European Commission

ERA Monitoring Handbook

2018

Research and Innovation

EUROPEAN COMMISSION

Directorate-General for Research and Innovation
Directorate A – Policy Development and Coordination
Unit A.2 – Research and Innovation Strategy

E-mail: Arie.VAN-DER-ZWAN@ec.europa.eu

European Commission
B-1049 Brussels

EUROPEAN COMMISSION

ERA Monitoring Handbook

2018

Produced and written by

PPMI: Mantas Pupinis & Haroldas Brožaitis
Science-Metrix: David Campbell, Bastien St-Louis, Étienne Vignola-Gagné, Grégoire Côté & Éric Archambault

Version
Date: 11/30/2018

2019 Directorate-General for Research and Innovation EN

EUROPE DIRECT is a service to help you find answers to your questions about the European Union

Freephone number (*)
00 800 6 7 8 9 10 11

(*) The information given is free, as are most calls (though some operators, phone boxes or hotels may charge you)

LEGAL NOTICE

Luxembourg: Publications Office of the European Union, 2019.

PDF ISBN 978-92-79-99761-7 doi:10.2777/764148 KI-01-19-102-EN-N

CONTENTS

TABLES ..... **IV**

ACRONYMS ..... **V**

1 GENERAL INTRODUCTION **1**

1.1 AIM AND SCOPE 1
1.2 HISTORY AND BACKGROUND OF THE ERA PROGRESS REPORT 2
1.3 STRUCTURE OF THE HANDBOOK 3

2 INDICATORS **4**

2.1 ESFRI 6
2.1.1 P2b – Headline indicator – Availability of national roadmaps with identified ESFRI projects and corresponding investment needs 7
2.1.2 P2b – EMM indicator – Share of developing ESFRI Projects in which a Member State or an Associated Country participates 7
2.1.3 P2b – EMM indicator – Share of operational ESFRI Landmarks in which a Member State or an Associated Country is a partner 8
2.1.4 P2b – EMM indicator – Share of developing ESFRI project and operational ESFRI Landmarks in which a Member State or an Associated Country is a partner 9
2.2 EURAXESS PORTAL 10
2.2.1 P3 – Headline indicator – Number of researcher postings advertised through the EURAXESS job portal, per 1 000 FTE researchers in the public sector (2012-2016) 10
2.3 EUROPEAN COMMISSION, JOINT RESEARCH CENTRE, COMPETENCE CENTRE ON COMPOSITE INDICATORS AND SCOREBOARDS (JRC-COIN) 11
2.3.1 P1 – Headline indicator – Adjusted Research Excellence Indicator (AREI) 11
2.4 EUROPEAN INNOVATION SCOREBOARD (EIS) 12
2.4.1 P1 – EMM indicator – European Innovation Scoreboard Summary Innovation Index (SII) 12
2.4.2 P5a – EMM indicator – Number of public-private co-publications per million population 13
2.4.3 P6 – EMM indicator – Exports of medium and high technology products as a share of total product exports 14
2.4.4 P6 – EMM indicator – Knowledge-intensive services exports as % of total services exports 14
2.5 EUROSTAT 15
2.5.1 P1 – EMM indicator – GBARD as a percentage of GDP 15
2.5.2 P2a – Headline indicator – GBARD allocated to transnational cooperation per researcher in the public sector 16
2.5.3 P3 – EMM indicator – Share of doctoral candidates with a citizenship of another EU Member State 18
2.5.4 P4 – EMM indicator – Share of female PhD graduates 19
2.5.5 P5a – Headline indicator – Share of product and/or process innovative firms cooperating with higher education institutions or public/private research institutions 20
2.5.6 P5a – EMM indicator – Share of public research financed by the private sector 22
2.5.7 P6 – EMM indicator – Non-EU doctorate students as a share of all doctorate students 24
2.6 THIRD ERA-LEARN 2020 ANNUAL REPORT ON P2P PARTNERSHIPS 25
2.6.1 P2a – EMM indicator – Member States participation in Public-to-public partnerships per researcher in the public sector 25
2.7 MORE2 AND MORE3 SURVEYS 26
2.7.1 P3 – EMM indicator – Share of researchers expressing satisfaction that the hiring procedures in their institution are open, transparent and merit-based 26
2.8 SHE FIGURES 28
2.8.1 P4 – Headline indicator – Share of women in grade A positions in HES 28
2.9 WEB OF SCIENCE™ (WOS™) 29
2.9.1 P2a – EMM indicator – International co-publications with ERA partners per 1 000 researchers in the public sector 29
2.9.2 P4 – EMM indicator – Gender dimension in research content 30
2.9.3 P5b – Headline indicator – Share of publications available in open access 32
2.9.4 P5b – EMM indicator – Share RFOs' (i.e. members of Science Europe or other important sources of national funding) publications that are available in OA 35
2.9.5 P5b – EMM indicator – Share of life sciences papers to which a country contributed and that have at least one open dataset in Figshare 36

2.9.6 P6 – Headline indicator – International co-publications with non-ERA partners per 1 000 researchers in the public sector 37
2.10 DIRECTORY AND REGISTRY OF OPEN ACCESS POLICIES (MELIBEA & ROARMAP) 38
2.10.1 P5b – EMM indicator – RFOs (i.e. members of Science Europe or other important sources of national funding) providing funds to cover costs of OA publishing as of August 2018 38
3 GENERAL APPROACH TO THE ANALYSIS AND PRESENTATION OF QUANTITATIVE INDICATORS 40
4 ADDITIONAL RELEVANT DETAILS 45
5 QUALITY PLAN: VERIFICATION AND VALIDATION OF DATA 51
6 DESK RESEARCH AND DOCUMENT REVIEW 57
6.1 CODING FRAMEWORK FOR SOFTWARE-SUPPORTED DESK RESEARCH 58
7 INTERVIEWS 62
7.1 INTERVIEW QUESTIONNAIRE FOR RFOS, RPOS AND STAKEHOLDER ORGANISATIONS 62
8 ASSESSMENT OF PROGRESS OF IMPLEMENTATION ON THE BASIS OF THE NATIONAL ACTION PLANS 71
ANNEX 1: LIST OF KEY TERMS 73
ANNEX 2: INDEX LIST OF INDICATORS 75
REFERENCES 77

TABLES

TABLE 1 MATRIX OF HEADLINE AND COMPLEMENTARY EMM INDICATORS 6
TABLE 2 SAMPLE TABLE SHOWING THE PRESENTATION LAYOUT USED TO REPORT THE DATA FOR EACH INDICATOR — GBARD AS A PERCENTAGE OF GDP (2009–2016) 44
TABLE 3 LIST OF POSSIBLE BIASES APPLICABLE TO THE HEADLINE AND EMM COMPLEMENTARY INDICATORS 46
TABLE 4 MATRIX OF HEADLINE AND COMPLEMENTARY EMM INDICATORS WITH POTENTIAL BIAS(ES) IDENTIFIED 47
TABLE 5 DIMENSIONS OF THE DATA QUALITY FRAMEWORK 52
TABLE 6 LIST OF COHERENCE CHECKS 54
TABLE 7 INCOHERENCE FOR SUM OF TRANSNATIONAL AND MULTILATERAL PUBLIC R&D (GBA_TNCOOR), IN MILLION EURO 55
TABLE 8 INCOHERENCE FOR SUM SECTOR (SECTPERF) (RD_E_GERDFUND) 56
TABLE 9 DATA SOURCE EXTRACTION DATES 57
TABLE 10 MAIN SOURCES USED IN THE DESK RESEARCH AND DOCUMENT REVIEW 58

ACRONYMS

AC	Associated Country
A&HCI	Arts & humanities citation index
BES	Business enterprise sector
CAGR	Compound annual growth rate
CWTS	Centre for science and technology studies, Leiden University
DG	Directorate-General
ERA	European Research Area
ERAC	European Research Area Committee
ERC	European Research Council
EMM	ERA monitoring mechanism
ESFRI	European Strategy Forum on Research Infrastructures
FTE	Full-time equivalent
GBARD	Government budget allocations for R&D
GDP	Gross domestic product
GDRC	Gender dimension in research content
GOV	Government sector
HEI	Higher education institution
HES	Higher education sector
HS	Health science
ISCED	International standard classification of education
JPI	Joint programming initiatives
JRC-COIN	Joint research centre, competence centre on composite indicators and scoreboards
MORE	Mobility and career paths of researchers in Europe
MS	Member State
NAP	National action plan
NSE	Natural sciences and engineering
OA	Open access
OECD	Organization for Economic Cooperation and Development
P2P	Public to public
PRI	Private research institute
REI	Research excellence indicator
RI	Research infrastructure
R&D	Research and development
R&I	Research and innovation
RFOs	Research funding organisations
RPOs	Research performing organisations
SCI Expanded	Science citation index expanded
SI	Specialisation index
SII	Summary innovation index
SSCI	Social sciences citation index

SSH	Social sciences and humanities
S&T	Science and technology
WiS	Women in science
WoS™	Web of Science™ database (by Clarivate Analytics)

1 GENERAL INTRODUCTION

The European Research Area (ERA) Monitoring Handbook of Indicators has been developed to accompany the 2018 ERA Monitoring Report. It provides guidance on the theoretical underpinnings, the collection of data and the calculation of all indicators presented in the main report and the individual country profiles. Also included is a discussion of any pertinent considerations for the use of data on progress towards the common ERA at the organisational, Member State/Associated Country and/or European level.

Current version of the handbook - ERA Monitoring 2018

The 2018 ERA Monitoring Report gathers, systematises and analyses internationally comparable data and indicators to monitor, at the pan-European level, progress towards a common ERA since its last monitoring in 2016. It covers a wide range of themes, aligned with the six key priorities underpinning the achievement of the ERA (European Commission, 2012, ERAC Secretariat, 2015b), including indicators on the effectiveness of national research systems, optimal transnational cooperation and competition, the openness of labour markets for researchers, gender equality and gender mainstreaming in research, optimal access to and circulation and transfer of scientific knowledge, including via digital ERA and international cooperation. The ERA Progress Report provides a crucial evidence base for policies in these areas.

Multiple lines of evidence have been used to triangulate the findings: the compilation of quantitative data, a desk research and document review, interviews, as well as an assessment of progress of implementation on the basis of the National Action Plans (NAPs). This Handbook serves as a resource detailing the relevant guidelines for the collection of quantitative and qualitative data pertaining to relevant information in implementing the ERA Monitoring Mechanism. Upon future developments and new additions to the ERA Monitoring Mechanism (EMM), the data collection instruments included in the Handbook will be revised accordingly. As such, it is designed to reflect the state of the art in the mapping and monitoring of the ERA.

1.1 Aim and scope

Aim

This Handbook aims to provide specific guidelines and recommendations concerning the necessary data and indicators for monitoring progress around the six ERA priorities for each Member State/Associated Country at country and organisational level.

In particular, the Handbook promotes cross-country uniformity in terms of data collection, indicator computation and data-validation procedures. Furthermore, it provides interested stakeholders with detailed information on the data needed to examine multiple dimensions of progress in the six key priorities underpinning the ERA. It serves as a reference document and provides users with the methods needed to undertake the following:

- Calculate the indicators, so as to increase consistency of ERA monitoring indicators across countries and time periods
- Analyse and synthesise the collected quantitative data
- Assess and ensure the quality of the collected quantitative data
- Conduct the desk research and document reviews required to gather the qualitative information intended to clarify the quantitative findings
- Conduct interviews with relevant stakeholders to complement the information gathered in the desk research and document reviews
- Conduct an assessment of progress of implementation on the basis of the National Action Plans (NAPs)

Scope

The Handbook is not intended to be specific to any version of the ERA Progress Reports. However, some indicators are added or replaced from one version to another. It remains nevertheless a live document intended to be used as the basis for the computation of indicators in current and future versions of the ERA Progress Report.

