This asymmetry in favour of industry can in turn can be seen as an endorsement within Open Science of the marketization of science and the specific neoliberal vision of the academy which underlies it (cf. Holzmeyer 2019).

Shelley-Egan et al. (2020) identify another asymmetry, this time at the expense of the public. The authors compare the Open Science agenda with that of the seemingly complementary Responsible Research and Innovation (RRI). RRI is a science policy movement, especially prominent in Europe, which seeks to better integrate science with society (Owen, Macnaghten, and Stilgoe 2012; von Schomberg 2019). Deriving from a tradition of participatory research, Technology Assessment and anticipatory governance, RRI aims to avoid "expert hubris" and unintended consequences. Shelley-Egan et al. argue that in contrast to RRI, Open Science's ambitions are more pragmatically focussed on terms of engagement with the public. Whereas "RRI's approach to opening up extends to an invitation to publics to co-define the aims and means of technical processes in order to increase their alignment with public values," "Open Science restricts ambitions for opening up to adjustments and improvements to processes based on quality criteria ultimately rooted in the existing research system." Open Science is thus seen as insufficiently critical of the value and direction of science. It is also seen as failing to fully appreciate "societal voices and citizens as legitimate conversation partners and beneficiaries of technology and knowledge", engaging publics on asymmetrical terms that seek mere dialogue between "technical experts and societal voices". Hence, "RRI focuses more on producing (ethically and societally) "good" outcomes than on resulting in the (epistemically and functionally) "best" outcomes, while OS for its part remains agnostic about the former and concerns itself almost entirely with the latter, and more often concerns itself with issues of efficiency, optimization, integration and potential." The authors suggest that this "pragmatism and instrumentality" of Open Science leaves it in line with prevailing political and institutional (i.e., neoliberal) aims.

Such a purely technocratic definition is no doubt at odds with the view of Open Science held by many advocates. Yet the equivocal nature of "Open Science" means that such readings are at least plausible, and hence should be taken as a call for the Open Science community to more fundamentally appraise the way its priorities are presented, and the deeper ways in which societal voices can be engaged as equals in setting research agendas. It further illuminates the ways in which the radicality of Open Science can be questioned, and the extent to which Open Science merely enables the further neoliberalisation and commodification of research knowledge.

2.10. Discussion

This synthesis of evidence is intended to focus attention on the ways prevailing capacities, resources and network centralities – combined with structural inequalities and biases – can help shape Open Science outcomes. Inequalities and dynamics of cumulative advantage pervade modern scholarship, and our results show that despite its potential to improve equity in many areas, Open Science is not exempt. Merton advises that cumulative advantage directs our attention to "the ways in which initial comparative advantages of trained capacity, structural location, and available resources make for successive increments of advantage such that the gaps between the haves and the have-nots in science (as in other domains of social life) widen until dampened by countervailing processes" (Merton 1988). From the above synthesis we can observe that this mechanism is at work at various levels throughout Open Science, potentially endangering equity. We have identified key areas for concern, summarised below in Table 2.

Aspect of OS	Area for concern	Group(s) most affected
General Factors	Costs of participation: OS is resource-intensive in terms of infrastructure, support, training.	Less well-resourced institutions and regions.
	Political agendas: OS requires political will, but political agendas shape OS implementation. Especially where economic growth is a stated ambition, this may be problematic.	Regions and institutions without such political backing, or where political goals promote inequitable OS implementations.
	Neoliberal logics: OS seen as potentially entrenching structures and ideologies of neoliberal commodification and marketisation of research knowledge as an economic resource to be exploited rather than as a common good for the well-being of humanity.	Science *per se*, but especially those disciplines and researchers who do not fit this agenda.
Open Access	Discriminatory business model: APC-based OA is exclusionary and risks stratifying authorship patterns.	Less well-resourced researchers, institutions and regions. May also impact specific demographics, including women.
	Predatory publishing: Limited issue which nonetheless primarily adversely affects non-dominant groups.	Authors from developing nations and early-career researchers
Open Data and FAIR Data	Situatedness of data practices: Data practices are highly context-dependent, meaning one-size-fits-all policies risk privileging some disciplines.	Qualitative researchers and disciplines
	Cumulative nature of data inequalities: Creating and exploiting Open Data is strongly linked to access to infrastructure and data-literacy.	Less well-resourced researchers, institutions and regions.
	Citation advantages of Open Data: Open Data seems linked to increased citations and hence early-adopters benefit (Matthew effect)	Less well-resourced researchers, institutions and regions.
Open Methods and Open Infrastructure	Transparency as a benchmark for quality: Open methods require additional training, effort, infrastructure. Well-resourced and high-status actors may potentially have an advantage.	Less well-resourced researchers, institutions and regions.
	Reproducibility as a *sine qua non* for research: Relatedly, meanings and limits of openness not uniform across disciplines. Uncritically extending quantitative standards methodologies may obscure necessary interpretive work or further devalue qualitative approaches.	Qualitative researchers and disciplines.
	Platform-logic of Open Science: Reliance on privately-owned platforms may frustrate the aims of Open Science and increase surveillance capitalism in academia.	Science as a whole.
	Lack of reward structures for contributions to open infrastructure: Open Science seems at risk if it relies on closed and proprietary systems; yet open infrastructures often rely on short-term project funding or volunteer labour which is not properly rewarded within current incentive structures.	Early-career researchers.
Open Evaluation	Open identities peer review: Peer review where reviewers are de-anonymised may either by discourage full and forthright opinion or opening especially early-career reviewers to potential future reprisals from aggrieved authors later on.	Early-career researchers, others from non-dominant groups.

Aspect of OS	Area for concern	Group(s) most affected
	Suitability of altmetrics as a tool for measuring impact: Altmetrics criticised for: lack of robustness and susceptibility to 'gaming'; disparities of social media use between disciplines and geographical regions; reliance on commercial entities for underlying data; indicating "buzz" rather than quality; under-representation of data from languages outside English; exacerbating tyranny of metrics.	All, especially non-English language research and areas where social media use is less pronounced.
Citizen Science	Logics of participation in Citizen Science: Evidence of biased inclusion in populations invited to participate; potential for data extraction absent anything else to echo colonial exploitation	The public, especially marginalised groups.
Interfaces with society, industry, policy	Resource-intensive nature of translational work: Making outputs open is not enough to ensue uptake and societal impact. The importance of (resource-intensive) translational work means richer institutions and regions may still dominate policy conversations.	Less well-resourced researchers, institutions and regions.
	Privileging of economic aims: The terms on which Open Science engages industry is asymmetrical, perhaps reflecting the importance of economic growth as a key aim. Industry is free to participate (or not) in open practices, as it suits them.	Science as a whole, but especially those domains not easily exploited by commerce.
	Exclusion of societal voices: Open Science's terms of inclusion of publics is accused of "instrumentalism" and asymmetry (experts/public).	The public.

Table 2. Summary of identified areas of concern for equity in Open Science

Ambiguity and politics: Open Science is an ambiguous and deeply political concept. We should not expect that all of the diverse practices, much less their many possible routes to implementation, that fall under this umbrella term should accord in every aspect. Equity is one aim amongst others and may conflict with others like efficiency and transparency. The policy-driven focus on Open Science's potential to fuel economic growth, in particular, seems designed to maintain economic advantage and hence conflicts with wider aims of global equity. Moreover, narrow focus on specific elements of Open Science, at the expense of a more holistic view of the (dys)functioning of the scientific system as a whole, may exacerbate such factors.

Resource-intensity and network effects: Cumulative advantage relates to logics of accumulation and preferential attachment based on network positionality and possession of resources. The resource-intensive and networked nature of Open Science means it is also vulnerable to these logics. Explicitly linking authorship channels to possession of resources potentially stratifies Open Access publishing. The expensive infrastructures and training necessary to participate in engaging with Open Data and methods means those privileged in these regards are primed to benefit most, at least initially. The importance of such underlying competences means that ensuring access is not enough to ensure equity of opportunity in an Open Science world absent broader measures to overcome the digital divide. In addition, the ways in which these underlying competences interplay with actor attributes to shape logics of participation in networked communities means that there are concerns for who is privileged by proposals to reform areas like peer review and research evaluation, as well as who contributes to open-source tools and services.

Narrow epistemologies: The term Open Science itself is often seen as exclusionary of the arts and humanities in the anglophone community. More pernicious, though, is the potential devaluation of epistemic diversity that attends Open Science's focus on transparency and reproducibility. Within the Open Science paradigm, the latter concepts are becoming almost synonyms for research quality itself, rather than just important means of assuring quality *in some domains*. Qualitative methodologies for which transparency is less possible and reproducibility less relevant may be further marginalised if this trend continues. If so, Open Science will only add to the further cumulative advantage of STEM subjects within the academy at the expense of social sciences and humanities.

Neoliberal logics: In addition, certain central assumptions of Open Science seem to further promote the commodification and marketisation of research. Making science more responsive to the market risks further intensifying competition at the expense of communalism. Further, platform-logic pervades Open Science's enabling infrastructures. Not only does this risk lock-in by commercial vendors, but logics of data accumulation and tracking further enframe researchers as something to be measured in a regime of surveillance capitalism. If so, Open Science may act to only further advantage the neoliberalisation of academia, which is often identified as a root-cause of many of the issues Open Science is claimed to fix.

2.11. Conclusion

The synthesis itself is subject to some key limitations, including some ironically linked to issues discussed. The authors all work in the Global North at relatively well-resourced institutions and are funded by an EC research grant whose conditions of application reflect a focus on the situation in Europe. Article search was primarily via databases (Web of Science and Scopus) which employ strict inclusionary criteria, and although this was combined with snow-balling and secondary literature searching, it still might be the case that our review has not captured all available evidence. Further, the language skills of the authors meant a pragmatic decision to only include articles in English. In addition, reviews are necessarily retrospective. Although we have tried to be as balanced as possible, these particularities of standpoint, resources and inclusion criteria no doubt influence our critique.

Our work here has been to scope the (English-language) literature to date concerning threats to equity within the transition to Open Science. This is of course preparatory work and by no means the end of the story. Directions for future work may include first the extension of this study to cover literature in languages beyond English. An additional study using the same methodology but involving a multi-lingual team covering the major world languages could be envisioned, and the present authors would be happy to collaborate in such an endeavour. Secondly, the issues raised in this work deserve much more scrutiny and so future primary research work involving qualitative and quantitative approaches on these issues is desired. Finally, this work has aimed primarily to scope the issues involved and is not strongly normative in the sense of producing specific recommendations on what policy actions may be suggested to correct potential negative effects on equity in the transition to Open Science. Such recommendations will be the focus of the upcoming ON-MERRIT Deliverable 6.4.

3. ON-MERRIT findings (WP3): Research cultures, Open Science and RRI

Scientific knowledge is a key resource for achieving societal and economic goals. Open Science (OS) and Responsible Research and Innovation (RRI) promise to fundamentally transform scholarship to bring greater transparency, inclusivity and participation to research processes, and increase the academic, economic and societal impact of research outputs. These form a cross-cutting agenda that stands to contribute to most of the UN's Sustainable Development Goals (SDGs), and are a central pillar of the European Commission's Digital Single Market strategy. Yet access to scientific products and processes is not made uniform simply because they are made available via the Internet. How equitable is the implementation of OS and RRI across a range of stakeholder categories, and in particular for those at the peripheries? Might RRI interventions, in some cases, actually deepen socioeconomic inequalities (the digital divide) and be in conflict with wider sustainable development goals? How do geographical, socio-economic, cultural and structural conditions lead to peripheral configurations in the European knowledge landscape? What factors are at play and what can be done (at a policy level) to foster absorptive capacity and enhance OS/RRI uptake and contributions to scientific production across regions?

Such questions lie at the heart of ON-MERRIT. The work conducted in ON-MERRIT's work package 3 (WP) "Research cultures, support and incentives" provides rich evidence to answer these and further questions. WP3 included several tasks which aimed to study how the application of RRI and Open Science policies, principles and practices affect research, researchers and their careers across diverse contexts. Here we provide an overview of key WP3 research results, as well as a related study from WP6 on reform of research assessment, highlighting findings of relevance for ON-MERRIT's three key SDG domains.

The following sections discuss and summarise key findings from four project deliverables:

- D3.1 "RRI and Open Science Datasets"
- D3.2 "Cumulative Advantage in Open Science and RRI: A Large-Scale Quantitative Study"
- D3.3. "Uptake of Open Science and Responsible Research and Innovation in Policy and Training"
- D6.1 Investigating Institutional Structures of Reward & Recognition in Open Science & RRI

3.1. Datasets on Open Science and RRI

Our first task was to gather multiple sets and sources of data, which could then be analysed and shared with the research community. We focused on two specific approaches:

1. A dataset on Promotion, Review and Tenure policies (PRT-policies) from institutions in seven countries (Austria, Brazil, Germany, India, Portugal, United Kingdom and the United States). The respective policies were collected by the study team and subsequently coded for a range of traditional (such as the length of one's CV or metrics related to the journals one has published in) and non-traditional indicators (such as the rate of Open Access (OA) publishing, the sharing of

research data and code, engagement with the public and citizen science). The full analysis was undertaken in ON-MERRIT WP6, and recently made available in our report D6.1 Investigating Institutional Structures of Reward & Recognition in Open Science & RRI. A corpus of scholarly research outputs processed from Microsoft Academic Graph (MAG) and CORE, a large aggregator of Open Access (OA) content.