The analysis of ERA progress in this study covers a timespan of approximately 10 years (2007-2017). Data from all 28 EU Member States and 16 Associated Countries have been used to examine progress at the European, regional, country and organisational levels. In addition to analysis of indicators foreseen in the ERA Monitoring Mechanism, this report is the first one to assess the progress of implementation of the National Action Plans adopted by ERA countries. The evidence base presented in this report is expected to support ongoing policy developments and efforts towards the improved implementation of ERA.

Current version of the Handbook

Although intended to act as a stand-alone document (i.e., untied to any of the specific versions of the ERA Progress Report), the current version of the Handbook was created to accompany the 2018 edition of the publication and thus includes some details specific to that edition. In the 2018 version, data are presented at the individual country (Member States and Associated Countries) level and the broader EU level for the current 28 EU Member States.

1.2 History and background of the ERA Progress Report

History

The ongoing European Research Area (ERA) Monitoring Mechanism aims to document and assess the recent progress in the ERA implementation process, while taking into account changes both in the key ERA priorities and in the corresponding responsibilities and actions of the ERA Partnership actors — the European Commission, the Member States and the Associated Countries, research funding and research performing organisations. As such, the overarching objective of this year's report is to assist the European Commission in implementing the 2018 ERA Monitoring Mechanism to assess the recent progress made towards achieving six ERA priorities.

Since the ERA's conception in 2000, the EU Member States and Associated Countries have made substantial progress on the implementation of relevant policies and initiatives, and the conditions for the completion of the ERA are now in place. Yet continuous progress requires balancing efforts and speeding up the pace of implementation among the various actors. For example, a 2014 analysis of the state of play in each Member State and a selection of Associated Countries highlighted that only half of the Member States had implemented measures to at least a medium degree, and that progress was particularly slow regarding gender issues in research. Additionally, regional differences in implementation were identified among Western European countries, which fared better than Central and Eastern European Member States. Notably, the distinction between Member States and Associated Countries did not appear to be relevant.

The European Council has declared that realising the ERA necessitates the monitoring of progress in close connection with the European Semester and invited the European Commission to establish such a monitoring mechanism. Consequently, the EMM was developed by the European Commission in close collaboration with Member States, with the aim of assessing compliance to the ERA at the levels of national and regional policies, RFOs and RPOs.

In this context, in September 2013, the European Commission published the results of the first ERA Progress Report, which presented an overview of the political context, actions taken and recent progress towards achieving the ERA. The report was accompanied by the ERA Facts and Figures report, where the state of play in each of the ERA priorities in EU Member States and Associated Countries were presented, with more detail on the situation in each country presented in 'country fiches'. The 2014 and 2016 ERA Progress Reports followed a similar structure and approach to the 2013 version; however, they included some important adaptations and additions, such as the state of play of support provided by RFOs for the adoption of ERA measures. The ERA progress reports have been produced using qualitative and quantitative information from various sources, including, but not limited to, information contained in National Reform Programmes, results from ad hoc ERA surveys, official internationally comparable statistics from Eurostat, and measures identified by the Institute for Prospective and Technological Studies of the Joint Research Centre.

Building on the monitoring approach suggested by the ERA Progress Report 2016 and using multiple lines of evidence to triangulate the findings, the study team gathered, coded, structured and analysed internationally comparable data and indicators to monitor progress in the implementation of the six ERA priorities. The primary focus of this study is on the quantitative headline and complementary ERA Monitoring Mechanism indicators identified by the European Research Area and Innovation Committee (ERAC). The quantitative findings have been enriched by substantial

qualitative data collected through document review and interviews with key stakeholders across national and sectoral contexts within ERA.

For the first time, this ERA Progress Report 2018 has also provided an assessment of progress with implementation of the National Action Plans. The study found that the following group of countries has progressed substantially with the implementation of their NAPs: Austria, Belgium, Finland, France, Ireland, the Netherlands, Norway, Switzerland and the United Kingdom. Among other things, this was also due to establishing very tangible objectives, which were possible to measure and follow-up. The majority of countries fell into the group, which managed to achieve around half of the objectives indicated in their respective NAPs (medium progress): Czech Republic, Denmark, Estonia, Germany, Greece, Italy, Latvia, Luxembourg, Malta, Portugal, Romania, Slovenia and Spain. NAPs of these countries tended to be well-written with tangible objectives, however, they have achieved less progress in our view mainly due to low status of the NAP as a strategic document in these countries. A positive finding was that the majority of NAPs were clearly structured according to ERA priorities, which means that the ERA countries do think and plan in terms of EU-level objectives aimed at achieving ERA. This can be seen as a clear success of the whole ERA implementation process.

While mainly building on the methodology developed for the 2016 Progress Report, the 2018 report has also dropped the so-called "composite" indicators due to difficulties in interpreting them.

Data in the ERA Progress Report

A portion of the ERA Progress Report is dedicated to reporting back on a core set of indicators, elucidated throughout by qualitative information gathered through document reviews, interviews and an assessment of progress of implementation on the basis of the National Action Plans (NAPs). This portion serves as the foundation for exposing progress at the organisational and national levels toward the common ERA. However, each year, the ERA Progress Report builds on previous versions by improving on the definition of indicators, introducing new indicators where there is a need, or refining the scope of the methods and approaches used for data collection and analysis.

1.3 Structure of the Handbook

The Handbook of Indicators on ERA monitoring is made up of eight sections and three annexes:

- The first (current) section provides a brief overview of the aim and scope of the Handbook, as well as a background to the ERA priorities and progress.
- The second section describes all indicators used in the ERA Monitoring publication, including definitions, rationale and computation method (with the necessary data, data source, formulas and any calculation specifications or comments that may be of relevance). The indicators are organised by the data source of their numerator.
- The third section describes the general approach used to analyse and present quantitative indicators, in particular the analysis of progress towards achieving the ERA.
- The fourth section provides relevant details concerning the indicators (e.g., limits and possible biases)
- The fifth section details the general quality plan of the ERA Monitoring publication, focusing on the methodological principles employed in the verification and validation of data.
- The sixth section presents the approach taken to conduct the desk research and document reviews.
- The seventh section presents the approach taken to conduct interviews with relevant ERA stakeholders.
- The eight section presents the approach taken to assess progress of implementation on the basis of the National Action Plans (NAPs).
- The first annex provides an overview of how key terms are defined.
- The second annex provides lists of the indicators sorted by priority, type (Headline, EMM, etc.) and alphabetical order.

The sections and annexes are followed by the bibliography.

2 INDICATORS

In May 2015, the consulting group ICF International (henceforth referred to simply as ICF) performed an appraisal of available or potential indicators and proposed a core set of 22 indicators with which to monitor progress across ERA priorities (ICF International, 2015). Building on ICF's work, the European Research Area and Innovation Committee (ERAC) selected eight core high level indicators (one per priority, or sub-priority for Priorities 2 and 5) that are regarded as being the most relevant in monitoring progress in achieving the ERA (ERAC Secretariat, 2015b). In addition to these Headline indicators, the ERAC selected two complementary ERA Monitoring Mechanism (EMM) indicators per priority (including the sub-priorities for priorities 2 and 5; selected at an ad hoc workshop of the ERAC in March 2016) for a total of 24 EMM indicators (including the Headline indicators). Table 1 lists the Headline and EMM indicators for each priority. Note that some of the complementary indicators for priority 5 and priority 6 are different from the ones originally selected by the ERAC, and that some indicators have been updated, modified or replaced due to changes and discontinuities in data collection.

A first modification was introduced for the complementary EMM indicators of Priority 2b (Make optimal use of public investments in research infrastructures). Here, findings are now provided on a combined indicator that better illustrates how level of engagement in ESFRI developing Projects and Landmarks are connected rather than independent.

For the headline indicator of Priority 5a, the underlying data coming from Eurostat was for the first time aggregated in a manner that made it possible to present a single metric (in terms of performance) merging both of its underlying dimensions ([1]); that is the share of product and/or process innovative firms cooperating with 1) universities or higher education institutions, or 2) with government, public or private research institutes. For growth, these two dimensions still had to be kept separated in this edition.

The indicators on the share of a country's peer-reviewed scientific papers that are available in Open Access (i.e. Total, Gold and Green OA) in Priority 5b have all been impacted by a revised definition of what constitute Green Open Access papers (see Section 2.9.3 for a description of this change). The indicator on the inclusion of OA policies in RIO policy repositories was discontinued since the new reporting guidelines for RIO policy reports no longer ask the experts to report on OA specifically. It has been replaced by a qualitative assessment of the NAPs and other information sources. New indicators were also added to Priority 5B to fill a data gap in the 2016 ERA Progress Report; no data was available in 2016 for the share of research funding organisations (RFOs) that provide funds to cover the costs of making publications available in OA and the share of research performing organisations (RPOs) making their research data available in OA. The share of research funding organisations (RFOs) that provide funds to cover the costs of making publications available in OA has been replaced by an identification of the RFOs (i.e. members of Science Europe or other important sources of national funding) that provide funds to cover costs of OA publishing along with an estimation of the share of the papers they supported that are available in OA. The share of research performing organisations (RPOs) making their research data available in OA has been replaced by the share of life sciences papers to which a country contributed and that have at least one open dataset in Figshare.

Due to discontinued data, the indicator on "Licence and patent revenues from abroad as a share of GDP" in Priority 6 has been replaced by two new indicators: "knowledge intensive services exports as percentage of total services exports" and "exports of medium and high technology products as a share of total product exports"; this modification coincides with a similar replacement in the 2018 European Innovation Scoreboard (EIS). Changes in the data for some countries also led to changes in EU28 aggregate scores the following two indicators: the share of doctoral candidates with a citizenship of another EU Member State (Priority 3) and non-EU doctorate students as a share of all doctorate students (Priority 6). Additional modifications in the approach used in computing EU-28 aggregate scores (e.g. imputation of missing data) led to some changes in the GBARD (EUR) allocated to Europe-wide transnational, as well as bilateral or multilateral, public R&D programmes per FTE researcher in the public sector (Priority 2a).

[1] The new aggregation provided by Eurostat enabled this change by removing duplicated count of firms falling in both types of partnerships.

Finally, the composite indicators combining findings from headline and complementary indicators within and across ERA priorities have not be computed in the 2018 ERA monitoring exercise.

The following sub-sections present the indicators according to the data source used for their computation. Refer to Annex 2 for a complete list of the indicators covered in this Handbook, sorted by priority, type (Headline or EMM) and alphabetical order.

Table 1 Matrix of Headline and complementary EMM indicators

Priority	Input Indicator	Output Indicator	Outcome/Impact Indicator
Priority 1: More effective national research systems	GBARD as percentage of GDP (Eurostat)	Adjusted Research Excellence Indicator (REI) (source: JRC)	European Innovation Scoreboard Summary Innovation Index (SII) (source: EIS)
Sub-priority 2a: Optimal transnational cooperation	Member States participation in public-to-public collaborations per FTE researcher in the public sector (Eurostat and ERA-Learn 2020 report on P2P)	GBARD allocated to Europe-wide transnational, as well as bilateral or multilateral, public R&D programmes per FTE researcher in the public sector (Eurostat)	International co-publications with ERA partners per 1 000 researchers in the public sector (WoS and Eurostat)
Sub-priority 2b: European Strategy Forum on Research Infrastructures (ESFRI)	Share of developing ESFRI Projects in which a Member State or an Associated Country participates (ESFRI)	Availability of national roadmaps with identified ESFRI projects and corresponding investment needs (ESFRI)	Share of operational ESFRI Landmarks in which a Member State or an Associated Country is a partner (ESFRI)
Priority 3: Open Labour Market for Researchers	Share of doctoral candidates with a citizenship of another EU Member State	Researcher's posts advertised through the EURAXESS job portal per 1 000 researchers in the public sector (EURAXESS and Eurostat)	Share of researchers expressing satisfaction that the hiring procedures in their institution are open, transparent and merit-based (MORE2 and MORE3 Survey)
Priority 4: Gender equality and gender mainstreaming in research	Share of female PhD graduates (Eurostat)	Gender dimension in research content (WoS)	Share of women in grade A positions in HES (WiS—Women in Science database)
Sub-priority 5a: Knowledge circulation	Share of product and/or process innovative firms cooperating with higher education institutions or public/private research institutions (Eurostat)	Share of public research financed by the private sector (Eurostat)	Number of public–private co-publications per million population (EIS)
Sub-priority 5b: Open access	RFOs providing funds to cover costs of OA publishing and share of RFOs' publications available in OA* Share of life sciences papers to which a country contributed and that have at least one open dataset in Figshare*	Share of publications available in open access (green and gold) (1findr and WoS)	Qualitative assessment of OA policies in NAPs and other information sources*
Priority 6: International cooperation	International co-publications with non-ERA partners per 1 000 researchers in the public sector (WoS and Eurostat)	Non-EU doctorate students as a share of all doctorate students (Eurostat)	Exports of medium and high technology products as a share of total product exports* and Knowledge-intensive services exports as percentage of total services exports* (EIS)

Note: The cells in light green represent Headline indicators while the cells in light grey hold EMM complementary indicators. For a discussion of the biases affecting the Headline and EMM complementary indicators, refer to Table 4 of the 2018 ERA Monitoring Handbook (Section 4).
* Due to data limitation, the indicators identified by an * replace the indicators originally identified by the ERAC. Refer to section 2 of the 2018 ERA Monitoring Handbook for full details on these indicators including the rationale behind the changes.