2. A full description of the methodology involved in collecting these datasets is available in Deliverable Report D3.1 "RRI and Open Science Datasets" on Zenodo. We also intend to publish the data itself via a data publication in the near future.

3.2. Cumulative Advantage in Open Science and RRI

Dynamics of cumulative advantage run deeply in science: initial success leads to beneficial circumstances later on. Multiple mechanisms related to this dynamic have been identified, such as the misallocation of rewards towards better known scientists (termed "Matthew Effect" by Robert K. Merton), increased chances to receive further funding after initial funding has been secured, and persistent under-representation of women in general. In our work, we wanted to explore how OS and RRI are related to these dynamics, whether they mitigated or potentially worsened them. To this end, we conducted four quantitative research studies addressing a range of research questions, including: Who produces and who consumes open access research literature? How is institutional performance related to the application of RRI policies and OA publishing? Does the uptake of OA publishing change existing hierarchies within academic publishing, and if so, in which ways across a subset of ON-MERRIT's target UN Sustainable Development Goals (SDGs) - SDG 2 - Zero Hunger, SDG 3 - Good Health and Well-Being and SDG 13 - Climate Action?

Regarding our first question, we investigated levels of production and consumption of Open Access (OA) research literature globally, measured the proportion of citations to OA literature, and tested for correlations with gross domestic product (GDP) per capita at the country and continental level. We find moderate correlations between OA production and OA consumption: institutions whose researchers publish more OA also cite more OA. Although we initially expected that countries with lower GDP (per capita) would have a higher OA consumption than production, we did not find any such correlation.

Building on data from the MoRRI project and combining it with data from the Microsoft Academic Graph, we investigated the relationship between policies on RRI and their potential impact. We found a strong overall correlation between one of the RRI pillars, measures of *public engagement with science*, and RRI policies at the national level (r=0.79, n=344). Furthermore, we found demonstrably higher levels of public engagement with science in countries where these policies are more embedded. On the other hand, we found no correlation between how a country performs in terms of gender equality policies and the actual balance in numbers of male vs. female researchers. Our results therefore indicate that policies are not always linked to practices in linear ways, and that individual indicators taken in isolation could be misleading.

Overall, the research conducted in this research stream highlights that it is the higher ranked, more prosperous and more prestigious institutions that appear best able to adopt, adapt to, and benefit from the evolving landscape of Open Access publishing. Moreover, these trends hold true over time, on the global level, and when broken down to individual continents and subject areas. We therefore have to conclude that structural inequalities in current academic publishing are not necessarily remedied by the Open Science movement, with specific trends such as APC-driven OA publishing potentially exacerbating dynamics of cumulative advantage. Importantly, if research on key global issues is only driven by well-resourced actors, it risks being oblivious to challenges faced by societies and communities less embedded into the global production of knowledge.

The above findings and much more related information is available in Deliverable 3.2 "Cumulative Advantage in Open Science and RRI: A Large-Scale Quantitative Study" on Zenodo.

3.3. The Uptake of Open Science and RRI in Policy and Training

Training and skills are key aspects in the uptake of Open Science and Responsible Research and Innovation practices. In our research we aimed at understanding current institutional structures for OS/RRI training and their relation to current levels of adoption of OS/RRI practices. To this end, we conducted:

- An international survey to assess their practices and opinions regarding OS/RRI, as well as the institutional support for these practices
- In-depth interviews with representatives responsible for training provision in 11 institutions across three continents to identify the support, drivers and barriers to OS/RRI from an institutional point of view.

For our survey, we received responses from 167 active researchers, with a slight skew towards more senior, male academics from Europe, working in the fields of Social Sciences, Engineering and Technology and the Natural sciences. Concepts of OS/RRI, such as Open Access publishing, Research Data Management, Reproducible Research, and Citizen Science, are looked upon favourably, as a different way to do research, although some reluctance and doubts were present on how to put them into practice. Research Integrity and Gender are the topics that gathered more consensus and are best implemented.

Interestingly, we found that the majority of our survey participants had not received training in any of the above OS/RRI topics (very often a large majority). The most popular topics for those who had received training were OA publishing, Research Integrity, Gender, Open Data and OS in general.

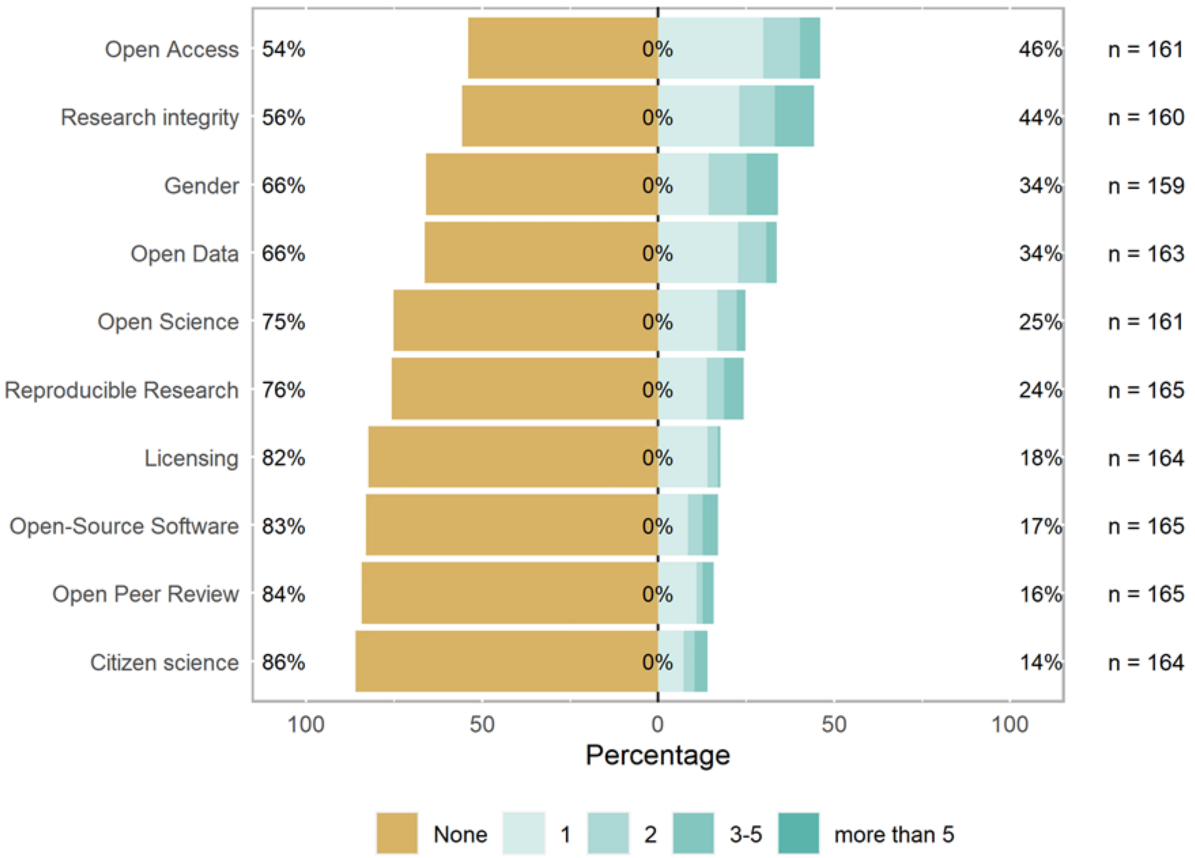

Figure 3. How many training events have you attended on these topics?

In our second study, we interviewed representatives from eleven higher education institutions responsible for implementing OS and RRI policies, from nine countries and in senior positions. Although in general researchers at these institutions are aware of and show some familiarity with OS, OA, RRI and FAIR data concepts, misunderstandings remain. Awareness differs across disciplines and levels of seniority and does not necessarily translate into practice. The main barriers to OS/RRI uptake which were mentioned by our interviewees are the lack of incentives, awareness, and time; concerns of sharing and legal issues; lack of infrastructure and services; cultural/behavioural issues; lack of funding/resources; lack of central coordination within and between institutions; and the need for OS/RRI policies. Interviewees advised that conversations regarding reform on research assessment criteria and publications metrics were underway.

Training support services for OS/RRI available at the institutions are focused on institutional services or tools, RDM (data management planning, GDPR and data sharing), Data protection and handling of sensitive data, OA, Open Science funder requirements, Research Integrity and Ethics. The main challenges faced in providing training are ensuring participation from diverse audiences; lack of staff; lack of institutional support (funding or central coordination); and tailoring training to audience needs. These issues may be mitigated through the integration of training in course curricula, the development of specific and more practical training, and the improvement of online materials.

These results highlight the difficulties involved in providing OS/RRI training and support services at the institutional level and reiterate the fact that training in OS/RRI is essential for researchers to be able to perform science in a solid and transparent way and comply with most funder's requirements and mandates worldwide. There is a need for skilled professionals and the development, normalisation and integration of OS and RRI into curricula. In addition, the role of communities in reinforcing practices and promoting a real cultural change must be fully embraced. More work should be undertaken to foster interoperable infrastructures, integrated training resources and peer-to-peer training, as well as increased resources for training staff and infrastructure.

All results are available in Deliverable 3.3. "Uptake of Open Science and Responsible Research and Innovation in Policy and Training" on Zenodo.

3.4. Research assessment reform for open and responsible research practices

Change is deep underway to make research more transparent and participatory through new open and responsible research practices. Key movements for change include Open Science, such as publishing Open Access (OA) or sharing research data and code, and approaches that make research and innovation more responsive to the needs of society (Responsible Research & Innovation, or RRI). Funders such as the European Commission, with its 95.5 billion Euro funding scheme Horizon Europe, are part of this movement, as increasingly requiring open and responsible practices within the research they fund. Yet, current research assessment processes are increasingly recognised as a barrier to this goal. Potential issues include the overuse of inappropriate indicators, an overemphasis on quantity over quality, and a neglect of open and responsible practices per se.

As part of our Horizon 2020 project ON-MERRIT (investigating issues of equity in open and responsible research), we wanted to quantify the extent to which practices and goals of Open Science and RRI activities are considered by universities across the globe when assessing researchers for promotion and tenure. To this end, we collected and analysed documents on the policies for promotion, review and tenure from 107 academic institutions with a total of 145 policies, across seven countries (Austria, Brazil, Germany, India, Portugal, UK and US). In order to draw meaningful conclusions on the level of countries, we sampled more institutions for countries with larger higher education systems, such as the US and the UK.

Across all countries and institutions, by far the most common indicator mentioned in the policies was "service to the profession", which includes activities such as organising conferences or mentoring PhDs. Other common indicators were ubiquitous concepts such as the "number of publications" or "impact". On the other end of the spectrum, data sharing was mentioned by no university, and OA publishing by one. Indicators referring to RRI concepts were also quite uncommon, with very few policies mentioning concepts related to gender or citizen science.

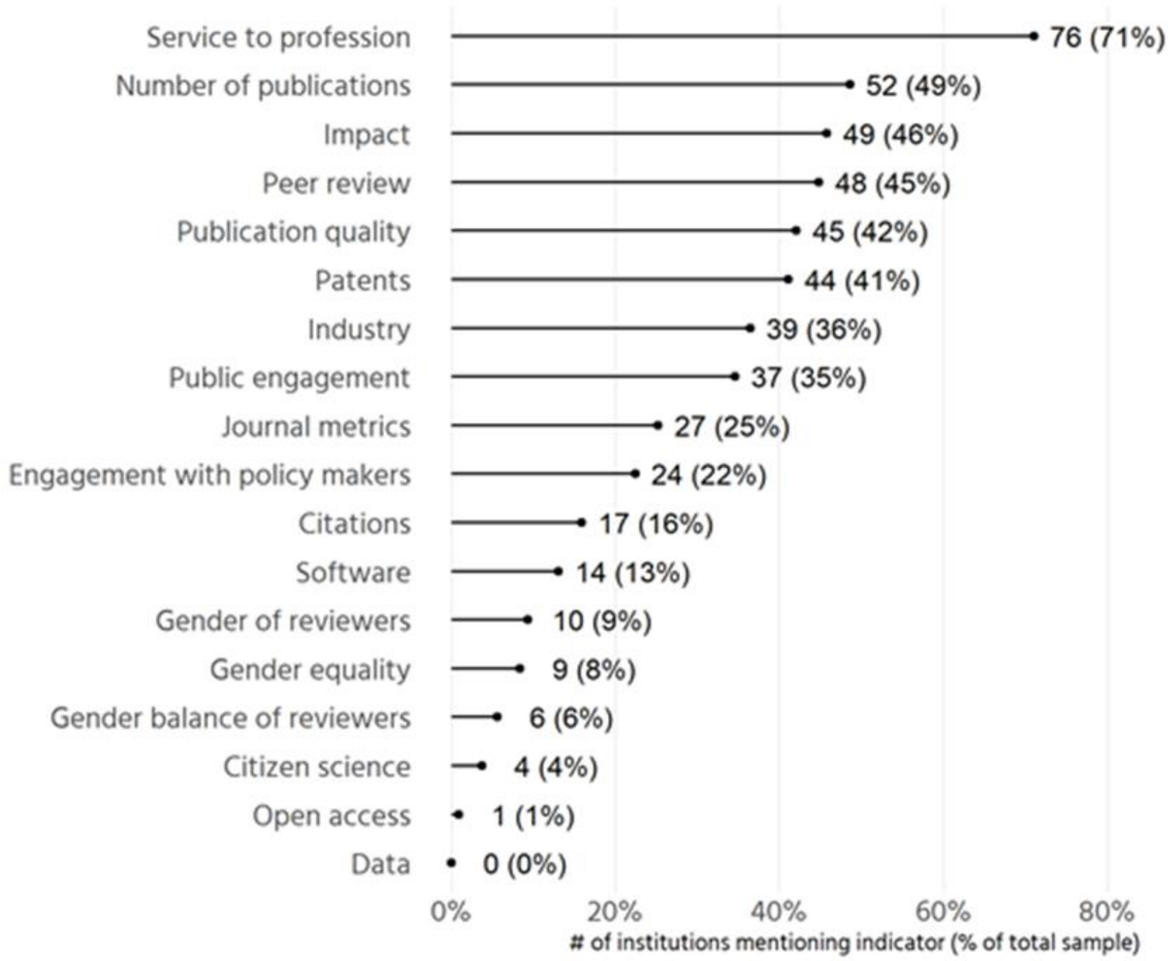

Figure 4. How common are various indicators used by universities for assessing scientists overall?

While institutions still seem to focus on more conventional indicators such as numbers of publications or impact, there are substantial differences between countries. For example, while all Austrian universities mention taking into account the number of publications, this is much less common in the UK. In turn, UK universities also seem not to give much weight to patenting, which is quite common in Brazil. All universities from these two countries, however, mention "service to the profession", which is much less common in other countries. Finally, only institutions from Austria and Germany consider gender in their policies.

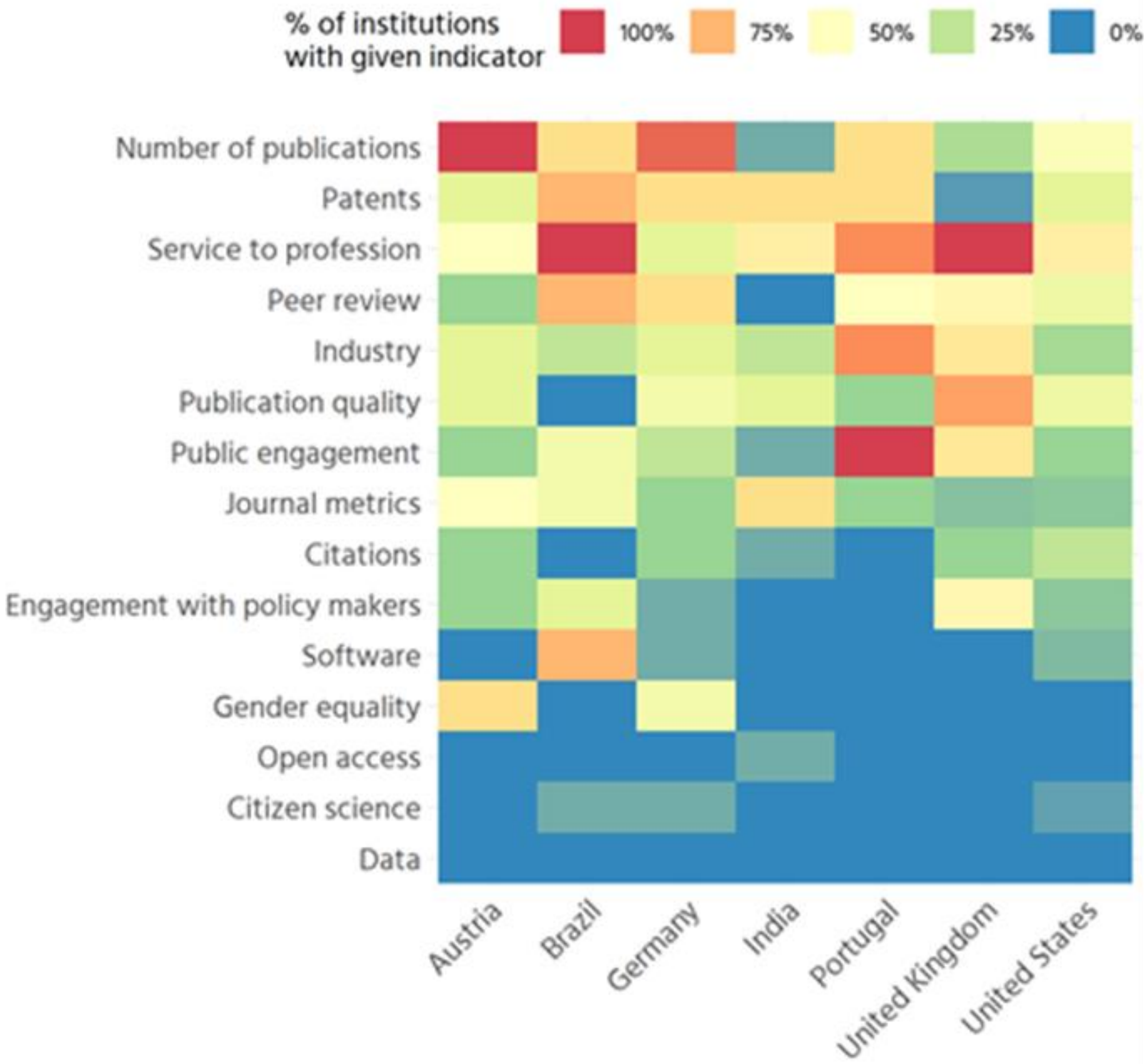

Figure 5. How common are various indicators across countries? The indicators (left side) are ranked by how frequent they are on average across all countries

As it stands, there seems to be much to be done when it comes to including indicators of Open Science and RRI into how institutions reward specific scientific practices. It can be argued (as Elizabeth Gadd recently has) that Open Science principles should not be the target of specific metrics, as they represent basic acts of good research practice. We believe that institutional policies for promotion, review and tenure are an important steppingstone for academia to transition into a world of openly available outputs of academic research. However, it should not be forgotten that various practices (such as data and software sharing) might be better suited to some disciplines than others. Implementing the same policies across all disciplines would only serve to marginalise research that quite simply works differently than some of the more "hard" sciences. Nevertheless, the need for reform could not be clearer, as our findings that open and responsible research practices are rarely considered within promotion and tenure policies clearly show.

More detail on our methods and our results is available in our report Investigating Institutional Structures of Reward & Recognition in Open Science & RRI.

3.5. Results of specific relevance for the SDGs

Following ON-MERRIT's focus on three key UN Sustainable Development Goals (SDG Zero Hunger (SDG 2), SDG Health/Well-Being (SDG 3) and SDG Climate Action (SDG 13), we investigated aspects of OA publishing across papers relevant to the three SDGs. To identify research relevant to these three SDGs, we relied on OSDG.ai[8], an open source initiative that integrates various existing approaches to classify research according to SDG. Our analysis shows that well-resourced actors publish OA more frequently in all SDG areas, as well as publishing in journals with on average higher APCs, which might worsen already existing structural hierarchies within academia.

Any observations of the growth of OA in research relevant to the SDGs 2, 3, and 13 have to be interpreted relative to the overall expansion of OA across science, as well as general structural specificites of the three areas. A key question in this regard is the breadth of research institutions contributing to the body of scientific publications. Contrasting the three SDGs in this respect shows that research in SDG Health/Well-Being (SDG 3) is more concentrated than research in SDG Climate Action (SDG 13). The top 20% of institutions[9] contribute up to 55% of the publications. Research on SDG Zero Hunger (SDG 2) is much less concentrated, with the top 20% of institutions contributing about 40% of publications.

Another area where substantial differences can be observed between research being conducted on the three SDGs, is the share of female authors. We found the share of female authorships to be increasing across all SDG domains, but on different levels. While this share has increased from 30% in 2006 to 37% in 2019 for research being conducted on SDG Health/Well-Being (SDG 3), research being conducted on SDG Climate Action (SDG 13) increased from below 20% of female authorships in 2006 to 27% in 2019. Thus, while the increase in percentage points is similar, female authorships are substantially more common in research on SDG Health/Well-Being. This finding is consistent with prior research (Larivière et al. 2013) and explained by higher rates of female researchers in care-related areas, while shares of female researchers are lower in areas related to mathematics and computer sciences.

The expansion of OA publishing has been well-documented (Piwowar et al. 2018, Iyandemye and Thomas 2019). Here we focus on how this growth materialises in research being conducted in the three SDGs, and how the growth of OA publishing is accompanied by increasing levels of Article Processing Charges (APCs). Overall, we find an equal growth in OA publishing across research being conducted on the three SDGs. OA publishing is slightly more common in research on SDG Health/Well-Being (SDG 3) than in the other two SDG areas (the share of OA publications being about 5% higher). Similar to the distinction discussed above, that more prestigious institutions publish more research, we also find that more prestigious institutions publish OA more frequently. However, this correlation is not equally strong for all SDGs. The share of OA publications of a given institution are only weakly related to the institution's prestige in SDG Climate Action (r = .11 to r = .21). This relationship is stronger for research on SDGs 2 and 3, however it is also declining (from r = ~.4 in 2008 to r = ~.23 in 2018). We can therefore conclude that there appeared to be a first-mover advantage, with more prestigious institutions publishing OA more frequently, but this advantage seems to diminish as OA publishing is becoming more common across science.

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[8] OSDG https://osdg.ai/

[9] Institutions were classified based on $P_{top\ 10\%}$ from the Leiden Ranking. This measure refers to the number of a university's publications that are within the top 10% cited of their field. The top 20% of institutions are measured as the top 20% of institutions according to their value of $P_{top\ 10\%}$.

Analysing OA publishing along the dimension of country income, we find higher rates of OA publishing among researchers from institutions from high income countries as well as low-income countries, with the countries in between exhibiting lower rates of OA publishing. This pattern is particularly salient for research being conducted on SDG Health/Well-Being, where publications by scholars from institutions from low-income countries in fact have the highest rates of OA publishing. This finding has been attributed to high levels of research funding on infectious diseases such as HIV or malaria in many sub-saharan African countries (Iyandemye and Thomas 2019). In this sense, there are multiple concurrent processes at play which shape overall rates of OA publishing.

A key aspect in this regard is which model of OA publishing is being employed. There is growing evidence that the APC-based publishing model is detrimental to equity in publishing outcomes (Olejniczak and Wilson 2020, Smith et al. 2021). In our analyses of research being conducted on the three key SDGs, we observe similar trends. First, we observe a small to moderate correlation between an institution's ranking (according to $P_{top\ 10\%}$ from the Leiden Ranking) and the average APC charged by journals the institution's authors publish in. This correlation is strongest in research on SDG Zero Hunger (r = .43 for institutions assigned by first author, 2015-2018), and lowest in SDG Climate Action (r = .25). This finding reveals remarkable differences between the bodies of research which are relevant to these two SDGs. As mentioned above, research being conducted on SDG Zero Hunger is generally less concentrated, with more equal contributions between institutions according to their prestige ranking. At the same time, this body of research is strongly structured by prestige levels when it comes to OA publishing. Considering only publications that involved an APC, researchers from less prestigious institutions publish more frequently in journals with low APCs in SDG Zero Hunger than in SDG Health/Well-Being. Importantly, in our sample there are only very few cases of researchers from less prestigious institutions publishing APC-based papers on SDG Climate Action. This gap likely stems from a combination of factors. Our approach did not find much research on SDG Climate Action (SDG 13) being conducted by researchers at institutions with low prestige. Combined with generally lower rates of OA publishing across institutions with low prestige, the share of APC-based OA by researchers from less prestigious institutions is therefore very small.

Investigating the relationship between institutional prestige and levels of APC over time, we observe an increasing gap between where researchers from less and more prestigious institutions in terms of the APCs charged by journals publish. This increasing gap cannot be attributed to rising levels of APCs among some major publishers, since we did not rely on historical data for APCs per journal. This increase is observable across research on all three SDG areas.

In sum, when investigating differential rates of OA publishing according to institutional prestige within the analysed SDGs, we found a clear hierarchy: more prestigious institutions publish more OA than less prestigious institutions, which is in line with the findings by Siler et al. (2018). However, across all three SDGs, but particularly in SDG2 and SDG3, the association between institutional ranking and the share of OA production is weakening. We can therefore conclude that while a first-mover advantage for better-resourced institutions to have higher rates of OA publishing is clearly visible, this advantage seems to diminish somewhat as OA publishing enters the mainstream. At the same time, there appear to be growing inequities related to the modes of publishing, with the APC-based model of OA publishing potentially exacerbating dynamics of cumulative advantage.