Source: Assembled by Science-Metrix from ERAC documentation

2.1 ESFRI

National roadmaps form part of the European Strategy Forum on Research Infrastructures (ESFRI) and are the blueprints for the setting of national priorities and funding strategies for pan-European research infrastructure activities. The ESFRI is a forum comprising EU Member States (MS) and Associated Countries (AC) that supports and guides policy relating to research infrastructures in

Europe. It also aims to encourage the effective use of research infrastructures through collaboration between EU countries and internationally. In 2012, the mandate of the ESFRI was expanded to include support for the implementation of projects and to maintain Europe's leadership role in research and innovation. ESFRI Member States have been encouraged to link national roadmaps to the European ESFRI roadmap in an effort to better allocate resources and efforts.

2.1.1 P2b – Headline indicator – Availability of national roadmaps with identified ESFRI projects and corresponding investment needs

Definition of indicator

This indicator presents the availability of national roadmaps for research infrastructures for each Member State and assesses if the national roadmap contains identified ESFRI projects with corresponding investment needs.

Rationale

This indicator pertains to sub-priority 2b (ESFRI), which aims to improve the effectiveness with which ESFRI regional and national research infrastructures (RIs) of pan-European interest are financed and shared across all MS/AC. It serves as a measure of the presence and comprehensiveness of national roadmaps and compliance to the request made by the European Commission for Member States to link their roadmaps to the ESFRI roadmap (European Commission, 2012). This relates to the key priority of increasing the effectiveness of investments in and use of RIs identified by the European Commission for the reinforcement of the ERA (European Commission, 2012).

Computation method

Data needed

(NRM)	National roadmap document
(RM)	ESFRI Roadmap

Source of data

For national roadmaps: *ESFRI website*

(https://ec.europa.eu/research/infrastructures/index_en.cfm?pg=esfri-national-roadmaps)

Specifications

This indicator reports three dimensions: the year that the roadmap was published (or latest update), a binary value (yes/no) if the roadmap identifies ESFRI projects and another binary value (yes/no) about the roadmap identification of funding requirement for ESFRI projects.

Comments/critical issues

Note that not all MS/AC have submitted a national roadmap to ESFRI (BE, CY, LV, LU, MT, SK, AL, AM, BA, FO, MK, GE, IS, MD, RS, TR, TN and UA are missing) and the last update varies from 2007 to 2018.

2.1.2 P2b – EMM indicator – Share of developing ESFRI Projects in which a Member State or an Associated Country participates

Definition of indicator

This indicator is the proportion of ESFRI projects in which a given country participates.

Rationale

This indicator pertains to sub-priority 2b (ESFRI) and relates to financial commitments for the construction and operation of ESFRI, national and regional research infrastructures (RIs) to improve access to RIs of pan-European interest. In an increasingly competitive, globalised and knowledge-based economy, the goal of ESFRI is to fully exploit the Member States' potential for scientific and technological innovation by structuring their research objectives, developing common protocols,

sharing expertise, fostering multidisciplinarity and maintaining competitiveness (ESFRI, 2016). Member States are therefore encouraged to take part in ESFRI projects, that is, early development phase projects aiming to establish RIs.

Computation method

Data needed

(PROJ) Number of ESFRI projects in which the country is participating in: **Unit=Total**;

($PROJ_{TOT}$) Total number of ESFRI projects: **Unit=Total**.

Source of data

ESFRI Executive Secretary

Specifications

$$Share\ (\%)\ of\ ESFRI\ projects\ in\ which\ the\ country\ participates = \frac{PROJ}{PROJ_{Tot}} \times 100$$

EU-28 computation

The EU-28 score is computed as an average of the MS scores.

Comments/critical issues

Between 2016 and 2018, eight developing ESFRI Projects became Landmarks and five new Projects were initiated. There was a total of 21 developing ESFRI Projects and 29 operational ESFRI Landmarks in 2016. For 2018, there were 18 Projects and 37 Landmarks. Note that since a country's participation in ESFRI Projects that matured into ESFRI Landmarks since 2016 might not have been renewed by participation in new projects, it is possible for this country's share of ESFRI Project participations to have decreased in absolute and relative terms. In such cases, care was taken not to conclude too rapidly to a disinvestment in RIs since the decrease in project participations simply reflects maturation into implementation phase projects in which a country is a partner. This was done by computing a combined indicator (Section 2.1.4) that better illustrates how level of engagement in ESFRI developing Projects and Landmarks are connected rather than independent. Note that using the total number of ESFRI Projects across countries as the denominator introduces a bias in favour of larger economies (e.g. the UK, Germany, France). Future editions of the ERA Progress Report should consider using the GDP or GBARD of countries as a denominator for this indicator.

2.1.3 P2b – EMM indicator – Share of operational ESFRI Landmarks in which a Member State or an Associated Country is a partner

Definition of indicator

This indicator is the proportion of ESFRI landmarks in which a given country is a partner.

Rationale

This indicator pertains to sub-priority 2b (ESFRI) and relates to financial commitments for the construction and operation of ESFRI, national and regional research infrastructures (RIs) to improve access to RIs of pan-European interest. In line with the previous indicator on ESFRI projects, ESFRI landmarks are successfully implemented ESFRI projects that are delivering science services or effectively advancing in their construction (ESFRI, 2016).

Computation method

Data needed

(LAND) Number of ESFRI landmarks in which the country is a partner: **Unit=Total**;

($LAND_{TOT}$) Total number of ESFRI landmarks: **Unit=Total**.

Source of data

ESFRI Executive Secretary

Specifications

$$Share\ (\%)\ of\ ESFRI\ landmarks\ in\ which\ the\ country\ is\ a\ partner = \frac{LAND}{LAND_{Tot}} \times 100$$

EU-28 computation

The EU-28 score is computed as an average of the MS scores.

Comments/critical issues

Observer countries are not counted as partner countries on Landmarks. Between 2016 and 2018, eight developing ESFRI Projects became Landmarks and five new Projects were initiated. There was a total of 21 developing ESFRI Projects and 29 operational ESFRI Landmarks in 2016. For 2018, there were 18 Projects and 37 Landmarks. Note that since the denominator of this indicator (total number of landmarks across countries) increased between the 2016 and 2018 assessments, it is possible that a country's relative participation to landmarks decreased even though the number of landmarks to which it participated remained constant between 2016 and 2018. Care was taken to highlight such cases in the ERA Progress Report. Note that using the total number of ESFRI Landmarks across countries as the denominator introduces a bias in favour of larger economies (e.g. the UK, Germany, France). Future editions of the ERA Progress Report should consider using the GDP or GBARD of countries as a denominator for this indicator.

2.1.4 P2b – EMM indicator – Share of developing ESFRI project and operational ESFRI Landmarks in which a Member State or an Associated Country is a partner

Definition of indicator

This indicator is the proportion of ESFRI project and landmarks in which a given country is a partner.

Rationale

This indicator pertains to sub-priority 2b (ESFRI) and relates to financial commitments for the construction and operation of ESFRI, national and regional research infrastructures (RIs) to improve access to RIs of pan-European interest. Tracking the total share of ESFRI projects and ESFRI landmarks allows for a more complete assessment of a country participation to research infrastructures than tracking the projects and landmarks individually. This is because ESFRI projects eventually mature into ESFRI Landmarks and a decrease in the former can be explained by an increase in the latter.

Computation method

Data needed

(PROJ_LAND) Number of ESFRI projects plus the ESFRI landmarks in which the country is a partner: **Unit=Total**;

(PROJ_LAND $_{TOT}$) Total number of ESFRI projects and landmarks: **Unit=Total**.

Source of data

ESFRI Executive Secretary

Specifications

$$Share\ (\%)\ of\ ESFRI\ landmarks\ in\ which\ the\ country\ is\ a\ partner = \frac{PROJ\_LAND}{PROF\_LAND_{Tot}} \times 100$$

EU-28 computation

The EU-28 score is computed as an average of the MS scores.

Comments/critical issues

Observer countries are not counted as partner countries on Landmarks. Between 2016 and 2018, eight developing ESFRI Projects became Landmarks and five new Projects were initiated. There was a total of 21 developing ESFRI Projects and 29 operational ESFRI Landmarks in 2016. For 2018, there were 18 Projects and 37 Landmarks. Note that using the total number of ESFRI Projects and Landmarks across countries as the denominator introduces a bias in favour of larger economies (e.g. the UK, Germany, France). Future editions of the ERA Progress Report should consider using the GDP or GBARD of countries as a denominator for this indicator.

2.2 EURAXESS Portal

EURAXESS is a pan-European initiative providing a diversity of support services to assist researchers in their career development in Europe or in maintaining their connection to European research. As part of the EURAXESS initiative, a job portal provides easy access to all open job offering throughout the ERA ([2]).

2.2.1 P3 – Headline indicator – Number of researcher postings advertised through the EURAXESS job portal, per 1 000 FTE *researchers in the public sector (2012-2016)*

Definition of indicator

This indicator is the ratio of the number of researcher posts advertised through the EURAXESS job portal to the number of researchers in the public sector.

Rationale

This indicator pertains to priority 3 (open labour market for researchers) and measures active international recruitment efforts by a given country's institutions. This relates to the goal of creating an open labour market for researchers established by the Commission for reinforcing the European Research Area (European Commission, 2012). Evidence suggests that researchers who have moved internationally have a greater research impact than those who have not and that countries with more open research systems perform better in terms of innovation (DG Research and Innovation, 2014). It is therefore interesting to monitor the effort made by a MS/AC to recruit international researchers. The indicator is normalised by 1 000 researchers (FTE) in the public sector in order to allow for a better comparison between MS/AC.

Computation method

Data needed

(RPA) Number of researcher's posts advertised through the EURAXESS job portal: **Unit=Total**;

(RES_{HES}) Researchers in the higher education sector: **Unit=Full time equivalent (FTE)**;

(RES_{GOV}) Researchers in the government sector: **Unit=Full time equivalent (FTE)**.

Source of data

For *(RPA)*: *the European Commission provided historical data from the EURAXESS portal;*

For *($RES_{HES\ or\ GOV}$)*: *Eurostat—Statistics on research and development (online data code rd_p_persocc).*

Filters applied

For *(RES_{HES})*: *SECTPERF set to "Higher education sector"*
PROF_POS set to "Researchers"

[2] http://ec.europa.eu/euraxess/

SEX set to "Total"
UNIT set to "Full-time equivalent (FTE)"

For *(RES_{GOV})*: *SECTPERF set to "Government sector"*
PROF_POS set to "Researchers"
SEX set to "Total"
UNIT set to "Full-time equivalent (FTE)"

Specifications

$$Researcher's\ posts\ advertised\ through\ the\ EURAXESS\ job\ portal\ per\ 1\,000\ researchers\ in\ the\ public\ sector = \frac{RPA}{(RES_{HES} + RES_{GOV})/1000}$$

EU-28 computation

(RPA) Sum of the 28 MS job postings

(RES_{HES}) & (RES_{GOV}) European Union (current composition) score from Eurostat table *rd_p_persocc*.