3.6. Summary

From these various lines of research, we can make the following conclusions: The current ways of how Open Science is being implemented favour better-resourced actors, particularly in the case of Open Access publishing. Policies aimed at fostering responsible practices of research and innovation are related to actual implementation in non-linear ways, where uptake of RRI practices hinges to a large degree on structural factors that predate the policies' implementation. A substantial share of researchers has not received any training on RRI and OS practices, which is exemplified in common challenges faced in providing adequate training, such as ensuring participation from diverse audiences; lack of staff; lack of institutional support (funding or central coordination); and tailoring training to audience needs. In terms of evaluating researchers for review and tenure decisions, it is increasingly suggested to include practices of OS and RRI in the list of criteria; as of today, this is only rarely the case. Research being conducted on the three key SDGs Zero Hunger (SDG 2), Health/Well-Being (SDG 3) and Climate Action (SDG 13) exhibits heterogenous trends, with increasing rates of female authorships and OA publishing across the board. Our findings provide a rich evidence base which informs the development of guidelines and recommendations, soon to be published as deliverable D6.4.

4. ON-MERRIT findings (WP4): Open Science in industry

Spurring growth and innovation in industry is a key goal of policy-makers. A commonly stated advantage of Open Science is greater return on investment for funders, as results are made re-usable to industry. According to the EC's Directorate-General for Research and Innovation, for instance, "Open Access to research results [is] the springboard for increased innovation opportunities, for instance by enabling more science-based start-ups to emerge" (Directorate-General for Research and Innovation, 2016) Are Open Science resources actually being taken up by industry, though? Recognising that studies to date in this area were scarce (Fell, 2019), ON-MERRIT set out to investigate how far small and medium-sized enterprises (SMEs) and industry actors take up Open Access publications, open data, etc., and to what extent these resources are integrated into their working environments, drivers and barriers in this context, as well as impacts on technological inventions.

Our investigations comprised (1) a literature review about the information seeking behaviour as well as the current uptake of OS resources in SMEs and industries, (2) a qualitative study (using interview/ questionnaire instruments) to investigate barriers and drivers to uptake of Open Science resources in industry, (3) a quantitative study of the extent to which openly available scientific work influences technological innovations and patents. ON-MERRIT's three key domains related to SDG research were included as cross-cutting issues across all these issues and we here highlight specific findings of interest in understanding barriers and drivers to uptake of Open Science resources in these domains here. As many pertinent issues were identified that apply across domains, however, we first provide an overview of general findings.

The following sections discuss and summarise three project deliverables:

- D4.1 Information Seeking Behaviour and Open Science Uptake in Industry: A Literature Review
- D4.2 Drivers and barriers to uptake of Open Science resources in industry
- D4.3 Quantifying the influence of Open Access on innovation and patents

4.1. Information Seeking Behaviour and Open Science Uptake in Industry

The literature examined in Deliverable 4.1 "Information Seeking Behaviour and Open Science Uptake in Industry" indicates that research outputs currently play a somewhat peripheral role in general information seeking behaviour in many industrial sectors, with a general lack of information-seeking skills amongst employees. Domain-specific knowledge is essential for exploiting scientific resources for commercial needs, and these skills are often acquired by either hiring graduates or directly collaborating with academia. Open access to research findings is found to provide efficiency gains (i.e., time and cost savings associated with accessing research), as well as enabling the development of new products, services, and companies, by lowering the barriers for companies of all sizes (from large firms to start-ups) for accessing basic research. However, academic sources (open or not) seem to be of low to medium relevance for the innovation needs of most companies. Only companies in certain sectors like chemical or pharmaceutical industries rely on academic knowledge to a considerable degree, while sources like customers, competitors or suppliers are of greater importance for the majority of companies. This has several reasons which in consequence also inhibit the uptake of Open Science resources. First, companies (especially SMEs) have difficulties in finding relevant academic sources, partly because their employees lack relevant skills for gathering sources, partly due to time constraints. Second, translating results from basic research into commercial innovation needs highly trained employees. These employees are commonly present in companies with a dedicated R&D department, i.e., companies with a research culture that also values engagement in the academic sphere (i.e. by publishing research findings). The apparent mismatch between basic research and industrial innovation may be attributable to a decline in the diffusion of basic research by industrial actors. Third, data published alongside scientific papers is very specific in many cases and therefore not suited for commercial exploitation. All these potential barriers seem to be of lower concern for companies with a focus on drug development, compared to general manufacturing companies.

4.2. Drivers and barriers to uptake of Open Science resources in industry

A commonly stated advantage of Open Access to publications and data is greater return on investment for funders, as results are made reusable to a range of societal actors including industry. Is open research data actually being taken up by industry? The concept of absorptive capacity is fundamental for understanding whether industrial actors are able to benefit from Open Science resources, such as research papers or data. Absorptive capacity refers to "…the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends" (Cohen and Levinthal 1990). Recent research (e.g., Huber, Wainwright and Rentocchini 2020) highlights how SMEs in particular struggle to benefit from Open Data.
How do companies find relevant resources to satisfy their information needs? The most common barriers in this regard were identified as difficulties in explicating information needs and finding relevant information, lack of time, accessibility, and concerns regarding content quality. Accessibility seems to be the most relevant factor in finding information (Guo 2009; Yitzhaki and Hammershlag 2004; Kwasitsu 2003; Su and Contractor 2011). Although recent studies (e.g., Kraaijenbrink and Groen 2006) document the ubiquity of searching for information on the Internet, personal contacts are still fundamental.

Research outputs currently play a peripheral role in general information seeking behaviours in many industrial sectors. The evidence points to a general lack of information-seeking skills amongst employees. Exploiting scientific resources for commercial ends requires subject-specific skills that are commonly acquired either through hiring graduates or directly collaborating with academia (Fell 2019; Starasts 2015). Open Access to research findings is associated with efficiency gains, as well as enabling the development of new products, services, and companies, by lowering access barriers to basic research.

How do academics collaborate with non-academic organisations in the industrial domain? Two publications by Perkmann et al. (2013) and Perkmann et al. (2021) analyse this in detail. Perkmann et al. (2013) is a literature review of papers from 1989-2011 studying "academic engagement", defined as "knowledge-related collaboration by academic researchers with non-academic organisations" (Perkmann et al. 2013, 424). Respective activities consist of "... collaborative research, contract research, and consulting, as well as informal activities like providing ad hoc advice and networking with practitioners" (Perkmann et al. 2013, 424) and play an important role in bringing academic research into the industrial world (Cohen, Nelson, and Walsh 2002). Perkmann et al. (2013) suggest that academic engagement is a multi-level phenomenon in that it takes characteristics from the individual, institutional and organisational context into account. Individual academic engagement is strongly linked to researchers who are well-established and -connected, are more senior, and have more social capital as well as a high number of publications and government grants. Academic engagement is directly linked to academic success, thereby exemplifying the 'Matthew effect' in academia (Merton 1968), "...according to which individual success is reinforced through a virtuous cycle of achievements and returns on those achievements" (Perkmann et al. 2013). This pattern is in line with the findings that male academics are more likely to engage with industry, take up more prominent positions, and are able to mobilise more resources and establish wider networks. Results are inconclusive on the institutional and organisational levels. Academic engagement has been found to correlate positively, negatively, or not at all with the research quality of academic institutions. Academic engagement strongly depends on highly motivated and successful individual researchers and is mostly independent of their affiliated institution or organisation. In a recent update, Perkmann et al. (2021) confirm some of the findings in (Perkmann et al. 2013): i) academic engagement is complementary and consistent with the promotion of academic research activities, ii) highly engaged researchers are more likely to be committed to academic engagement, iii) academic engagement correlates positively with acquiring research funding and iv) academic engagement is driven by individual traits. With regard to gender, women engage less in academic engagement than men. Academic engagement is also found to depend on peer influence and discipline and to correlate with academic entrepreneurship.

In our qualitative study Deliverable 4.2 "Drivers and barriers to uptake of Open Science resources in industry", we continued our investigations regarding the uptake of RRI and Open Science in SMEs and industry by consulting industry players using interview/questionnaires. For maximal understanding of a particular context, the interviews were focussed on industry respondents in Austria, while the questionnaire sought broader insights from respondents across Europe about the current uptake of Open Science resources in SMEs and industries. In general, these studies highlighted that knowledge about Open Science is rather low and to a certain degree related to respondents' educational backgrounds. However, we found that Open Data, Open Access and also Open-Source code already play an important role in the respective companies. For example, our interview partners mentioned using weather data, location data, open-source code libraries, or open access publications of the corresponding domains. However, this uptake strongly depends on the characteristics of the companies and the employees' background. For example, all our interview partners hold a master's degree and some also a PhD degree and they worked mostly in start-ups, thus, they need to use OS resources to stay competitive. The qualitative investigation identified several drivers that support the uptake of Open Science resources: (1) employment of people with a university, (2) offering incentives and support for uptake as motivation, (3) targeted training to increase awareness and uptake, (4) knowledge transfer via interdisciplinary cooperation, and (5) focus on the benefits of exploiting the wisdom of the crowd. We also identified barriers that hinder the uptake of Open Science resources: (1) relative scarcity of (especially health-related) open data, (2) licence restrictions for the commercial use of some data sets, (3) the reliability and validation of data, and (4) fees for Open Access publishing.

4.3. Quantifying the influence of Open Access on innovation and patents

In our quantitative study Deliverable 4.3 "Quantifying the influence of Open Access on innovation and patents", we were interested in finding to which extent openly available scientific work impacts technological inventions.

Citation practices differ between academic writing and scientific patenting. In academia, only authors are expected to cite all relevant work, whereas in patenting, both inventors and examiners are legally obliged to support claims made in the patent application through citations (van Raan 2017). US patent law requires the patent examiner to select references carefully (Tijssen 2001). The European Patent Convention demands that examiners consult and include (relevant) scholarly literature (Verbandt & Vadot, 2018). However, evidence suggests that most citations are made by the inventors themselves. In a large-scale study of patents issued by the United States Patent and Trademark Office (USPTO) after 2001, Ahmadpoor & Jones (2017) found that while examiners were responsible for 36% of patent-to-patent citations, they only contributed 4% of non-patent literature. Scientific non-patent references (SNPRs), on the other hand, should not be interpreted in every case as constituting the key sources of an invention, but rather as indicative for a spectrum of science-technology interactions, ranging from signalling the "awareness of scientific results" to considerable direct contributions to the innovation (Tijssen 2001). Drawing on patents from the field of nano-scale technologies, Meyer (2000) investigated the impact of scientific results on innovation through patent citation analysis to find SNPRs mainly present the general background of an invention, rather than constituting a direct link. Based on interviews with a sample of 33 Belgian inventors active in nanotechnology, biotechnology and life science about their motivation to cite SNPRs, Callaert, Pellens & Van Looy (2014) found that SNPRs rarely reflect the role of research as a source of inspiration for technological invention and should therefore not be interpreted as evidence for a direct link between scientific work and technological invention.

There are important trends in patent citation practices. First, the distribution of non-patent literature (NPL) is highly skewed, a large proportion of patents lack references completely (van Raan 2017). Examining a patent sample from the United States Patent and Trademark Office (USPTO) and the European Patent Office (EPO) between 1996 and 2001, Callaert et al. (2006) estimated that 55% (USPTO) respectively 64% (EPO) of NPL are SNPRs published in journals. There is, however, conflicting evidence concerning coverage across journals. While Guerrero-Bote, Moed, & De-Moya-Anegón (2021) estimated that within five years, patent citations cover one third of Scopus-indexed journals, van Raan's (2017) comprehensive review found that SNPRs appeared only in a small group of journals. In another work on "sleeping beauties", publications whose impact (in terms of citations) is not immediate but grows over time, van Raan & Winnink (2018, 2019) noticed a considerable time-lag between an SNPRs publication date and the patent application. The lag has shortened over the years, which the authors attribute to inventor-author self-citations. Another recent patent citation analysis found that scientific articles making a novel contribution to a field were significantly more likely to have a technological impact measured by SNPRs (Veugelers & Wang 2019).

Narin, Hamilton & Olivastro (1997) found national citation circles where inventors cited a large proportion of scientific articles authored at prestigious universities and laboratories in their own country and funded by important research funders (NSF, NIH). Ke (2020) found a similar dominance of scientific articles linked to research funded by the US government and the NIH. Tijssen (2001) observed an increasing proportion of Dutch-invented patents that cite domestic research, particularly driven by author-inventor self-citations and patents from large multinational tech firms. Cross-country comparisons need to take national citation practices into account in the interpretations of their findings, which are governed by the respective patenting law as well as the availability of literature (Callaert et al. 2006). As in scholarly communication, there are field-specific differences in patent citation. Ke (2020) reports large variations among the different technology sectors in terms of SNPRs coverage, with biotechnology and drug patents having above-average SNPR uptake and growth rates. Similarly, Hötte, Pichler & Lafond (2020) observed an increase of SNPRs among patents targeting low-carbon energy technologies. The number of SNPRs is a widely considered indicator for the "science intensity" of a field of innovation (van Vianen, Moed & van Raan 1990). However, an econometric model based on survey responses and indicators for the patent value suggests that it might be only informative for some fields (Harhoff, Scherer, Vope, 2003).