Malta's EURAXESS researcher job posts are missing in the numerator for years 2013-2015. This has a negligible impact given Malta's very low number of RPAs.

Comments/critical issues

None identified.

2.3 European Commission, Joint Research Centre, Competence Centre on Composite Indicators and Scoreboards (JRC-COIN)

The JRC-COIN of the European Commission develops and implements various methodologies to produce composite indices summarising multi-dimensional phenomenon into simplified pictures. These simplified pictures convey key messages to decision makers on key European issues, thereby assisting the development of policies and the monitoring of progress towards key objectives ([3]).

2.3.1 P1 – Headline indicator – Adjusted Research Excellence Indicator (AREI)

Definition of indicator

This indicator defines the research excellence of a country through a composite indicator integrating four components: share of top 10% most highly cited publications per total publications (data source: CWTS); PCT patent applications per population (OECD); European Research Council (ERC) grants per public R&D (DG-RTD, Eurostat, OECD) and participation in Marie Skłodowska-Curie fellowships (DG-EAC).

Rationale

This indicator pertains to priority 1 — that is, to more effective national systems. As one of the key types of actions promoted under the ERA to achieve this priority, it relates to the establishment of Research Performance Based Funding (RPBF) systems (i.e. systems applying the core principles of international peer review in grant competitions), and it becomes highly relevant to monitor the establishment of such systems and their impact on research excellence across ERA countries. The adjusted REI does this by integrating four dimensions of high relevance to monitor progress towards more effective national R&I systems, looking at both the funding mechanisms and the resulting R&I outputs (Vértesy, 2018). It covers ERC grants per public R&D, which is a good proxy to appreciate the success of countries in securing ERA-wide project-based competitive funding. It covers participation in Marie Skłodowska-Curie fellowships, which is a good proxy to appreciate the extent of researcher exchanges across national, sectoral and disciplinary boundaries (regardless of career stage), which are themselves expected to foster more integrated and efficient R&I ecosystems. It

[3] https://ec.europa.eu/jrc/en/coin

covers PCT patent applications per population, which is a good output indicator to capture the inventiveness of national R&I systems. Finally, it covers the share of top 10% most highly cited publications per total publications (HICIT), which is a good proxy of the excellence of the research output of a nation.

Computation method

Data needed

For details on the methodology, please refer to Vértesy (2018).

Source of data

Calculations by European Commission, DG Joint Research Centre, Competence Centre on Composite Indicators and Scoreboards (JRC-COIN).

Specifications

For details on the methodology, please refer to Vértesy (2018).

EU-28 computation

Precomputed in the JRC data.

Comments/critical issues

From Vértesy (2018):

> "We note that countries on the ERA periphery with a low number of publications and PCT patents show a high degree of fluctuation for the HICIT and PCT components. We noticed that PCT data should be considered unreliable for some or all of the years for the following countries: AL, AM, BA, CY, EE, GE, LT, LV, MD, ME, MK, MT, TN. It is also important to note that the trend of AREI score growth over time is driven, to a large extent, by the expansion of the ERC program. This gives reason to treat growth over time with caution and use as a benchmark the compound average growth (CAGR) figures of the EU28."

2.4 European Innovation Scoreboard (EIS)

Formerly called the Innovation Union Scoreboard, the European Innovation Scoreboard provides an international benchmark of the innovation performance of ERA countries, taking account of the multi-faceted nature of innovation (http://ec.europa.eu/growth/industry/innovation/facts-figures/scoreboards_en).

2.4.1 P1 – EMM indicator – European Innovation Scoreboard Summary Innovation Index (SII)

Definition of indicator

The Summary Innovation Index (SII) is composite indicator produced every year by the European Commission as part of the European Innovation Scoreboard (DG Internal Market, Industry, Entrepreneurship and SMEs, 2018). It is used to benchmark MS/AC, accounting for a wide spectrum of innovation indicators.

Rationale

This indicator pertains to priority 1 (More effective national research systems). It integrates a multitude of indicators distributed across ten dimensions covering framework conditions (Human resources; Attractive research systems; and Innovation-friendly environment), investments (Finance and support; and Firm investments), innovation activities (Innovators; Linkages; and Intellectual assets) and impacts (Employment impacts; and Sales impact). It thus presents a comprehensive picture of the state of a country's R&I system along the full path from inputs, through outputs, and on to outcomes/impacts. It is therefore highly relevant to monitor progress towards more effective national research systems under priority 1.

Computation method

This composite indicator encompasses 27 innovation indicators collected from various sources. The reader is referred to the latest European Innovation Scoreboard report (DG Internal Market, Industry, Entrepreneurship and SMEs, 2018) for more details.

Source of data

DG Internal Market, Industry, Entrepreneurship and SMEs.

EU-28 computation

Precomputed in the European Innovation Scoreboard data.

Comments/critical issues

The very broad set of indicators (27 in total) covered by this composite indicator mean that it covers a wider set of issues than those specific to Priority 1; in fact, some of the indicators included in the SII are also EMM indicators in other ERA priorities (e.g. public–private co-publications per million population (Priority 4) and international scientific co-publications (Priority 2a and Priority 6)). It is therefore less specific to this priority than the adjusted REI, which is truly focused on the input and output indicators of highest relevance to the performance of domestic R&I systems under Priority 1. In fact, the SII is less suited to the monitoring of this priority than the adjusted REI, since it is primarily designed to capture the performance of R&I systems rather than their effectiveness (ERAC Secretariat, 2015a).

2.4.2 P5a – EMM indicator – Number of public-private co-publications per million population

Definition of indicator

This indicator is the number of publications co-authored by at least one researcher from the public sector and one researcher from the private sector per capita, according to their affiliation address and by full counting (refer to Annex 1 for a definition of full counting).

Rationale

This indicator pertains to sub-priority 5a (optimal access to and circulation and transfer of scientific knowledge) and relates to open innovation and knowledge transfer between the public and private sectors. In order to align needed skills with training, Member States have put in place measures, such as joint programmes and research training in private companies, to stimulate the partnership between universities, research institutions and the private sector (DG Research and Innovation, 2015). This indicator may serve as a proxy to measure the level of sharing of scientific knowledge and the level of collaboration between research institutions, scientists and businesses.

Computation method

Data needed

($PAP_{PUB\text{-}PRIV.COLLAB}$) Number of co-publications between the public and the private sectors: **Unit=Total (full counting)**;

(POP) Total population: **Unit=Total**.

Source of data

DG Internal Market, Industry, Entrepreneurship and SMEs.

EU-28 computation

Precomputed in the European Innovation Scoreboard data.

Comments/critical issues

None identified.

2.4.3 P6 – EMM indicator – Exports of medium and high technology products as a share of total product exports

Definition of indicator

This indicator is the ratio of the value of medium and high technology exports in national currency and in current prices to the value of total product export. The medium and high technology exports include products from the following SITC Rev3 category: 266, 267, 512, 513, 525, 533, 54, 553, 554, 562, 57, 58, 591, 593, 597, 598, 629, 653, 671, 672, 679, 71, 72, 731, 733, 737, 74, 751, 752, 759, 76, 77, 78, 79, 812, 87, 88 and 891

Rationale

This indicator pertains to priority 6 (international cooperation) and it reflects the ability of a country to commercialise medium and high technology products in international markets. Medium and high technology products are usually the results of innovation and R&D efforts. The ability to commercialise such products in the international market will play a role on the competitiveness of a country as well as on the attractiveness of its R&D system to foreign partners and talents (i.e. brain gain). Due to discontinued data, this indicator, together with "Knowledge-intensive services exports as % of total services exports", replaces the indicator "Licence and patent revenues from abroad as a share of GDP" from the last ERA Progress Report.

Computation method

Data needed

($EXP_{MID-HIGH-TECH}$) Value of medium and high technology exports (products from the following SITC Rev3 category: 266, 267, 512, 513, 525, 533, 54, 553, 554, 562, 57, 58, 591, 593, 597, 598, 629, 653, 671, 672, 679, 71, 72, 731, 733, 737, 74, 751, 752, 759, 76, 77, 78, 79, 812, 87, 88 and 89): **Unit = national currency and current prices**

(EXP_{TOT}) Value of total product export: **Unit = national currency and current prices**.

Source of data

DG Internal Market, Industry, Entrepreneurship and SMEs.

EU-28 computation

Precomputed in the European Innovation Scoreboard data.

Comments/critical issues

None identified.

2.4.4 P6 – EMM indicator – Knowledge-intensive services exports as % of total services exports

Definition of indicator

This indicator is the share of knowledge-intensive services exports in total service exports. The knowledge-intensive services exports are defined as the sum of credits from items SC1, SC2, SC3A, SF, SG, SH, SI, SJ and SK1 of the Extended Balance of Payments Services Classification (EBOPS) 2010.

Rationale

This indicator pertains to priority 6 (international cooperation). It can be seen as a proxy to measure the competitiveness of the knowledge intensive service sector in the international market. As highlighted by the European Innovation Scoreboard:

> "this indicator reflects the ability of an economy, notably resulting from innovation, to export services with high levels of value added, and successfully take part in knowledge-intensive global value chains."

In turn, this indicator informs, to some extent, on the attractiveness of its R&D system to foreign partners and talents (i.e. brain gain). Along with "Exports of medium and high technology products as a share of total product exports", this indicator replaces the indicator "Licence and patent revenues from abroad as a share of GDP" from the last ERA Progress Report.

Computation method

Data needed

($EXP_{KNOW-INTEN-SERV}$) Knowledge-intensive services exports (SC1, SC2, SC3A, SF, SG, SH, SI, SJ and SK1 of EBOPS 2010): **Unit=Euro**

($EXP_{TOT-SERV}$) Total services exports: **Unit=Euro**.

Source of data

DG Internal Market, Industry, Entrepreneurship and SMEs.

EU-28 computation

Precomputed in the European Innovation Scoreboard data.

Comments/critical issues

None identified.

2.5 Eurostat

Eurostat is the official statistical office of the European Union. It provides reliable and objective statistics on European Member States and Associated Countries, allowing for comparison at the country and regional level. Most statistics are freely available online through the Eurostat website. The statistics produced at Eurostat cover a wide range of topics divided among nine primary themes: General & regional statistics, Economy & finance, Population & social conditions, Industry, trade & services, Agriculture and fisheries, External trade, Transport, Environment & energy, and Science & technology.

2.5.1 P1 – EMM indicator – GBARD as a percentage of GDP

Definition of indicator

This indicator is the government budget allocations for R&D (GBARD) divided by the gross domestic product (GDP) of a given country. GBARD represents budget provisions and not actual spending.

Rationale

This indicator pertains to priority 1 (More effective national research systems). Public funding for R&D is a key driver, if not *the* key driver, of the strength and international competitiveness of domestic R&I systems. It is therefore highly relevant to consider input indicators of R&D investments to contextualise the strength of national R&I systems as measured by output indicators. The GBARD covers all government financed R&D (including government financed R&D performed in business enterprise, private non-profit or HES sectors), giving a complete representation of government investment in R&D. Normalising by GDP accounts for the relative size of a country's economy and allows comparing the scores across MS/AC.

Computation method

Data needed

(GBARD) Government budget allocations for R&D: **Unit=Euro**;

(GDP) Gross domestic product at market price: **Unit=Euro**.

Source of data

For *(GBARD)*: *Eurostat— Statistics on research and development (online data code: gba_nabsfin07);*

For *(GDP)*: *Eurostat—Annual national accounts (online data code: nama_10_gdp).*

Filters applied

For *(GBARD)*: *NABS07 set to "Total R&D appropriations"*
UNIT set to "Million euro"

For *(GDP)*: *UNIT set to "Current prices, million euro"*
NA_ITEM set to "Gross domestic product at market prices"

Specifications

$$\text{GBARD as a percentage of GDP } = \frac{GBARD}{GDP} \times 100$$

EU-28 computation

Eurostat pre-computed EU-28 score were used for both the denominator and the numerator.