While an increasing body of research focuses on Open Access to scientific research articles (Pinfield 2015, Piwowar 2018), few studies examine the specific impact of Open Access on innovation using SNPRs. Bryan and Ozcan (2020) investigated a sample of 43 medical and biotechnology journals published between 2005 and 2012. Similar to the effect on public sector research (Staudt 2021), they found a modest increase of citations to NIH-funded research after the introduction of the NIH Open Access policy, while citation rates to non-funded research stagnated. Bryan and Ozcan (2020) found that small biotechnology companies likely benefit most from Open Access because they require access to robust and specific scientific knowledge but often cannot afford subscriptions. Studying small and medium sized pharmaceuticals companies using regression models, ElSabry & Sumikura (2020) also suggest that smaller companies benefit from Open Access. In particular, they found a positive Open Access effect on small and medium-sized enterprises (SME) without collaborators at universities or other public research institutions that usually can make use of subscribed journals.

To investigate the influence of Open Access on innovation and patents, we combined publicly available data sources about patents and scholarly publications to explore the uptake of Open Access to scientific literature cited in patents. Investigating over 22 million patent families indexed in Google Patents, we found that around one third were supported by at least one citation to non-patent literature. However, the number of references per patent family can vary considerably across technological sectors and inventor countries. Focusing on scientific articles cited in patents, we found an Open Access citation advantage, suggesting that openly available research articles are more likely to be cited in patents than closed access work. In line with the general trend, Open Access uptake grew over the years, with nearly half of cited articles published between 2008 and 2020 being openly available. In line with research on both technology-science linkage and Open Access, we found considerable country and subject specific variations. Particularly patents representing inventions from the US and the UK cited disproportionately more often Open Access work. Concerning disciplinary differences, it is interesting to note that patents belonging to the classification “A - human necessities” stand out as having the greatest percentage of references to Open Access literature, which covers fields of innovation linked to sustainable development goals (SDG) like agriculture, food and health. These patents show not only a stronger link to research in terms of the penetration of SNPR, but also to research that is openly available.

4.4. SDG specific findings

- **SDG 2: Zero Hunger (Agriculture):** From the literature review, we found that information needs in Agriculture are often tailored to the individual farming-specific context, with information sought from family members, other growers or advisers, as well as trade literature and the internet. Our studies confirmed this, with social contacts the most relevant source of information in the agricultural domain. This highlights the often-localised nature of knowledge in Agriculture. We found some evidence of use of Open-Source code and Open Data (especially weather data) amongst our interviewees, however.
- **SDG 3: Good Health and Well-being:** In health research, information-seeking behaviour (according to the literature) relies on a range of sources from textbooks and scientific journals to online resources (including PubMed). The information seeker’s age was a potential factor, with older participants somewhat preferring traditional media compared to younger cohorts. In our qualitative study, we similarly found that literature/publications are the most important sources of information. Our interviewees highlighted the value of Open Science, although a major obstacle was that health-related Open Data is scarce. On the one hand, publishing (even anonymized) health related data is a challenge due to privacy reasons and GDPR. On the other hand, trust, validation, and compliance play a major role in this regard. As the COVID-19 crisis has highlighted the importance of rapid sharing of scientific information, it is also interesting to note that our patent analysis found evidence that patents are beginning to reference bioRxiv preprints, although not yet in great numbers.
- **SDG 13: Climate Action:** In climate research, our findings show that literature/publications are the most important sources of scientific information. Interviewees in this domain highlighted issues of using Open-Source code because of compliance concerns. However, two interviewees advised they

make use of Open Data such as OpenStreetMap, although also flagged challenges relating to the validation of the data used.

The COVID-19 pandemic has shown the potential of rapid sharing of scientific knowledge as a basis for innovation and evidence-based policy in mission-driven research. Our findings confirm the literature in suggesting that there is interest in the uptake of Open Science resources, especially Open Data and Open-Source code/software, amongst industry players. However, the results show the difficulties of uptake, with contexts of company, leaders and employees and their (educational) background.

5. ON-MERRIT findings (WP5): Open Science and RRI in policy-making

Set against the backdrop of the grand societal challenges that are reflected in the UN Sustainable Development Goals (SDGs), the ON-MERRIT project aims to critically interrogate whether Open Science and Responsible Research and Innovation (RRI) live up to the positive claims of their proponents and whether cumulative advantage and disadvantage may be present within or exacerbated by Open Science and RRI practices. Open Science (OS) and Responsible Research and Innovation (RRI) promise to make scholarship transparent, inclusive, and participatory. In addition, they aim to increase the academic, economic and societal impact of research outputs by fostering the use of publicly available scientific outputs by civil society actors, policymakers, and the general public.

Work Package 5 of ON-MERRIT investigated how Open Science might impact the uptake and use of scientific outputs by policymakers, specifically. Here, we share our research aims and findings and how they relate to the wider aims of the ON-MERRIT project. These results can be found in the following ON-MERRIT deliverable reports:

- D5.1 Scoping report of previous research on the role of Open Science resources in deliberative policy-making
- D5.2 Results of a survey on the uptake of Open Science in information seeking practices in policymaking
- D5.3 Networks of engagement in deliberative policymaking: Expert reflections on barriers to participation

5.1. Investigating the role of open research outputs in decision-making

Governance increasingly relies on expert knowledge, with demand for public participation to strengthen the legitimacy of the policy process. However, there is a tension between the normative demands for knowledge-driven governance and participatory governance. Indeed, expert knowledge has been framed as a threat to democracy, as the principles underlying democracy (e.g., inclusion, equality) seem to be patently incompatible with epistemic needs, which raises the issue of the legitimacy of experts. This epistemic-democratic tension raises serious problems for the policy-expertise-relationship. Understanding the prospects for Open Science practices depends upon investigating the role of scientific evidence in policy making more broadly. The work conducted in Work Package 5 provides ample material to answer this and further questions. Our strategy was, first, to synthesise research on uptake of (open and closed) research outputs within policy-making (results of which have been made available in our report D5.1 Scoping Report: Open Science Outputs in Policy-Making and Public Participation). Further, we used surveys and interviews to understand the extent to which policymakers make use of scientific resources (results are available in Deliverable 5.2). Finally, we investigated participatory processes (research that aims to include a broad range of social groups) to understand how they provide a knowledge basis for deliberative policy-making. We invited policy-active researchers to a series of workshops, each themed for one of ON-MERRIT's case-study disciplines, who were then asked to share their experience with participatory processes, reflect on barriers to participation as well as facilitating policy-making through their research, and question how the voices of various stakeholders (including their own) were or were not heard (results available in Deliverable 5.3).

5.2. Open Science Outputs in Policy-making and Public Participation

When starting our work on uptake of scientific outputs by policy makers, our first task was to review existing work on research uptake. We quickly realized that empirical evidence regarding the impact of OS practices on policy advice was scant at best. In fact, in some areas, most notably public health, the relationship between evidence and policy is described as a “gap” to highlight the difficulties that prohibit the use of scientific results in policy making. How can open research practices impact research uptake, then, if policy makers do not make sufficient use of scientific outputs as it is? Deliverable 5.1 addressed this question by systematically summarizing evidence on how policy makers use scholarly resources with a special focus on open research practices.

The discussion surrounding scientific policy advice is most developed in the area of public health, while in other domains (agriculture, climate), the problem seems to be of a different kind. In particular, the evidence-policy gap describes difficulties of translating scientific evidence into actionable policies. Indeed, researchers and policymakers are described as living in different and frequently incompatible worlds. Policymakers resort to scientific advice when dealing with uncertainty and ambiguity, seeking information that is timely, relevant, credible, and readily available. They also struggle with knowledge management and appraisal of research outputs, in addition to a lack of resources, knowledge, and skills to make use of research. Awareness of scientific developments among policymakers is low, and few academics take part in the policy process. On the other hand, access to relevant and clear information and good relationships between researchers and policymakers foster research uptake. Policymakers prefer receiving information through personal networks rather than academic publications. Our findings further suggest that improved infrastructure for information sharing could have a positive impact on the use of evidence in policy making. The deliverable further suggests that both RRI and Open Science continue earlier attempts to negotiate the role of science in society. The science-society relationship amounts to a complex interplay of competing forces and trade-offs between academic autonomy and the capacity of science to serve societal needs. RRI invites us to rethink the science-society relationship by bringing together societal relevance, claims to autonomy, public policy, and Open Science practices in novel ways, drawing on elaborated methods and conceptual frameworks from the long history of negotiating the science-society relationship.

5.3. Uptake of Open Science in information seeking practices in policy-making

Whereas Deliverable 5.1 sought to review existing evidence on research uptake by policymakers, Deliverable 5.2 used survey and interview instruments to better understand policymakers’ habits of information-seeking and use, as well as general levels of awareness of open research practices. A case study of Portuguese policymakers sought to refine findings from the scoping report.

Our respondents reported using scientific information regularly in support of their political and legislative work. As was found already in our literature review, within this setting, academic literature is often of marginal importance as policymakers and their support staff predominantly rely on policy briefs, along with personal communication. Indeed, we found Open Access to primary scientific literature deemed unlikely to have a significant impact on the extent of scientific policy advice, even though support for the concept and principles of Open Science among policymakers was high.

The case of Portugal is special in many ways, even if some of our findings do corroborate existing literature on information-seeking behaviours. What marks Portugal out is largely explained by the fact that policy-making is not considered a career, and many policy-makers are former academics who maintain close ties with academia. Our study also challenges the general notion of an "evidence-policy gap", especially amongst our interview cohort of policy-makers who identify as academics. The idea that academics and policy-makers inhabit different worlds is therefore untenable as a general claim; in fact, the case of Portugal shows that where policymakers are recruited from within academia, the distinction of two groups and the diagnosis of a gap between those groups is markedly less plausible. Respondents' familiarity with both worlds frequently renders the issue of uptake obsolete as policymakers with academic credentials do not have a problem reading or understanding academic literature.

In summary, we found scant evidence that Open Science significantly impacts research uptake. The study does, however, challenge the applicability of the "evidence-policy gap"-concept to certain national contexts. We saw strong support for the aims of Open Science and its principles of democratization of knowledge, mitigation of inequalities and societal impact in both our survey and interviews. However, this is not backed by a deep knowledge of the aims and principles of Open Science, except amongst interview respondents with links to academia. Our research shows limited potential for many elements of Open Science to directly impact research uptake. Rather, our findings seem to reinforce the importance of translation to render scientific outputs understandable to policy-makers. Further, interviewees were acutely aware that research and policymaking follow different (often conflicting) logics, and were also perceptive about the role, function, and limits of expertise in government. There is a need for more structured and continuous flows of scientific information for policy-makers. The Portuguese case, then, represents a new type of policy-active academic, namely one who moves between academia and policy- (or decision-) making roles (and sometimes back).

5.4. Networks of Engagement in Deliberative Policy-making: Expert Reflections on Barriers to Participation

So far, we have discussed results pertaining to research uptake more generally, with Portugal providing an interesting, counterintuitive case study. The final task of Work Package 5 sought to provide insights with respect to the question: Does Open Science in fact support scientific uptake by policy-makers, and are forms of cumulative advantage or disadvantage at play and impact participation in policy-making?

We started from the recognition that the intention of RRI is to reform the science-society relationship in terms of increased equity by bringing together public policy, societal relevance, and effective implementation. Researchers who conduct projects aligned with RRI principles and practices work with a broad range of societal actors, engaging them in participatory practices that seek to provide policymakers with knowledge. As such, these researchers are often gatekeepers as well as enablers for engagement in participatory research. This seems to beg the question: Which societal actors, both within and outside of academia, participate in Open Science and RRI research and policy-making? Which societal actors are excluded, and why? In response to these questions, we conducted a qualitative study composed of in-depth interviews and workshops with policy-active researchers whose research resonates with RRI practices. They were asked to participate in one of three workshops focused on three domains of interest: climate, agriculture and health, to discuss uptake of scientific research in the process of policy-making, improving equality in representation, access and impact in policy-making, as well as the potential impact of Open Science.

We identified several key factors that influence scientific policy advice: understanding on the part of researchers of the policy sphere in which they operate, congruence between research aims and policy goals, strategic development and maintenance of relationships based on trust and credibility, awareness of policy positions taken at certain international organizations (UN, WHO, OECD) as these serve to define the normative foundation for policy-making at national and sub-national levels, upstream engagement between researchers and policy-makers, and with civil society actors and impacted communities, fostering relationships between communities and their policy-makers, and cognitive (rather than physical) accessibility of research findings and outputs.