Comments/critical issues

This indicator is reported for year 2017 when available. However, nearly all 2017 scores are flagged as *provisional* by Eurostat.

2.5.2 P2a – Headline indicator – GBARD allocated to transnational cooperation per researcher in the public sector.

Definition of indicator

This indicator is the government budget allocations for R&D (GBARD) allocated to transnational cooperation normalised by the number of researchers from the public sector. Transnational coordinated R&D contains GBARD allocated to Europe-wide, bilateral or multilateral transnational public R&D programmes and GBARD allocated to transnational public R&D performers. However, for this indicator, only the GBARD allocated to Europe-wide transnational public R&D programmes and the GBARD allocated to bilateral or multilateral public R&D programmes are taken into account. This is because these latter two components address cooperation through programmes, while the third sub-category (GBARD allocated to transnational public R&D performers) does not involve joint programming and therefore does not contribute to ERA sub-priority 2a (implementing joint research agendas).

Rationale

This indicator pertains to sub-priority 2a — that is, implementing joint research agendas to address grand challenges of high importance to Europeans. It reflects a given country's emphasis on collaboration and sharing of experiences in R&D across borders, whether national, regional or organisational. Europe-wide transnational public R&D programmes include R&D programmes that involve the flow of funds across borders for research purposes, as well as those that include transnational cooperation. Bilateral or multilateral public R&D programmes comprise non-European Commission funded R&D research conducted jointly by at least two Member State governments, involving either the flow of funds or transnational cooperation. Thus, this indicator is a good proxy to measure government support to transnational collaborations across the ERA.

Computation method

Data needed

($GBARD_{TRANS(EU\text{-}WIDE)}$) Amount of GBARD allocated to Europe-wide transnational public R&D programmes: **Unit=Euro**;

($GBARD_{TRANS(BI\text{-}MULTI)}$) Amount of GBARD allocated to bilateral or multilateral public R&D programmes: **Unit=Euro**;

(RES_{HES}) Researchers in the higher education sector: **Unit=Full time equivalent (FTE)**.

(RES_{GOV}) Researchers in the government sector: **Unit=Full time equivalent (FTE)**.

Source of data

For *($GBARD_{TRANS}$)*: *Eurostat—Statistics on research and development (online data code: gba_tncoor);*

For *($RES_{HES\ or\ GOV}$)*: *Eurostat—Statistics on research and development (online data code rd_p_persocc).*

Filters applied

For *($GBARD_{TRANS(EU\text{-}WIDE)}$)*: *NABS07 set to "National contributions to Europe-wide transnational public R&D programmes"*
UNIT set to "Million euro"

For *($GBARD_{TRANS(BI\text{-}MULTI)}$)*: *NABS07 set to* "National contributions to bilateral or multilateral public R&D programmes"
UNIT set to "Million euro"

For *(RES_{HES})*: *SECTPERF set to "Higher education sector"*
OCCUP set to "Researchers"
SEX set to "Total"
UNIT set to "Full-time equivalent (FTE)"

For *(RES_{GOV})*: *SECTPERF set to "Government sector"*
OCCUP set to "Researchers"
SEX set to "Total"
UNIT set to "Full-time equivalent (FTE)"

Specifications

$$GBARD\ allocated\ to\ transnational\ cooperation\ per\ researcher\ in\ the\ public\ sector$$

$$= \frac{GBARD_{TRANS(EU-WIDE)} + GBARD_{TRANS(BI-MULT\ )}}{RES_{GOV} + RES_{HES}}$$

EU-28 computation

The numerator is the sum of all MS' $GBARD_{TRANS(EU\text{-}WIDE)}$ and $GBARD_{TRANS(BI\text{-}MULTI)}$. Note that DE (2007-2010, 2016); HU (2013); IS (2008, 2009, 2011, 2013); NL (2012-2016) $GBARD_{TRANS(BI\text{-}MULTI)}$ portion is missing but the MS were kept in the EU-28 computation, contributing only their $GBARD_{TRANS(EU\text{-}WIDE)}$ portion. This may result in a slight underestimation of the EU-28 scores. However, the time-series does not appear to be affected.

The numerator is the sum of all MS' RES_{HES} and RES_{GOV}.

To maximize the number of MS included in the EU-28 average, data was imputed for PL (2016). Imputation follows the rules as outlined in sub-section "Computation of EU-28 aggregate scores" under Section 4. Also, France was not included in the EU-28 average due to missing data.

Comments/critical issues

The portion of GBARD allocated to bilateral or multilateral public R&D programmes was not available for DE (2007-2010, 2016); HU (2013); IS (2008, 2009, 2011, 2013); NL (2012-2016) so it was not taken into account in the computation of the indicator. This may result in a slight underestimation of these countries scores in those years as well as for the EU-28 scores. However, the time-series do not appear to be affected.

2.5.3 P3 – EMM indicator – Share of doctoral candidates with a citizenship of another EU Member State

Definition of indicator

This indicator is the proportion of doctoral candidates with a citizenship of another Member State to the total number of doctoral candidates in a given country.

Rationale

This indicator pertains to priority 3 (open labour market for researchers). This priority seeks to improve framework conditions for researcher mobility across Europe in order to retain highly skilled Europeans rather than have them pursue career goals in other competitive economies (Science-Metrix, 2016). Actions are expected from Member States to expand structured doctoral training programmes and remove barriers for cross-border mobility. This indicator can act as a proxy to monitor the extent to which a country's academic system is open to other European doctoral candidates (the openness may be in the portability of a national grant or other mechanism that may facilitate the switch to a new country academic institution). By promoting an open academic system, a MS/AC can attract and retain skilled students who will eventually contribute to the R&I workforce either in academia or the industrial sector.

Computation method

Data needed

($PhD_{F.MS}$) Number of doctoral candidates from another Member State: **Unit=Number**;

(PhD_{TOT}) Number of doctoral candidates: **Unit=Number**.

Source of data

For *($PhD_{F.MS}$)*: *Eurostat—Learning mobility (online data code: educ_uoe_mobs02);*

For *(PhD_{TOT})*: *Eurostat—Participation in education and training (online data code: educ_uoe_enrt01).*

Filters applied

For *($PhD_{F.MS}$)*:
UNIT set to "Number"
PARTNER set to each Member State separately
SEX set to "Total"
ISCED11 set to "Doctoral or equivalent level"

For *(PhD_{TOT})*:
UNIT set to "Number"
WORKTIME set to "Total"
ISCED11 set to "Doctoral or equivalent level"
SEX set to "Total"
SECTOR set to "Total"

Specifications

$$Share\ (\%)\ of\ doctoral\ candidates\ with\ a\ citizenship\ of\ another\ EU\ Member\ State = \frac{\sum PhD_{F.MS}}{PhD_{TOT}} \times 100$$

EU-28 computation

Numerator is the sum of all Member State's number of doctoral candidates from another MS.

Denominator is the sum of all Member State's number of doctoral candidates.

To maximize the number of MS included in the EU-28 average, data was imputed for EL (2013-2014); LU (2013); SI (2016); ES (2014-2015). Imputation follows the rules as outlined in sub-section "Computation of EU-28 aggregate scores" under Section 4.

Comments/critical issues

At the time of computation, the "PARTNER" filter did not include an option for "Europe (excluding reporting country)". Therefore, to obtain the total number of doctoral candidates with a citizenship of another Member States, it was necessary to sum the number of doctoral candidates of the 27 Member States partners for individual Member States (or 28 Member States partners for Associated countries).

ISCED

The International Standard Classification of Education (ISCED11) categorises education programmes by level. ISCED level 8 covers:

- Programmes leading to advanced research qualifications devoted to advanced study and original research. Includes academic and professional Doctoral programmes and can be referred to as 'Doctoral or equivalent' for international comparison purposes.

2.5.4 P4 – EMM indicator – Share of female PhD graduates

Definition of indicator

This indicator is the proportion of women PhD graduates to the total number of PhD graduates. Some of the text below has been taken directly from the *She Figures Handbook 2015* (DG Research and Innovation, 2016a).

Rationale

This indicator pertains to priority 4 (and relates to gender balance in career progression) through measuring the rate of graduation of women from the highest level of tertiary education. The European Commission has noted that '[t]he persistence of gender bias in careers, of gender imbalance in decision-making roles, and the lack of a gender dimension in research programmes remain common challenges' (DG Research and Innovation, 2014). In light of this, a key priority for reinforcing the European Research Area is emphasising gender equality and gender mainstreaming in research (DG Education and Culture, 2011). This indicator aims to characterise the rate and progress of women's graduation from doctoral programmes.

Computation method

Data needed

(PhD_F) Number of women PhD graduates: **Unit=Total**;

(PhD_{TOT}) Total number of PhD graduates: **Unit=Total**.

Source of data

For *F* and *T*: *Eurostat – Education Statistics (online data code: educ_uoe_grad02)*.

For *F* and *T* for AL, BA, AM, GE, IL, MD and UA: *UNESCO – Tertiary graduates by level of education*

Filters applied

For Eurostat *(PhD_F)*: *UNIT set to "Number"*
AGE CLASS set to "Total"
SEX set to "Females"
ISCED11 set to "Doctoral or equivalent level"
ISCEDF13 set to "Total"

For *Eurostat (PhD_{TOT})*: *UNIT set to "Number"*
AGE CLASS set to "Total"
SEX set to "Total"
ISCED11 set to "Doctoral or equivalent level"
ISCEDF13 set to "Total"

For UNESCO *(PhD_F)*: *INDICATOR set to "Graduates from ISCED 8 programmes in tertiary education, female (number)"*

For *UNESCO (PhD_{TOT})*: *INDICATOR set to "Graduates from ISCED 8 programmes in tertiary education, both sexes (number)"*

Specifications

$$Share\ of\ women\ PhD\ graduates = \frac{PhD_F}{\mathrm{PhD}_{TOT}} \text{ x } 100$$

EU-28 computation

Eurostat pre-computed EU-28 scores were used for years 2014-2016. For 2013 the numerator is the sum of all Member State's number of female PhD graduates and the denominator is the sum of all Member State's number of PhD graduates. No MS is missing from the 2013 EU-28 computation.

Comments/critical issues

The 2016 ERA monitoring used the International Standard Classification of Education (ISCED) 1997 to report on educational data from 2005 to 2012. Although ISCED 2011 was available, the She Figures used ISCED 97 and this classification scheme was used for consistency. Since the She Figures 2018 report used ISCED 2011, this classification was also applied here. Historical data based on ISCED 2011 only goes back to 2013.

ISCED

The International Standard Classification of Education (ISCED11) categorises education programmes by level. ISCED level 8 covers:

Programmes leading to advanced research qualifications devoted to advanced study and original research. Includes academic and professional Doctoral programmes and can be referred to as 'Doctoral or equivalent' for international comparison purposes.

2.5.5 P5a – Headline indicator – Share of product and/or process innovative firms cooperating with higher education institutions or public/private research institutions

This indicator underwent a change between the ERA progress report 2016 and the 2018 version. Due to the nature of the data source (microdata not available), this indicator was divided into two indicators in the 2016 ERA progress report; (a) Percentage of product or process innovative firms cooperating with public or private research institutes, and (b) Percentage of product or process innovative firms cooperating with universities or other higher education institutions. Merging Eurostat pre-aggregated data at the country level for these two categories of firms would have led to double counting of firms falling under both categories. However, for the most recent data of the community innovation survey (CIS9), Eurostat compiled a new category that is adequately aggregating the two categories previously used to compute indicators a and b. The new category, "Enterprises co-operating with universities, other higher education institutions, Government, public or private research institutes" now enables the computation of only one indicator to cover this dimension. Therefore, only one value is now reported for assessing performance. However, since historical data does not contain this new category, the growth was computed separately for indicator a and b.

Definition of indicator

For performance (2014):

The indicator is the proportion of product and/or process innovative firms co-operating with universities, other higher education institutions, Government, public or private research institutes to the total number of product and/or process innovative firms.

For growth (2012–2014):

(a) The indicator is the proportion of product and/or process innovative firms cooperating with universities or higher education institutes (HEIs) to the total number of product and/or process innovative firms.

(b) The indicator is the proportion of product and/or process innovative firms cooperating with Government, public or private research institutes (PRIs) to the total number of product and/or process innovative firms.

Rationale

This indicator pertains to priority 5 (knowledge circulation) and helps to assess the potential for knowledge transfer and open innovation between the public and private sectors within a given country. A higher rate of private firm engagement with HEIs or PRIs should better facilitate the transfer of research results to the market in line with the goal of optimising circulation of, access to and transfer of scientific knowledge established by the European Commission (2012). This indicator represents the degree of cooperation between private industry and other sectors and can be used as a proxy for the willingness of private firms to collaborate with higher education and/or public/private research institutes and the potential for knowledge transfer.

Computation method

Data needed

($COOP_{HEI,\ PRI\ or\ HEI\ \&\ PRI}$) Product and/or process innovative firms cooperating with HEIs, PRIs or either one of the two (or both): **Unit=Total**;

(FIRM) Total number of product and/or process innovative firms: **Unit=Total**.

Source of data

For *($COOP_{HEI,\ PRI\ or\ HEI\ \&\ PRI}$)*: *Eurostat—Community innovation survey (online data codes: inn_cis9_coop, inn_cis8_coop);*

For *(FIRM)*: *Eurostat—Community innovation survey (online data codes: inn_cis9_type inn_cis8_type).*

Filters applied

For *($COOP_{HEI,\ PRI\ or\ HEI\ \&\ PRI}$)*:
SIZECLAS set to "Total"
*NACE_R2 set to "Innovation core activities (*Com.Reg. 995/2012*)" or "Innovation core activities (Com.Reg. 1450/2004)" (for 2012 $COOP_{PRI}$ only[4])*
TYPE_INN set to "Product and/or process innovative enterprises, regardless of organisational or marketing innovation (including enterprises with abandoned/suspended or on-going innovation activities"
INDIC_IN set to "Enterprises co-operating with universities or other higher education institutions", "Enterprises co-operating with Government, public or private research institutes" or "Enterprises co-operating with universities, other higher education institutions, Government, public or private research institutes"
UNIT set to "Number"
TIME set to "2014", "2012" (depending on which table is used)

For *($FIRM_{HEI,\ PRI\ or\ HEI\ \&\ PRI}$)*:
SIZECLAS set to "Total"
*NACE_R2 set to "Innovation core activities (*Com.Reg. 995/2012*)" or "Innovation core activities (Com.Reg. 1450/2004)" (for 2012 $FIRM_{PRI}$ only[5])*

[4] See Comments/critical issues for an explanation of why *Com.Reg. 1450/2004 is used for $COOP_{PRI}$ and $FIRM_{PRI}$*

[5] Ibid.

TYPE_INN set to "Product and/or process innovative enterprises, regardless of organisational or marketing innovation (including enterprises with abandoned/suspended or on-going innovation activities"
INDIC_IN set to "Total number of enterprises in the population in 2014" (change 2014 for 2012 depending on which table is used)
UNIT set to "Number"
TIME set to "2014", "2012" (depending on which table is used)

Specifications

$$Share\ (\%)\ of\ innovative\ firms\ cooperating\ with\ HEI = \frac{COOP_{HEI}}{FIRM_{HEI}} \times 100$$

$$Share\ (\%) of\ innovative\ firms\ cooperating\ with\ PRI = \frac{COOP_{PRI}}{FIRM_{PRI}} \times 100$$

$$Share\ (\%) of\ innovative\ firms\ cooperating\ with\ HEI\ or\ PRI = \frac{COOP_{HEI\ \&\ PRI}}{FIRM_{HEI\ \&\ PRI}} \times 100$$

EU-28 computation

For performance (2014):

The numerator was computed as the sum of all MS $COOP_{HEI\ \&\ PRI}$ and the denominator was computed as the sum of all MS $FIRM_{HEI\ \&\ PRI}$. However, IE, ES and UK had no data available for $COOP_{HEI\ \&\ PRI}$, so they were imputed by taking the maximum value of the other two categories taken separately which will always be smaller than the true value. This resulted in $COOP_{HEI}$ being used for IS and UK while ES was given the value of $COOP_{PRI}$. Using the data for the MS where all data was available (i.e. merged and by sub-categories), we could estimate that the average underestimation of the scores using this approach roughly equals 15% across MS. However, the underestimation varies substantially across countries. Accordingly, the score of EU-28 which includes the above exceptions for IE, ES and UK might be slightly underestimated.

For growth (2012–2014):

(a) The numerator was computed as the sum of all MS $COOP_{HEI}$ and the denominator was computed as the sum of all MS FIRM. No MS had missing data.

(b) The numerator was computed as the sum of all MS $COOP_{PRI}$ and the denominator was computed as the sum of all MS FIRM. DE, IE, NL, SI and SE were not included in the EU-28 numerator and denominator due to missing data.

Comments/critical issues

At the time of producing the data, the category "Innovation core activities (Com.Reg. 995/2012)" of the NACE R2 filter was unavailable for the data on cooperation with Government, public or private research institutes in table *inn_cis8_coop*. Therefore, the category *"Innovation core activities (Com.Reg. 1450/2004)"* was used instead. This small difference in definition is stated in the table note. Additionally, note that the component focusing on cooperation with research institutes does not only capture public research institutes as would be desirable in order to focus on knowledge transfer between the public and private sectors. Instead, it also covers cooperation with private research institutes.

2.5.6 P5a – EMM indicator – Share of public research financed by the private sector

Definition of indicator

This indicator is the share of the total amount of research funds allocated to the public sector from all sources coming from the private sector.

Rationale

This indicator pertains to priority 5 (Knowledge circulation) and relates to the open innovation and knowledge transfer between the public and private sectors. In Europe, the private sector employs

relatively few researchers. Young graduates have little experience outside academic circles and often lack the skills to pursue a career in the private sector (DG Research and Innovation, 2015). Enterprises are encouraged to fund research in the public sector to align their needs with academic training and facilitate the transition of young graduates to the job market. This indicator can be used as a proxy for cooperation and knowledge transfer between the public and private sectors.

Computation method

Data needed

($F_{HEI-BES}$) Amount of research funds allocated to the higher education sector by the business enterprise sector: **Unit=Euro**;

($F_{HEI-ABES}$) Amount of research funds allocated to the higher education sector by the abroad business enterprise sector: **Unit=Euro**;

($F_{GOV-BES}$) Amount of research funds allocated to the government sector by the business enterprise sector: **Unit=Euro**;

($F_{GOV-ABES}$) Amount of research funds allocated to the government sector by the abroad business enterprise sector: **Unit=Euro**;

(F_{HEI}) Amount of research funds allocated to the higher education sector by all sectors: **Unit=Euro**.

(F_{GOV}) Amount of research funds allocated to the government sector by all sectors: **Unit=Euro**.

Source of data

Eurostat—Statistics on research and development (online data code rd_e_gerdfund).

Filters applied

($F_{HEI-BES}$) *SECTPERF set to "Higher education sector"*
SECTFUND set to "Business enterprise sector"
UNIT set to "Million euro"

($F_{HEI-ABES}$) *SECTPERF set to "Higher education sector"*
SECTFUND set to "Abroad - Business enterprise sector"
UNIT set to "Million euro"

($F_{GOV-BES}$) *SECTPERF set to "Government sector"*
SECTFUND set to "Business enterprise sector"
UNIT set to "Million euro"

($F_{GOV-ABES}$) *SECTPERF set to "Government sector"*
SECTFUND set to "Abroad - Business enterprise sector"
UNIT set to "Million euro"

($F_{HEI-TOT}$) *SECTPERF set to "Higher education sector"*
SECTFUND set to "All sector"
UNIT set to "Million euro"

($F_{GOV-TOT}$) *SECTPERF set to "Government sector"*
SECTFUND set to "All sector"
UNIT set to "Million euro"

Specifications

$$Share\ (\%)\ of\ public\ research\ financed\ by\ the\ private\ sector$$

$$= \frac{F_{HEI-BES} + F_{HEI-ABES} + F_{GOV-BES} + F_{GOV-ABES}}{F_{HEI-TOT} + F_{GOV-TOT}} \times 100$$

EU-28 computation

Eurostat pre-computed EU-28 scores were used. Note that the financing from the abroad business enterprise sector is missing for EU-28 (see comments/critical issues below)

Comments/critical issues

$F_{HEI\text{-}ABES}$ is missing for BG (2009); NL (2011-2014) and RO (2007) but the indicator was still computed for these MS. This may result in a slight underestimation in the score.

$F_{GOV\text{-}ABES}$ is missing for BG (2013, 2014); 2015 (LU, EE); PL (2011, 2013, 2015); TR (2007, 2008) and UK (2007-2010) but the indicator was still computed for these MS. This may result in a slight underestimation in the score.

$F_{HEI\text{-}ABES}$ and $F_{GOV\text{-}ABES}$ are both missing for 2007-2015 (EU-28, DE); 2012-2014 (BA, RS); 2007-2008 (BG, HU); 2007, 2009 (LU, NL); CH (2008, 2010, 2012, 2014); EL (2012, 2014), IS (2007-2009, 2011); LV (2007-2011); ME (2011, 2013-2015); PL (2007) but the indicator was still computed for these MS. This may result in a slight underestimation in the score. Note that the financing by the abroad business enterprise sector is usually small compared to the financing by the local business enterprise sector and the above issues did not appear to create breaks in series or noticeable outliers (i.e. those that would point to an underestimation).

2.5.7 P6 – EMM indicator – Non-EU doctorate students as a share of all doctorate students

Definition of indicator

This indicator is the proportion of Non-EU doctoral students to the total number of doctoral students in a given country.

Rationale

This indicator pertains to priority 6 (international cooperation) identified by the Commission for reinforcing the European Research Area. By attracting outstanding researchers from international locations, the EU will improve its capacity to address grand challenges and increase its competitiveness. Enrolling international students represents the first step toward this goal. However, approaches to increasing international collaboration vary from MS to MS and are uncoordinated. As such, it is interesting to monitor the openness and attractiveness of each country's education system and research institutions with this indicator.

Computation method

Data needed

(PhD_{World}) Foreign doctorate students: **Unit= Number**;

(PhD_{EU28}) EU28 doctorate students (excluding reporting country): **Unit= Number**;

(PhD_{TOT}) Total EU doctorate student: **Unit= Number**.

Source of data

For *(PhD_{World})*: *UNIT set to "Number"*
PARTNER "World total except for the reporting country"
SEX set to "Total"
ISCED11 set to "Doctoral or equivalent level"

For *(PhD_{EU28})*: *UNIT set to "Number"*
PARTNER set to each Member State separately
SEX set to "Total"
ISCED11 set to "Doctoral or equivalent level"

For *(PhD_{TOT})*: *UNIT set to "Number"*
WORKTIME set to "Total"
ISCED11 set to "Doctoral or equivalent level"

SEX set to "Total"
SECTOR set to "Total"

Specifications

$$Non-EU\ doctorate\ students\ as\ a\ share\ (\%)\ of\ all\ doctorate\ students = \frac{PhD_{World} - \sum PhD_{EU28}}{PhD_{TOT}} \times 100$$

EU-28 computation

Numerator is the sum of all Member State's number of doctoral candidates from a foreign non-EU country.

Denominator is the sum of all Member State's number of doctoral candidates.

To maximize the number of MS included in the EU-28 average, data was imputed for EL (2013-2014); LU (2013); SI (2016); ES (2014-2015). Imputation follows the rules as outlined in sub-section "Computation of EU-28 aggregate scores" under Section 4.

ISCED

The International Standard Classification of Education (ISCED11) categorises education programmes by level. ISCED level 8 covers:

Programmes leading to advanced research qualifications devoted to advanced study and original research. Includes academic and professional Doctoral programmes and can be referred to as 'Doctoral or equivalent' for international comparison purposes.

Comments/critical issues

None identified.