Participation in RRI-resonant research and policy-making is largely determined by the policy sphere in which a researcher works (representative, deliberative or participatory), and the research design and methods used to create the scientific knowledge. We identified three different approaches to research that largely overlap with the three policy spheres above: Within a traditional academic approach, it is primarily researchers and policy-makers who participate; in a multi-stakeholder approach, the range of actors includes various stakeholders selected for their relevance to the problem at hand, typically involving researchers, other experts, representatives from the business world, policy-makers and other civil servants, and representatives of CSOs and NGOs. With a strongly participatory approach, the range of actors is further broadened to include people who have historically been marginalized from processes of both scientific knowledge production and policy-making. Even so, some remain excluded from RRI-resonant research and policy-making, most notably researchers who are perceived as not credible or legitimate, due to inequalities related to race, gender, age, geopolitical position, as well as institutional affiliation and field, as well as researchers without adequate funding or institutional support for policy-oriented work. Likewise, the world's most poor and vulnerable remain largely left out, despite best efforts of researchers practising strongly participatory research, because these groups are difficult to reach due to the digital divide, language marginalization, and limited resources for this type of research. In summary, we found that the following groups influence public participation in policy-making:

- Researchers, through their choice of research design and methods
- Policy-makers, through their (un)willingness to engage with the various approaches to research that the science-policy interface implies
- Research funders, by offering only limited support for participatory, policy-oriented research
- Academic and scientific institutions, by maintaining norms that run counter to this aim and disincentivizing researchers from facilitating participation

So, while there are several key factors that influence scientific uptake by policy-makers, Open Science is not chief among them. Additionally, Open Science and RRI as they are currently practised are not doing enough and are not yet widely enough adopted to have a significant impact on expanding equitable participation in scientific knowledge production and policy-making.

5.5. SDG-specific findings on Open Science, RRI and academic policy advice

We next present key findings of relevance for research into ON-MERRIT's target Sustainable Development Goals. The relationship between researchers and policy-makers has been described as a gap, highlighting the difficulties that stand in the way of research uptake such as lack of time, resources, and skills, on the part of policymakers, as well as lack of relevant, timely research output and lack of effective communication, on the part of researchers. However, in-depth engagement with this view as well as with the potential role of Open Science outputs in academic policy advice suggests that this claim is valid only under certain conditions and for certain fields. Indeed, the gap diagnosis is plausible, in a strict sense, only for the field of public health, but for reasons to be discussed below, not for climate science or agriculture. The research performed within ON-MERRIT suggests that policy advice follows vastly different logics and strategies depending upon the policy model, the model of the science-policy-interface, and ultimately, upon the models of participation and knowledge involved. Indeed, the diagnosis of an evidence-policy gap is most pronounced in public health, with scant evidence for a similar phenomenon in the other two domains, which suggests that the translation of scientific evidence into actionable policies is more difficult for medicine.

We found that (Western) medicine is based on a universalist view of knowledge; in fact, participants to our health workshop stated clearly that participatory processes to include local knowledge are unwanted as lay expertise is not taken seriously. A possible reason is the way medical knowledge acts as a social resource, serving to certify epistemic authority in doctor-patient interactions.

Climate research likewise draws on universal results (e.g., physics) that can be difficult to translate into recommendations actionable at the local level (e.g. individual or community action). Climate is very far removed from direct experience. This is the case because climate is by definition a global phenomenon, which in our data is evident in the higher relevance accorded to supranational actors (UNO, OECD, IPCC) in terms of defining climate policy goals and action plans, and in bestowing legitimacy upon the former. This is also reflected in the dominance of what has been defined as the linear model of the science-policy interface in climate policy advice, corresponding to the representative democracy model, in which knowledge transfer is understood as a linear process from researchers to policymakers. Developing in-depth relationships with policymakers to receive information as well as maintaining academic reputations (for legitimacy) is fundamental in this regard, although many of our respondents also lean heavily onto community-based research to develop adaptive capacity.

In agriculture, research uptake is much more dependent upon local conditions/expertise, which explains the high provenance of participatory approaches within this field. In agriculture, implementing policy recommendations necessarily depends upon local conditions, which in part explains the need to include local stakeholders not just in implementation, but already at the stage of problem definition, as our workshop participants concurred. These variations impact not only in the strategies researchers employ to influence policy, but also the prospects for Open Science practice to meaningfully alter research uptake. In what follows, we summarize three project deliverables, ON-MERRIT D5.1 Scoping Report: Open Science Outputs in Policy-Making and Public Participation (Reichmann et al. 2020), ON-MERRIT D5.2 Uptake of Open Science in information seeking practices in policy-making (Correia et al. 2021), and ON-MERRIT D5.3 Networks of Engagement in Deliberative Policy-making: Expert Reflections on Barriers to Participation (Cole et al. 2021), respectively, to describe specific findings with respect to these three areas.

5.5.1. SDG 2: Zero Hunger (Agriculture): The importance of local knowledge

Within the field of agriculture, the emphasis is on the local and regional levels of implementation as opposed to global policy arenas (WHO, UNO, etc.), with the fundamental difficulty, according to our workshop participants, being the translation of high-level policies (e.g., the EC's Common Agricultural Policy) into effective local action. This suggests that for SDG 2, the local context and conditions vary vastly, which corresponds to a complex interplay at the level of academic policy advice, between the regional, national, and supranational levels (e.g., regions, nations, EU/AU). This constellation entails a very specific role for supranational entities in terms of defining high-level policy goals. In terms of creating and utilizing knowledge, agriculture is defined by the fundamental importance of local, particularistic knowledge which is difficult to reconcile with scientific (universalistic) knowledge and necessitates the inclusion of local stakeholders in the process of knowledge creation and utilization, but also (already) at the stage of problem definition.

Therefore, participatory approaches are in high regard amongst this group of policy-active researchers to foster the inclusion of local practitioners, reflective of the fact that knowledge of the regional context is crucial for implementing agricultural policies. Nevertheless, some participants subscribed to a linear understanding of the science-policy interface where they, the experts, provide policymakers with knowledge, but do not interfere in the definition of policy goals. Nevertheless, this policy sphere is defined by the importance of co-creative approaches to develop problem definitions involving all affected stakeholders (even if counter to policy agendas, to problem definitions of traditional science - this is unthinkable in health policymaking according to participants). The case of agriculture suggests that RRI should be interpreted as a middle-range concept. Effective translation of research results into practice seems successful only in areas with regional relevance, while in other cases we observe the aforementioned evidence-policy gap.

Generally, the support for, and use of, participatory approaches was highest in the field of agriculture, which was also reflected in high levels of awareness for the material needs of participants of co-creative activities on the part of researchers. Specifically, many workshop participants spoke to the importance of supplying tangible benefits to those taking part in participatory approaches, which is very close to involving stakeholders with a view towards regional implementability of policies. In this group, many researchers represented a normative reading of the RRI concept. Support for participatory approaches is founded in their direct experience: In local contexts, traditional research designs can come across as western-centred which clashes with a demand for local support and buy-in already at the stage of defining the research question. Evidently, westernised concepts of doing research can be off-putting to some groups and therefore require translation. It should be noted, however, that working regionally can sometimes create tension with participatory approaches as in some regions this is predicated upon seeking permission from some local authority.

5.5.2. SDG 3: Good Health and Well-being: Universal knowledge and social exclusion

One of the most salient issues in the health policy literature concerns the “evidence-policy gap” which describes how topical scientific expertise is not used in respective policy decisions despite its availability (Graham et al. 2006; Haines, Kuruvilla, and Borchert 2004). This problem has been described as a major obstacle in reaching SDG 3 (Panisset et al. 2012). In agriculture and climate science, awareness of a possible evidence-policy gap appears to be lower (but see e.g., Hooper, Foster, and Giles-Corti 2019).

Relationships between policymakers and researchers are described in terms of mutual misunderstanding or mistrust. Reasons are manifold and range from fundamental differences in goals and values to differences in communication style (e.g., Merlo et al. 2015). Evidence for the evidence-policy gap is mostly qualitative, building upon survey and interview data. The primary reason given for its existence is a cultural schism between academia and policy-making. The two domains are described as being fundamentally different in terms of aims, values, culture, and organisation. The preferred solution (dominant in the literature) suggests improving communication, i.e., researchers should adapt their means of approaching policymakers, and policymakers should engage more with research. Some argue that more systematic forms of exchange could enhance the uptake of health-related research and that more work is needed in translating research evidence for practitioners and health professionals.

Tools for communication and decision support were most frequently mentioned as facilitating research uptake, as well as the implementation of knowledge infrastructures to support research use and access to research evidence – e.g., centralized repositories for sharing research, access to journals and databases, and appropriate wireless access in hospitals. In passing, let us note that this argument is similar in structure to Open Science advocates suggesting that reforming science means, foremost, reforming scholarly communication. Our work suggests, further, that the depth of the gap diagnosed in the literature is rooted in a universalistic approach to knowledge: Western medicine at least appeals to a universalist conception of knowledge according to our workshop participants, which effectively shuts out any reference to local, situated knowledge. In part at least, this seems to explain the highly developed discussion in the health policy literature suggesting a gap between (abstract) knowledge and (local) implementation.

Participants were acutely aware, however, that the process of problem definition is in itself a genuinely political act, and that universalism is equally at odds with the political nature of policy work. Those who engage in such processes become political actors themselves, a role that clashes with traditional forms of scientific identity and compromises the epistemological idea of "impartial knowledge" (however flawed that assumption may be). (Cole et al. 2021: 32 f.) (Epistemological) Universalism thereby presents a challenge for participatory processes and the inclusion of situated knowledge, e.g., through inviting lay expertise into these conversations. The examples given by participants in that regard suggest that the universality of the knowledge in question might even be a consequence of exclusion processes of closing these deliberations to any other form of knowledge. In one particular example of dialogue between medical experts and other stakeholders regarding environmental factors of cancer, the deliberation process was ultimately unsuccessful as it was deemed dangerous to their reputation by medical professionals from the outset, as the latter did not want to engage in what they considered to be a legitimization of lay expertise. In this, two forms of uptake are at stake: a) uptake of knowledge (lay-knowledge, situated knowledge, to some extent medical knowledge from the fringes) and b) uptake of a specific policy goal.

Participatory approaches can likewise be repurposed by policymakers to generate legitimacy. In another example, a research team used participatory approaches to engage community members in creating situated scientific expertise so that their local knowledge could be meaningfully included in a policy-making process. Sometimes there are political advantages for elected policy-makers to embrace participation within the policy-making process. One solution to the legitimacy challenge involves framing policy work in terms of indisputable values (e.g., human rights and gender rights). Our study participants relied on a normative foundation of policy goals supplied by supranational actors such as the WHO, UNO, OECD, etc. as it was deemed impossible to set political goals without a consideration of facts (e.g., in arguments about the health and environmental risks of coal). Importantly, then, the normative grounding of policy goals is justified by ethical norms presented as "universally a common agenda" to suggest that they are beyond debate. The SDGs were found to serve a similar function in terms of legitimacy construction for policy goals (even though they are a product of (contingent) political decisions), thus underlining the key role of supranational political actors. (Cole et al. 2021: 33)

5.5.3. SDG 13: Climate Action: Global phenomena, local action

Workshop participants from the field of climate science are mostly taking a traditional academic or a multi-stakeholder approach and for the most part not using strongly participatory research design and methods. This means that in their work, though the multi-stakeholder approach broadens and diversifies the range of actors engaged in knowledge production and policy-making, they do not reach the most marginalized populations. In our sample, only researchers working in the domains of agriculture and health are doing this. Climate science can be characterised by a universalist approach to knowledge, which produces difficulties of translation into local action and explains the importance, stressed by many participants to our climate science workshop, of global policy arenas (OECD, UNO, IPCC) in defining climate policy goals and targets. Experts provide policymakers with expertise but also contribute to the formation of policy goals, e.g., by providing reflexivity and deliberation, integration of local knowledge and practice; other groups are rarely involved in this process as a matter of research design.

Climate targets are such that they can only be enforced globally. However, the relevant institutions do not have the power to enforce them. Within SDG 13, congruence of policy goals and research results is especially important; workshop participants stress how (international) climate targets often clash with other (national) policy goals such as economic growth, a dynamic that tends to affect which experts are consulted. Climate policy advice adheres to the representative democracy model of the science-policy interface in which policymakers consult with experts but no-one else. At the system level, this creates the problem of inaccessibility of the system as policymakers are difficult to persuade of the value of participatory processes. Linearity also implies problematic power dynamics i.e., political motives easily can get in the way. Within this policy area, high-level political bodies such as the UN and the OECD are important as granters of legitimacy for policy goals. The linearity of the science-policy interface also explains the observed importance of personal relationships as policymakers do not read publications, rendering the translation of results into policy briefs fundamental as research papers are deemed too complex for policymakers' needs. Nevertheless, participants in our workshop expect that participatory approaches can help to educate policymakers (e.g., the limits of modelling) while agreeing that participation of stakeholders is key not to overlook salient issues. Aside from the inaccessibility of academic literature, relationships are important because a lot of the relevant information is tacit and not accessible to those not part of the process.

The role of Open Science was considered marginal since in climate policy advice, policymakers rely on relationships and consultations, mostly, and not on academic publications. At any rate, more participation by marginalized groups was deemed desirable by participants. APCs are an issue for research that is not project related. For participants, the problem is not access but information overload. The ways in which transparency in OS may foster trust also emerged as an important theme for many participants. There was recognition that opening data may deepen trust in research for which there are perceived conflicts of interest, for instance in ensuring reporting of all medical and pharmaceutical trials including negative results. However, there are definite limits to such transparency and its effect on trust. A case reported by a workshop participant reveals tensions between transparency and trust, showing that full transparency is difficult to attain: anti-climate-change activists used the lack of (tacit) knowledge about data analysis procedures to advocate mistrust in that data. In this case, there also seemed to be a related dimension of strategic openness, wishing to maintain some competitive advantage by keeping certain methods of analysis confidential.