2.6 Third ERA-Learn 2020 Annual Report on P2P Partnerships

The mission of the ERA-Learn 2020 project — an initiative started in January 2015 that builds upon previous ERA-NET projects — is to provide an integrated framework that will strengthen the community of P2P (public-to-public) partnerships and support national funding organisations (ERA-Learn, 2015).

2.6.1 P2a – EMM indicator – Member States participation in Public-to-public partnerships per researcher in the public sector

Definition of indicator

This indicator is the amount of combined funds committed to Cofunds, Art. 185s, JPIs, FP7 ERA-NETs and self-sustained networks and budgets for joint calls relative to the number of FTE researchers in the public sector.

Rationale

This indicator pertains to sub-priority 2a (transnational cooperation) and relates to the implementation of joint research agendas. ERA-NET projects, JPIs and Article 185 initiatives are all P2P partnerships. Article 185 is a reference to the Treaty on the Functioning of the European Union. Data on the amount of funds committed by Member States to these joint research programming efforts are captured in each edition of the ERA-Learn 2020 Annual Report on P2P Partnerships (ERA-Learn, 2017 for the latest edition) and can therefore be used to assess the state of play in regard to P2P partnerships in all Member States within the ERA.

Computation method

Data needed

(CBUDG) Committed budget to ERA-NET, JPIs and Article 185 initiatives: **Unit=euro**;

(RES_{HES}) Researchers in the higher education sector: **Unit=Full time equivalent (FTE)**;

(RES_{GOV}) Researchers in the government sector: **Unit=Full time equivalent (FTE)**.

Source of data

For *(CBUDG)*: *3rd Annual Report on Public-Public Partnerships (ERA-Learn, 2017).*

For *(RES)*: *Eurostat—Statistics on research and development (online data code: rd_p_persocc).*

Specifications

$$Participation\ in\ Public-to-public\ partnerships\ per\ researcher\ in\ the\ public\ sector = \frac{(CBUDG)}{(RES_{HES}) + (RES_{GOV})}$$

EU-28 computation

Numerator is the sum of all Member State's Committed budget to ERA-NET, JPIs and Article 185 initiatives. Denominator is Eurostat pre-computed EU-28 score. No MS are missing from the EU-28 score.

Comments/critical issues

Data are only available for Member States. Note that since the 2016 edition of the ERA Progress Report, the amount and quality of information for joint calls was greatly improved, both for current and past data (personal communication with Optimat representative in charge of the data). Therefore, there can be notable differences in this report when compared to the previous ERA Progress Report (Science-Metrix, 2017).

2.7 MORE2 and MORE3 surveys

The MORE3 Global survey, conducted in 2016, succeeded the MORE2 HEI survey. The MORE surveys collected data on mobility patterns, career paths and working conditions of researchers working in HEIs. The surveys were designed and implemented in order to offer maximum accuracy at the EU and individual country levels. The MORE3 survey reached more than 10 000 individual researchers located in the EU-28 and the Associated Countries.

2.7.1 P3 – EMM indicator – Share of researchers expressing satisfaction that the hiring procedures in their institution are open, transparent and merit-based

Definition of indicator

This indicator represents the proportion of researchers having answered positively to the three following questions from the MORE2 and MORE3 surveys:

MORE2: "What is your opinion on the following issues: 1) Are you satisfied with the extent to which job vacancies are publicly advertised and made known by your institution? 2) Do you think that the recruitment process at your home institution is sufficiently transparent? 3) Do you think that recruitment at your home institution is sufficiently merit-based?", with answer categories "yes", "no" and "N/A / no opinion".

MORE3: "What is your opinion on the following issues with respect to recruitment in your home institution: 1) Research job vacancies are sufficiently externally and publicly advertised and made known by the institution. 2) The recruitment process is sufficiently transparent. 3) Recruitment is sufficiently merit-based.", with answer categories "I agree", "I don't agree" and "N/A".

Note that the questions were stated slightly differently between the two editions, in particular on question 1 with regard to the "externally" wording. However, as stated in the MORE 3 indicators report (DG Research and Innovation, 2017), these differences are unlikely to have caused the large differences observed between the 2012 and 2016 scores.

Rationale

This indicator pertains to priority 3 (Open labour market for researchers) and relates to the perception that researchers have regarding their respective institution. Institutions with recruitment processes that are open, transparent and merit based are considered more attractive for researchers and may thus provide a better and more open labour market. Most attractive institutions also have the potential to interest researchers from abroad and contribute to international and inter-sectoral mobility, which is thought to boost the competitiveness of research systems.

Computation method

Data needed

(Np_i) Respondent having answered positively to the three questions on openness, transparency and merit-based recruitment procedures. **Unit=Head count**;

(Nn_i) Respondent having answered negatively to ***at least*** one of the three questions on openness, transparency and merit-based recruitment procedures among those who responded "I agree" or "I don't agree" to all three questions. There are more cases combining positive answers with "N/A" then cases combining negative answers with "N/A". Accordingly, counting respondents having answered negatively to ***at least*** one of the three questions among those who did not respond "I agree" or "I don't agree" to all three questions would overestimate the denominator relative to the numerator. For this reason, any respondent with at least one "N/A" is excluded from the computation. **Unit=Head count**;

(W_i) Sampling weight at the country level (provided in the raw data of the MORE2 [column weihc] and MORE3 [column weifos] surveys). For both the MORE2 and MORE3 survey, these weights differ per country and per field of science.

Source of data

MORE2 and MORE3 Survey raw datasets

Specifications

$$Share\ (\%)\ of\ researchers\ \text{expressing satisfaction that the hiring procedures in their institution are open, transparent and merit based} = \frac{\sum(Np_i \times W_i)}{\sum(Nn_i \times W_i + Np_i \times W_i)}$$

Where the sums are taken over all the respondents *i* of a given Member State or Associated Country.

EU-28 computation

Numerator is the sum of all Member State's weighted respondent having answered positively to the three questions.

Denominator is the sum of all Member State's weighted respondent having answered positively to the three questions plus the respondent having answered negatively to at least one of the three questions.

No MS are missing from the EU-28 score.

Comments/critical issues

Weighting procedures are described in the document 'Guidelines for the data analysis of the EU HEI survey data' (IDEA Consult, 2013) and (IDEA Consult & WIFO, 2017). The sampling weight used was the one to be applied for the computation of results at country level and field of science (i.e., weihc for the 2012 dataset and weiFOS for the 2016 data). It serves to increase accuracy when aggregating results at this level.

2.8 She Figures

The She Figures provide statistics on the state and the progression of gender equality in science and technology (S&T) across Europe. Women are still well under-represented in S&T, but even more so in decision-making positions in research institutions. In an effort to have a more balanced gender representation in scientific research, such statistics provide information on the progress to correct this gender bias. Some of the text below has been taken directly from the *She Figures Handbook 2015* (DG Research and Innovation, 2016a).

2.8.1 P4 – Headline indicator – Share of women in grade A positions in HES

Definition of indicator

This indicator presents the proportion of women occupying the highest-level research positions (Grade A) in HES to the total of Grade A positions.

Rationale

This indicator pertains to priority 4 (gender equality in research) and relates to gender balance in career progression. This indicator enables tracking the progress made with regard to women's presence at the highest level of academia by analysing its trend through time. According to the DG Research and Innovation (2016b), women represented a majority of university graduates in the first stage of tertiary education (~60 %), while still representing close to half of them in the second stage of tertiary education (~47 %) in the EU-28 in 2013. Despite this figure, women represent a small minority of Grade A professors (21 %, 2013), heads of higher education institutions (20 %, 2014) and board members (including leaders) in research decision-making (28 %, 2014) (DG Research and Innovation, 2016b). Therefore, it is relevant to monitor the proportion of women present at each level of academia in order to observe whether there is progress toward reducing vertical segregation, defined as the under- or over-representation of a clearly identifiable group of workers in occupations or sectors at the top of an ordering based on 'desirable' attributes (EGGE, 2009).

Computation method

Data needed

($GRADE.A_{FEM}$) Number of women in grade A academic position (reference population = researchers): **Unit=Head count**;

($GRADE.A_{MALE}$) Number of men in grade A academic position (reference population = researchers): **Unit=Head count**.

Source of data

DG Research and Innovation—WiS—Women in Science database (for reference year 2016).

Additional data provided by Helsinki Group in the context of the ERA Progress Report 2016 were used for reference year 2014 and 2015. When divergence occurred between the two sources of data, the WiS database was prioritised.

Specifications

$$Proportion\ of\ women\ in\ grade\ A\ academic\ positions = \frac{GRADE.A_{Fem}}{GRADE.A_{Male} + GRADE.A_{Fem}} \times 100$$

EU-28 computation

Numerator is the sum of all Member State's number of women in grade A academic position.

Denominator is the sum of all Member State's number of researchers in grade A academic position.

No MS are missing from the EU-28 score for 2016. Luxembourg and the UK are missing from the EU-28 aggregate growth score.

Senior grades/Academic staff

The grades presented in ERA monitoring are based upon national mappings according to the following definitions:

(A) The single highest grade/post at which research is normally conducted.

Comments/critical issues

The classification of academic positions into grades may vary across countries. This should be taken into account when comparing or aggregating statistics.

It is important to note that these data are not always completely cross-country comparable as the seniority of grades is not yet part of a formal international classification. Furthermore, it is not always possible to distinguish research staff from teaching staff, although the target population is researchers in higher education institutions (excluding staff involved in teaching or administration only and not at all in research).

Also, note that in the growth computation, the reference population changed for the following countries: IE, EE, LT researchers (2014 score) to academic staff (2016 score) and ES, RO Academic staff (2014) to researchers (2016). Caution is advised when analysing the growth of these countries.

2.9 Web of Science™ (WoS™)

The Web of Science (WoS™), produced by Clarivate Analytics, was used as the main data source for computing the indicators presented in this section. The version of the WoS™ used in this monitoring exercise includes three databases: the Science Citation Index Expanded (SCI Expanded), the Social Sciences Citation Index (SSCI), and the Arts & Humanities Citation Index (A&HCI). Together these databases index some 12 000 journals whose publications are peer reviewed and cover all major fields of scientific research in the natural sciences and engineering (NSE), health sciences (HS) and social sciences and humanities (SSH). The WoS™ includes comprehensive bibliographic information on peer-reviewed scientific publications, such as their titles, abstracts, authors, author affiliations and references. This information can be analysed and tracked to measure an entity's (e.g. a country, an institution, a researcher) contribution to the scientific literature and its collaboration behaviour with other entities. For the purpose of this project, only high-quality and original contributions to scientific knowledge are considered. This covers two types of peer-reviewed documents: research articles and reviews, which are collectively referred throughout as 'publications' (or 'papers'). Note that a licence from Clarivate Analytics is required to access WoS™ for the purpose of producing large-scale bibliometric datasets.

2.9.1 P2a – EMM indicator – International co-publications with ERA partners per 1 000 researchers in the public sector

Definition of indicator

This indicator measures, using fractional counting (refer to Annex 1 for a definition of fractional counting), the number of publications of an ERA country (or region within the ERA) involving at least one co-author from another ERA country. The number is presented relative to the given country's (or region's) researcher population size.

Rationale

This indicator pertains to sub-priority 2a, which relates to the implementation of joint research agendas within the ERA. The number of international co-publications with ERA partners per 1 000 researchers in the public sector is a good proxy to measure the outcomes resulting from the transnationally allocated research funding that is promoted under sub-priority 2a. The normalisation by the number of researchers accounts for size differences across countries, allowing their direct comparison.

Computation method

Data needed

($PAP_{ERA.COLLAB}$) Number of co-publications with another ERA country: **Unit=Total (fractional count)**;

(RES_{HES}) Researchers in the higher education sector: **Unit=Full time equivalent (FTE)**;

(RES_{GOV}) Researchers in the government sector: **Unit=Full time equivalent (FTE)**.