In summary, climate science is characterized by a gap between local action/knowledge and the global nature of climate and climate targets. In climate policy advice especially, academic credentials are important (more so than in agriculture for instance); policy advice follows certain rules that some (marginalized) populations have difficulty following (due to their social position, credibility, etc.). Congruence acts as a mediating factor in relationship-formation which is also important for policy-active researchers as they need to be aware of policy-makers' goals so they can align their strategies. Some foster the inclusion of NGOs and CSOs as a way to represent marginalized groups, but there especially, academic language acts as a barrier to improving equality of representation.

5.5.4. Summary: How does Open Science make a difference in policy-making with respect to the 3 SDGs?

In general, the role of making research openly accessible in research uptake is marginal, since policymakers predominantly rely on personal relationships or secondary summaries like policy briefs when seeking scholarly advice. Commentators of the situation point out that policymakers have to solve a twofold problem, simultaneously dealing with ambiguity (of evidence) and uncertainty (of decision making) (Cairney et al. 2016). This gap can be exploited, as evident in the vast amounts of industry-funded research sowing doubt to counter scientific evidence (e.g., tobacco, anthropogenic climate change). That being said, while our participants concurred that a potential impact of (especially) Open Access is predicated upon policymakers' getting their information from academic publications (a condition which is rarely met), the literature on the evidence-policy gap did suggest, rather very similar in spirit to discussions of Open Science uptake, that improved scholarly communication (in terms of clarity and brevity) could equally boost research uptake by policymakers, as could improved infrastructure dedicated to information management and sharing. The prevalence of the gap in health policy making, but not in the other SDG areas discussed above, suggests that the gap diagnosis constitutes a middle-range theory at best. Indeed, taken together, our findings suggest that the relationship between knowledge and implementation (evidence and policy) can be understood along the following dimensions:

1) epistemology (universalist versus situated/local),
2) frame of action (global, with a corresponding primacy of global institutions in defining policy goals, versus local/individual)
3) science-policy interface (representative, deliberative, participatory)

These findings suggest fundamental differences in importance for regional/local, national and global policy arenas in the three SDG areas under study here (which is evident in our data). The evidence-policy gap is most pronounced in health because there, a universalist epistemology meets the need to manage doctor-patient relations, creating a translation problem at the level of knowledge. In agriculture, participatory approaches dominate because regional implementation of high-level policies depends on local, situated knowledge. Finally, the situation is more vexed in climate science because climate is a global phenomenon by definition and can only be defined at a very high level, making for the importance of global institutions and the ultimate difficulties of local implementations (rendering participatory approaches rather difficult).

	Scope of Knowledge	Frame of action	Science-Policy Interface
SDG 2	Regional	National/Regional	Participatory
SDG 3	Universal	Individual	Representative/Linear
SDG 13	Universal	Global	Representative/Linear

Table 3. How knowledge and action frame impact the science-policy interface

In the broader context of the ON-MERRIT project, the consolidated results of this work package contribute to a new understanding of the role of Open Science outputs in policy-making (they are quite limited). Our findings demonstrate that systems of inequality, including racism, sexism, ageism, classism and lingering colonialism manifest in academic and policy-making contexts in ways that advantage already privileged actors while further disadvantaging those already operating at a disadvantage. Our findings indicate that women researchers in particular are practitioners of multi-stakeholder and participatory research and engaging in the science-policy interface in ways that reflect these approaches.

Our work suggests limited potential for many elements of Open Science to directly impact research uptake, with our survey confirming the literature in demonstrating the importance of policy briefs and personal connections in policy-makers' information-seeking behaviours, and the secondary importance of direct engagement with scientific literature. We therefore find that Open Access is unlikely to have a significant impact on the general uptake of scientific resources amongst policy-makers, stressing the importance of translation for research uptake.

For the case of Portugal, our work challenges the general notion of the "evidence-policy gap", especially amongst our interview cohort of policy-makers who also identify as academics. Finally, regarding the ON-MERRIT project's interest in the issue of sustainable development and the societal challenges that are implicated in the UN SDGs, our findings offer insight into how research can be designed to effectively respond to pressing on-the-ground realities and how researchers (and societal actors) can interact with policy-makers to work collaboratively toward both immediate and longer-term solutions. Based on these findings, we offer the selected recommendations to researchers, funders, and academic and scientific institutional leaders that are presently the object of a co-creative process.

6. ON-MERRIT findings on gender aspects of the transition to Open Science and RRI

6.1. Is Open Science adoption gendered?

Gender has been identified as a cross-cutting issue in science policy and Responsible Research and Innovation. Therefore, ON-MERRIT investigated how gender equality might be affected by the Open Science transition. There exists a plethora of data documenting gender stratification in academia. The kinds of challenges and biases researchers face when they take OS and RRI approaches to scientific inquiry can lead to negative career implications. There was anecdotal evidence to this effect within our data, demonstrating broader inequalities at play within academic institutions. For example, data from the US show the over-representation of men in senior career ranks and the over-representation of women in lower positions (National Center for Education Statistics 2019a). The same gender trend, only more extreme, was found in the UK (Higher Education Statistics Agency 2020) and across the EU, where women are under-represented in academic roles generally, and grossly under-represented as professors (Healy, Ozbilgin, and Aliefendiouglu 2005). These data demonstrate stratification within academia based on gender. They do not offer evidence as to why, but as with all data that document a gender bias, they suggest institutional and systemic biases that favour (white) men and disadvantage all others. Stratification across career ranks by gender directly influences the salaries and lifetime earnings that a given person, based on the intersecting nature of their race and gender, can accrue. The unequal distribution of economic rewards for conducting academic research also bears out within career ranks, where the gender pay gap is observed in the US (National Center for Education Statistics 2019b) and across the EU (CARSA 2007).

6.2. Background: Open Science adoption and gender

There is strong evidence that women are under-represented as authors in academic publishing. Larivière et al. (2013, 212) found that among articles published between 2008 and 2012 and indexed in the Web of Science databases, “women account for fewer than 30% of fractionalized authorships”. This is in line with West et al. (2013), who similarly found the share of female authorships to be slightly below 30% for data from JSTOR in the period of 2000-2009. Although female participation in terms of authorship has risen significantly, from about 10% for the period 1900-1960 (West et al. 2013, 2) to the aforementioned 30%, there remains work to do to achieve parity. Moreover, inequality persists in other aspects: women are underrepresented in terms of first authorships (Larivière et al. 2013; West et al. 2013) and last authorships in fields where the last author position signifies prestige and seniority (West et al. 2013).

Focusing on the individual level, Olejniczak and Wilson (2020) investigated author attributes related to Open Access (OA) publishing. They found a higher likelihood for male authors from prestigious institutions, with previous federal (USA) research funding, or an association with a STEM field, to publish OA in journals with an Article Processing Charge (APC). Their contribution concludes that “[p]articipation in APC OA publishing appears to be skewed toward scholars with greater access to resources and job security.” The role of institutional support in covering APCs is evidently more urgent for researchers without an affiliation to a research-oriented institution. Scholarly outlets charging APCs might preclude this growing segment of researchers from contributing to the scientific record (Gray 2020, 1673; Burchardt 2014; ElSabry 2017). Based on our analyses, publishing OA seems more common with women than with men; the share of female authors appears to be higher among OA articles than non-OA articles, while previous literature (Olejniczak and Wilson 2020) found that female authors tend to publish OA less often than men.

Gender equality in academia has been found to correlate with gender equality at the national level, with several confounding variables: Institutions in Eastern Europe and South America have a higher share of female researchers; however, this has been attributed to lower wages for jobs in academia in these regions, leading men to pursue careers in other economic sectors or in other countries (Guglielmi 2019). Further, while Eastern European countries exhibit greater gender parity overall, this has been attributed to these countries' history of communism (Larivière et al. 2013) which in turn relates to higher educational attainment among women, compared to other countries, or to further structural or cultural factors. The relationship between gender policies and outcomes in terms of gender parity is, therefore, complex and not easily distilled into recommendations for further policies. The literature review shows that gender stratification has been explored, and as described above, patterns of inequality apply even when institutions are in principle encouraging the uptake of RRI and OS.

6.3. Gendered academia: Gender stratification and Open Science uptake

With respect to academia, project findings essentially confirm existing dynamics of gender stratification in academia and suggest that Open Science's agenda of inclusivity should not stop at the reception side of academic outputs (in the form of Open Access to data and publications, say) but should look towards improving access to scientific production. In general, we found that the way OS and RRI affect research, researchers and their careers greatly varies across countries and disciplines.

Our research looked at correlations between the existence of gender equality policies and gender balance in research through the combination of MoRRI indicators and various rankings and data corpuses (The Leiden Ranking, THE World University Ranking, Microsoft Academic Graph, Unpaywall). For instance, while the UK has implemented numerous policies to promote gender equality, men still significantly outnumber women among the academic workforce. In terms of the under-representation female researchers, the situation is similar in German universities. Gender balance is better in the Czech Republic than in most other European countries; however, the country scores exceptionally poorly in the adoption of gender-focused RRI policies, and there is a substantial national gender pay gap.[10]

Our analysis of promotion, review, and tenure (PRT) policies in several countries had three aims: 1) to discover the most common institutional performance indicators, 2) to examine how research assessment indicators for career progression are used by institutions to incentivize researchers, and 3) to assess the extent to which PRT policies foster and support OS/RRI practices.

We used correlation matrices and principal component analysis to assess PRT policies, as described in D6.1 (Section 4.1), finding strong positive correlations among three gender equality indicators: 1) consideration of the candidate's gender, 2) consideration of the reviewers' gender, and 3) gender balance among reviewers. Policies referring to wider societal impact (interaction with policy-makers, industry, or the general public) tend to mention more than one of them. One third of the institutions sampled in D6.1 actively seek to promote women and minority groups (at least in cases where two candidates are equally qualified), while

[10] Note, however, that there could be a time lag here at play between an introduction of a policy and being able to observe its effects.

almost half (44.3%) actively seek the representation of women and minorities on promotion committees. However, the surveys also had a relatively high number of respondents that were unable to answer gender-related questions. This might indicate low levels of knowledge on these issues.

Respondents were also asked to reflect on the role of gender and diversity criteria in promotion decisions, reporting on a push in their respective institutions for getting underrepresented groups into leadership positions. At the same time, respondents said that criteria adjustment cannot compensate for structural inequality. Respondents pointed to the impact of gender differences upon publication patterns. Some argued that equity is not about adjusting criteria, but about opportunities to do research, making it clear that promotion criteria are merely one barrier amongst many in fostering equity in research careers.

Following Larivière et al. (2013) and West et al. (2013), we then looked into the representation of women in academic publishing, analysing, in D3.2, the gender distribution among authors across the three SDGs (agriculture, climate, health) that ON-MERRIT investigates. Authorship has been operationalized as follows: “An instance of authorship consists of a person and a paper for which the person is designated as a co-author.” (West et al. 2013, 3) Consequently, “female authorship” designates the proportion of women among designated co-authors within, e.g., a discipline/field or country.

Overall, the share of female authorship increases over time across all SDGs, while the share of female authorship was found to be lower than that of male authorship. The proportion of female authorship is highest in SDG Health/Well-Being (SDG 3) (30% in 2006, 37% in 2019), followed by SDG Zero Hunger (SDG 2) (28% in 2006, 35% in 2019), and lowest in SDG Climate Action (SDG 13) (19% in 2006, 27% in 2019). Regarding gender and author position, we found a clear gender difference between first and/or single authors and last and middle authors. Female authors are overrepresented among first authors (32%-43% in 2019, across SDGs) but underrepresented among last authors (22%-30%). When comparing the three SDGs, the gender gap remains stable over time for first authors (10-12 percentage points), but increases for last authors, where the share of female authorship grows faster in Health/Well-Being (SDG 3) than in Zero Hunger (SDG 2) and Climate Action (SDG 13). Overall, we observe an upward trend in the percentage of research outputs authored by women across the three SDGs, with the share increasing from 19-30% in 2006 to 27-37% in 2019. We found the percentage of female authorship to be highest for Health/Well-Being (SDG 3) and lowest for Climate Action (SDG 13). These findings corroborate previous results (Larivière et al. 2013; West et al. 2013). Also, in line with previous findings, we found a substantial difference in the share of female authorship in terms of authorship positions. The last position on the byline, associated with prestige or seniority in many medical and natural sciences fields (Helgesson and Eriksson 2019), has a lower share of female authorship than middle authors, while single and first author positions have a higher percentage of female authorship.

Based on our analysis of institutional Open Science and RRI policies, there appears to be a gap between outspoken appreciation of OS and concrete adoption into practice. This is especially so for OA Publishing, Research Data Management, Reproducible Research, Open Peer Review, Licensing, Citizen Science, and Gender. In particular, it seems that the responsibility for RRI-related issues is not centrally coordinated within institutions, as is usually the case with OS. Amongst the interviewees of D3.3, the awareness of RRI as a concept was relatively low, even where understanding of its individual pillars (like ethics, science communication, and gender equity, for example) is high. While this may reflect a sampling bias within our pool of interviewees, it also points to the topic’s smaller degree of institutionalization. Fostering a more coherent approach to RRI within institutions may improve recognition of this agenda.

6.4. Gender differences in information-seeking behaviours in industry

There is scant evidence of gender differences in information-seeking behaviours in industry. Of all publications we reviewed, only one (Le et al. 2016) explicitly investigated gender differences in information-seeking behaviours. Eleven of the publications reported the gender distribution of their participants. The remaining nineteen did not mention the gender distribution at all. Thus, there is a research gap with respect to gender differences in information-seeking behaviours and information needs.

We found only one study investigating gender differences in information-seeking behaviours and none investigating gender differences and Open Science uptake in industry. Analysing information-seeking behaviours of general practitioners in health care, Le et al. (2016) found that although men and women search for information equally frequently, there are gender differences regarding the selection of information sources, e.g., male practitioners prefer pharmaceutical sales representatives and non-refundable continuing medical education (CME) meetings, but are less likely to find colleagues, refundable CME meetings, guidelines and websites important. Practitioners aged above 44 are confident to retrieve information via medical journals, while younger practitioners prefer to gather information from colleagues, other medical specialists, from the College of General Practitioners guidelines, and via websites. Additionally, practitioners working in partnerships or collaborative practices are more likely to get information from other colleagues than practitioners working on their own. Further research seems warranted to analyse how gender mediates general information-seeking behaviours and the uptake of Open Science resources in particular.

We then investigated empirically whether gender has any impact upon information-seeking behaviours, finding no significant differences between men and women. To clarify, since only two women participated in the interview study, we describe in D4.2, we were unable to derive any conclusions regarding gender and information-seeking behaviours. And although 33% of the survey respondents identified as women, no statistically significant differences were found in the information-seeking behaviours of men and women. The survey results as well as the literature review, therefore, document a clear research gap regarding gender and its impact upon information-seeking behaviours.

6.5. Gender effects in scientific policy advice

Our research reported in D5.3 (Cole et al. 2021) found that gender may play a determining role in whether researchers are able to get access to policy-makers, that some researchers experience institutional marginalisation when they conduct RRI-resonant research, and that gender may play a role in shaping the inclusivity or exclusivity of research practises. To the first point, we found that women researchers have experienced gender discrimination when attempting to gain access to policy-makers for the purposes of sharing research results or engaging them in participatory research. Meanwhile, some men acknowledged that they are aware that their privilege within patriarchal cultures gives them an advantage in engaging with policy-makers. Both men and women observed that gender influences perceptions of a researcher's legitimacy, and that this happens in ways that benefit men and disadvantage women. Therefore, some women participants reported using gendered techniques, like appearing deferential, in order to engage with policy-makers who are men, particularly where an age differential is also at play.

To the second point, our research found that those who conduct RRI-resonant research, especially that which uses participatory methods and includes marginalised or disadvantaged communities, are framed within their institutions as doing "care work". This term refers to work (usually under- or unpaid) that pertains to the reproductive sphere of social life in some way (e.g., parenting or taking care of elderly relatives). Within the context of academic and research institutions, certain disciplines or fields within the social sciences, and certain methods, are often marginalised on the basis of being perceived as care work rather than “scientific” research. Therefore, researchers who conduct co-creative and participatory research face institutional biases related to their research programs, but also, insofar as they are women, they face additional institutional biases on the basis of their gender (see the stratification trends that demonstrate this in the introduction to this section). In fact, we found, within our sample, that women conducting RRI-resonant research are practising participatory methods, and therefore, they are at risk of experiencing a duality of bias within their institutions–as women but also as researchers who do “care work” (which is to say nothing of the ways in which race, ethnicity, age and sexuality intersect with gender and structure experiences of oppression).

To the third point, we found that those who embrace and articulate a feminist, post-colonial and/or participatory approach to research are doing this work in ways that truly expand and diversify their research teams and the range of participants that are invited into their work. We observed that while some men in our sample use participatory methods, only men in our sample take the traditional academic approach that does not foster the broadening of inclusion in research or policy-making. On the other hand, some of those who use participatory methods spoke of taking such approaches in order to resist the “patriarchal” institutional norms within academic and scientific communities that have historically discriminated against and marginalised women and have therefore contributed to the persistence of cumulative advantage and disadvantage.

7. Conclusions and next steps

At the outset of ON-MERRIT, a set of several interrelated questions were posed that aimed to better understand the impact of selected aspects of RRI, in particular Open Science, upon the attainment of several of the UN's sustainable Development Goals. The project looked into the implementation of OS and RRI across a range of stakeholder categories to ask whether RRI interventions might actually deepen socioeconomic inequalities (such as the digital divide) and conflict with the SDGs. This deliverable summarised the work undertaken in ON-MERRIT across the three research work packages studying the role of Open Science and RRI resources in academia, industry, and policy. To reiterate briefly, the project was organised around a set of research questions relating to the following issues pertaining to Open Science impact in research, industry, and policy-making, to determine how the attainment of three of the UN's SDGs are being shaped by the Open Science transition.

In relation to SDG2 (Zero Hunger), ON-MERRIT documents an increase in research publications between 2006 and 2019, with a significant increase in OA publications, particularly in low-income countries (while in absolute numbers, high-income countries come before low- and middle-income countries in terms of OA output). Information needs in Agriculture are often tailored to the individual farming-specific context, with information sought from family members, other growers or advisers, as well as trade literature and the internet. Our studies found social contacts were the most relevant source of information in the agricultural domain, highlighting the often-localised nature of knowledge in Agriculture. We found some evidence of use of Open-Source code and Open Data (especially weather data) amongst our interviewees. In agriculture, emphasis is on the local and regional levels of implementation as opposed to global policy arenas (WHO, UNO, etc.), which creates the difficulty of translating high-level policies into effective local action. For SDG 2, the local context and conditions vary vastly, which at the level of policy advice corresponds to a complex interplay between the regional, national, and supranational levels, creating a very specific role for supranational entities in terms of defining high-level policy goals. Agriculture is defined by the fundamental importance of local, particularistic knowledge which is difficult to reconcile with scientific (universalistic) knowledge, necessitating the inclusion of local stakeholders in the process of knowledge creation and utilisation. Therefore, participatory approaches are in high regard to foster the inclusion of local practitioners, reflective of the fact that knowledge of the regional context is crucial for implementing agricultural policies. The case of agriculture suggests that RRI (responsible research and innovation) should be interpreted as a middle-range concept.

In relation to SDG3 (Good Health and Well-Being) ON-MERRIT documents an increase in the number of publications between 2006 and 2019. In health research, information-seeking relies on a range of sources from textbooks and scientific journals to online resources. There, older cohorts somewhat prefer traditional media compared to younger cohorts, and literature/publications are the most important sources of information. Open Science is valued, although a major obstacle was that health-related Open Data is a challenge due to privacy reasons and GDPR. Trust, validation, and compliance play a major role in this regard. Patents are beginning to reference bioRxiv preprints, although not yet in great numbers. The health policy literature identifies a major obstacle to SDG3, the "evidence-policy gap", which describes how topical scientific expertise is not used in respective policy decisions despite its availability. The gap is located in a schism between academia and policy-making, two domains described as being fundamentally different in terms of aims, values, culture, and organisation. The literature suggests improving communication, i.e. researchers should adapt their means of approaching policymakers, and policymakers should engage more with research, with some advocating for more systematic forms of exchange to enhance research uptake (research translation). Tools for communication and decision support were most frequently mentioned as facilitating research uptake, as well as the implementation of knowledge infrastructures to support research use and access to research evidence (arguments similar to suggestions by advocates of Open Science). Our own work suggests that the gap is rooted in a universalistic approach to knowledge that effectively shuts out any reference to local, situated knowledge. Our work further suggests that practitioners are acutely aware that universalism is equally at odds with the political nature of policy work. Those who engage in such processes become political actors themselves, a role that clashes with traditional forms of scientific identity and compromises the epistemological idea of “impartial knowledge” (however flawed that assumption may be).

In relation to SDG13 (Climate Action), ON-MERRIT documents an increase in the number of publications between 2006 and 2019 with an average yearly growth rate of 5-7%. SDG13 exhibits a larger gap in the publishing landscape when comparing low-ranking and high-ranking institutions (relative to SDG2). With regards to Open Access publications, SDG13 has grown by over 50% from 2006 to 2018. The majority of publications emerged from high-ranked institutions. Low-income countries have a greater share for the years 2015-2018, while high income countries have a higher rate of OA publications than middle income ones. In climate research, literature/publications are the most important sources of scientific information, with some issues pertaining to using Open-Source code because of compliance concerns. Climate targets are such that they can only be enforced globally. However, the relevant institutions do not have the power to enforce them. Within SDG 13, congruence of policy goals and research results is especially important; workshop participants stress how (international) climate targets often clash with other (national) policy goals such as economic growth, a dynamic that tends to affect which experts are consulted. Climate policy advice adheres to the representative democracy model of the science-policy interface in which policymakers consult with experts but no-one else. At the system level, this creates the problem of inaccessibility of the system as policymakers are difficult to persuade of the value of participatory processes. The role of Open Science was considered marginal since in climate policy advice, policymakers rely on relationships and consultations, mostly, and not on academic publications. At any rate, more participation by marginalised groups was deemed desirable by participants. APCs are an issue for research that is not project related. For participants, the problem is not access but information overload.

In relation to gender issues, project findings essentially confirm existing dynamics of gender stratification in academia and suggest that Open Science’s agenda of inclusivity should not stop at the reception side of academic outputs (in the form of Open Access to data and publications, say) but should look towards improving access to scientific production. In general, we found that the way OS and RRI affect research, researchers and their careers greatly varies across countries and disciplines. With respect to information-seeking behaviours, there is scant evidence of gender differences. We found that gender may play a determining role in whether researchers are able to get access to policy-makers, that some researchers experience institutional marginalisation when they conduct RRI-resonant research, and that gender may play a role in shaping the inclusivity or exclusivity of research practises.

Beyond these cross-cutting issues, this report has synthesised the major findings from ON-MERRIT. We have shown the difficulties inherent in implementing Open Science and RRI across a range of contexts, including academia and its interface with industry and policy. From these diverse results, as part of a co-creative process (to be detailed in the upcoming Deliverable 6.4), ON-MERRIT identified four key threats to equity in the transition to Open Science and RRI:

- **Resource-intensity:** Existing research as well as ours shows that practicing Open Science (and the host of practices that fall under it) requires considerable resources, be they economic, institutional, or social/cultural in nature. The structural inequalities that exist within institutions, regions and nations, and on a global scale, create structural advantages for well-resourced actors and structural disadvantages for less-resourced actors, in terms of capacity and ability to engage in Open Science practices.
- **Article Processing Charges:** Existing research as well as ours shows that the article processing charge (APC) model within Open Access publishing seems to discriminate against those with limited resources (especially those from less resourced regions and institutions). Specifically, less resourced institutions have lower rates of uptake of RRI policies and practices overall, including OA publication, and more resourced institutions have higher rates of OA publication and publish in journals with higher APCs. These facts seem to be having effects of stratification in terms of who publishes where.
- **Inclusion in policy-relevant research:** Open Science and RRI both promise greater uptake of science by policy-makers and greater equality of access to processes of scientific knowledge production and policy-making. Yet, we have found that both processes take place within broader social systems within which inequalities structure access to both and privilege certain actors while disadvantaging others. Therefore, only a small fraction of the populations of researchers and broader publics have access to either, and the most marginalized, vulnerable, and poor remain mostly excluded. Contributing to this problem, we have found that institutional norms within funders and research-performing organisations often work against those who wish to broaden inclusion within knowledge production and at the science-policy interface. And, the cognitive inaccessibility of research outputs prevents use of them by policy-makers and by broader publics who may wish to engage with scientific knowledge for democratic purposes.
- **Reform of reward and recognition:** There is broad consensus that institutional norms within research-performing organizations and funders not only do not support the uptake of Open Science and RRI practices, but often get in the way of them by discouraging these in favor of traditional academic and scientific practices, which are rewarded by existing practices surrounding promotion, tenure and funding. Even when institutional policies supporting Open Science and RRI are in place, actual practices do not, for the most part, reflect them. This disadvantages those who wish to take up Open Research (putting early-career researchers especially at risk).

As its final aim, ON-MERRIT is currently working with stakeholders to co-create a set of evidence-based recommendations for funders, institutions and researchers to address and mitigate these issues. These recommendations will be made public to the research community in March 2022.

We hope that the wider Open Science community will take these criticisms in the constructive spirit in which they are meant, as a springboard to help recognise and further address such issues. As stated earlier, none of this is meant to diminish the aims of Open Science *per se* or negate the good that Open Science brings and has the potential to bring. Rather, it is to align ourselves with Fernández Pinto (2020), who questions “the particular way the ideal has been conceived and implemented by the Open Science movement, as well as the way it has been brought about through Open Science policies. In this sense, the faulty logic of open science that I aim to highlight … refers precisely to the inconsistency between the ideal and its current implementation.” Given its commonly held aim of increasing equity, any potential for Open Science to actually drive inequalities must be taken seriously by the scientific community in order to realise the aim of making science truly open, collaborative and meritocratic.

8. References

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