Source of data

For *($PAP_{ERA.COLLAB}$)*: *WoS™ (Clarivate Analytics);*

For *($RES_{HES\ or\ GOV}$)*: *Eurostat—Statistics on research and development (online data code rd_p_persocc).*

Filters applied

For *(RES_{HES})*:
SECTPERF set to "Higher education sector"
OCCUP set to "Researchers"
SEX set to "Total"
UNIT set to "Full-time equivalent (FTE)"

For *(RES_{GOV})*:
SECTPERF set to "Government sector"
OCCUP set to "Researchers"
SEX set to "Total"
UNIT set to "Full-time equivalent (FTE)"

Specifications

$$Intl.co-publications\ with\ ERA\ partners\ per\ 1\ 000\ researchers = \frac{PAP_{ERA.Collab}}{\left(\frac{RES_{GOV}+RES_{HES}}{1000}\right)}$$

EU-28 computation

Numerator is the sum of all Member State's Number of co-publications with another ERA country. Note that since fractional count is used this calculation does not lead to double counting.

Denominator is the sum of Eurostat pre-computed EU-28 scores for researchers in the higher education sector and the researchers in the government sector.

No MS are missing from the EU-28 score.

Comments/critical issues

As most peer-reviewed scientific publications involve an actor from the public sector (at least 97 % in recent years; Science-Metrix, unpublished data), the denominator for this indicator was limited to the government and higher education sectors.

2.9.2 P4 – EMM indicator – Gender dimension in research content

Definition of indicator

This indicator relates to the proportion of a given country's scientific production (measured by the number of peer-reviewed scientific publications by full counting, see Annex 1 for more details) in which a gender dimension has been identified in the research content relative to the same proportion at world level. The resulting indicator is a specialisation index (SI), whereby a score above 1 means that a country is specialised — i.e. it puts more emphasis on the gender dimension in its research output — relative to the world, while a score below 1 means that it is not specialised relative to the world.

The concept of the gender dimension in research covers both the biological characteristics (i.e. the sex) and social/cultural aspects (i.e. the gender) of men and women. Scientific publications that involve a gender dimension are extracted by performing keyword-based queries in the titles, abstracts and author keywords of scientific publications. The selected keywords focus on well-defined gender topics (e.g. feminism, gender pay gap, gender equality, LGBT), as well as research content in which a distinction, or a comparison, is made between men and women (e.g. publications reporting sex-disaggregated data). Excluded from the gender dimension are studies pertaining to the animal kingdom (e.g. feminisation of fish populations) and other non-human biological entities, such as plants. Papers investigating specific medical conditions (e.g. menopause, erectile dysfunction) were also specifically excluded as they would return a very large number of scientific publications in the medical fields.

This indicator was presented for the first time in *She Figures 2015* (DG Research and Innovation, 2016b). At the time, the indicator was simply presented as the proportion of a country's research output integrating a gender dimension in its research content (GDRC). This was adequate since the data were reported by main field of science. In the context of the ERA monitoring exercise, the data are only presented for all fields combined. Since the gender dimension in research content is more frequently observed in particular subfields (e.g. Nursing, Cultural Studies, Clinical Medicine) relative to others (e.g. Acoustics, Civil Engineering, Mining & Metallurgy), it is important that the GDRC indicator accounts for the distribution of a country's publication output across subfields so as to optimise cross-country comparability of the scores. For example, if one country publishes most of its output in the medical sciences, and another country publishes most of its output in the physical sciences, it is obvious that the former country will have a greater proportion of its total output integrating the GDRC than the latter. In the context of the ERA Monitoring Mechanism, the GDRC takes care of this issue by comparing the proportion of a given country's output integrating the GDRC to the world reference by subfield, and subsequently aggregates the subfield scores accounting for how prevalent each subfield is in the corresponding country's total output.

More specifically, the ratio of publications including a gender dimension to the total number of publications is first computed at the subfield level (according to the Science-Metrix classification; Archambault, Caruso and Beauchesne, 2011) for each MS/AC as well as for the world (all countries combined). The ratios are then normalised by the world ratios (for each subfield) to obtain a SI for each subfield. The SIs of each country across subfields are then multiplied by the corresponding subfield proportion in the given country's total output; if the SI of a country for GDRC in the Social Sciences Methods subfield equals 1.14 and this subfield represent 3 % of the country's total output, then the weighted SI for this country and subfield will equal 0.0342 (i.e. 1.14 * 0.03). Subsequently, the weighted SI scores of a given country are summed across subfields to obtain an aggregated SI score reflecting the country's emphasis on GDRC research relative to the world, while accounting for differences in the specialisation patterns of countries across scientific subfields.

Rationale

This indicator pertains to priority 4 (gender equality in research) and relates to the promotion of cultural and institutional change on gender. Since 2014, applicants to Horizon 2020, the latest EU Research and Innovation funding programme, are required to specify how they intend to integrate a gender dimension in their research content. This new requirement makes it relevant to start monitoring the extent to which researchers in different countries incorporate this aspect in their research content to provide baseline figures against which to measure progress in the future.

Computation method

Data needed

($PAP_{CO\text{-}GD\text{-}SUB}$) Number of papers with a gender dimension in a given subfield for a given country (i.e. a MS or AC): **Unit=Total (full counting)**;

($PAP_{CO\text{-}SUB}$) Total number of papers for a given country (i.e. a MS or AC) in a given subfield: **Unit=Total (full counting)**;

($PAP_{W\text{-}GD\text{-}SUB}$) Number of papers with a gender dimension in a given subfield for the world (all countries combined): **Unit=Total (full counting)**;

($PAP_{W\text{-}SUB}$) Total number of papers in a given subfield for the world: **Unit=Total (full counting)**;

($PAP_{CO\text{-}TOT}$) Total number of papers for a given country (i.e. a MS or AC): **Unit=Total (full counting)**.

Source of data

Computed using WoS™ (Clarivate Analytics).

Specifications

$$Gender\ dimension\ in\ research\ content = \sum_{SUB}^{TOT} \frac{\frac{PAP_{CO-GD-SUB}}{PAP_{CO-}}}{\frac{PAP_{W-GD-SUB}}{PAP_{W-SUB}}} \times \frac{PAP_{CO-SUB}}{PAP_{CO-T}}$$

Comments/critical issues

Note that full counting is used (refer to Annex 1 for a definition of full counting). Also note that this indicator is characterised by strong yearly fluctuations, especially for the smaller countries, which make it difficult to analyse trends in the short term. To circumvent this issue in the analysis of growth, as well as to maximise the coverage of countries, a four-year rolling window (or four-year moving average of the scores) was applied in presenting the data.

2.9.3 P5b – Headline indicator – Share of publications available in open access

Definition of indicator

This indicator is the proportion of a country's research publications that are available in open access (OA) as per Peter Suber's definition ([6]) of gratis OA, which refers to the removal of barriers to access; gratis OA thus includes libre OA, which refers to the removal of price barriers as well as permission barriers. In addition to the proportion of total OA, the indicator is also produced for two sub-types of OA: gold and green. The former refers to

> papers made available for free by the publishers themselves, be it on their website (e.g., in fully gold OA journals on Springer Open and BioMedCentral, or as hybrid OA, that is, OA papers from otherwise paywalled journals on, for example, Springer's website) or on the site of an aggregator (e.g., Scielo, and also PubMedCentral, on which the majority of papers are archived by the publishers themselves) (Archambault et al., 2016).

Green OA refers to

> papers made available for free by parties other than publishers, usually the authors themselves, who archive papers in institutional repositories or subject repositories such as arXiv, or commercial repositories such as ResearchGate. (Archambault et al., 2016).

Note that social media repositories such as ResearchGate and Academia are no longer indexed in the 1findr database (which is the data source that was used to compute this indicator, see below). However, OA papers from such repositories were included in this indicator in the last ERA progress report. Therefore, the share of papers available in OA is lower in many instances in this report than it was in the last edition.

In brief, 1science provided an index list of peer-reviewed publications available in OA through their 1Findr database.[7] The URLs pointing to the OA version of these publications were harvested and coded by OA type: gold or green. The sum of the proportions for gold and green OA add up to more than the total proportions of OA since there can be overlap in the categories;[8] though a single repository can be only green or gold in type, some papers can be accessible through multiple URLs, some of which may be coded as gold OA, while others may be coded as green OA. A single paper

[6] http://sparcopen.org/our-work/gratis-and-libre-open-access/

[7] https://1findr.1science.com/home

[8] In computing the total share of OA papers for a country, papers available in both green and gold OA were not double counted.

available through multiple online sources can thus be both green and gold, even though a single online source can only be green or gold.

Not all OA sources could be exhaustively tagged as green or gold given that the database covers hundreds of thousands of distinct URL domains, and thus a certain portion of these domains remained of unknown type prior to data production. Given the presence of these unknowns varied across countries, ranging from a few percentage points to up to 20, Science-Metrix designed an approach to account for these unknowns to avoid underestimating green and gold open access for the most affected countries. Because notably stronger efforts were made to code gold than green URLs in 1findr,[9] Science-Metrix hypothesised that green OA sources heavily dominated among the remaining unknown URLs. After manually validating this hypothesis using randomly selected URLs of an unknown type, we decided to automatically tag all the remaining URLs of an unknown type as green sources to avoid underestimating this category. This decision was strongly supported by the fact that about 90% of all remaining URLs on ERA publications could be tagged as green sources in the manual validation. To account for possible variation of the proportion of green OA sources among the URLs of an unknown type across countries, manual validations were also performed for some of the smallest ERA countries. This additional validation step confirmed that green sources, while still dominant (i.e. 70%), were less present for these countries than they were across the ERA. This is because previous efforts to code gold URLs were targeting URLs pointing to large number of papers. Accordingly, gold sources from smaller countries and with less content had less chances to be tagged during this initial coding effort. To alleviate any problem that could arise when trying to properly measure gold and green OA for these countries, the 30 most frequent unknown sources for each country were manually codified, ensuring that any notable remaining sources for each country were coded.

In the end, it is important to note that the effect of automatically attributing the remaining sources to the green category, while notable, is still small. Indeed, the maximal overestimations and underestimations of green and gold OA that could result from this decision is around 2 percentage points in both cases, and this is true for each country and the EU-28.

The OA papers, identified through the 1findr database, were then matched to a large-scale bibliographic database of peer-reviewed literature — the WoS™ — to enable computation of the proportion of all publications that is available in OA: total, green and gold.

Three scores are computed for the headline indicator for P5b: the share of all papers that is available in OA (all types), the share of all papers that is available in gold OA, and the share of all papers that is available in green OA. These indicators are simple to compute as they are the number of papers in the WoS that are also indexed in 1findr (total OA), and retrieved from gold sources (gold OA) or green sources (green OA), divided by the overall number of papers in the WoS.

Rationale

This indicator pertains to sub-priority 5b (optimal access to and circulation and transfer of scientific knowledge) and relates to the open access of publications and data resulting from publicly funded research. Open access articles are publicly accessible online without restrictions (DG Research and Innovation, 2015). Articles published in open access format can be freely read by anyone who can access the web. It therefore facilitates the mobility, transfer and circulation of knowledge between scientists, research institutions, the private sector and citizens who might lack the resources necessary to access the scientific literature, including circulation across national borders.

ERA members are expected to implement legal frameworks with the intention of making scientific research openly available (Science-Metrix, 2016), but open access may require more financial support from funders (DG Research and Innovation, 2015) since the publication costs related to open access publishing are otherwise covered by the authors. Several prominent organizations in the landscape of European research—including the European Commission—recently adopted Plan S, which sets an ambitious agenda for "all scholarly publications resulting from public research funding [to] be published in Open Access journals or on Open Access platforms" as of 2020.[10] This

[9] Gold URLs are generally easier to identify compared to green sources.

[10] https://www.scienceeurope.org/making-open-access-a-reality-by-2020/

indicator enables assessing the state of play as regards the extent to which ERA countries disseminate the results of their research via OA channels.

Computation method

Data needed

(PAP_{OA}) Number of publications in OA (includes gold and green OA publications): **Unit=Total (full counting)**;

(PAP_{Gold}) Number of publications in gold OA (Publication that can be retrieved through at least one URL pointing to a gold website): **Unit=Total (full counting)**;

(PAP_{Green}) Number of publications in green OA (Publication that can be retrieved through at least one URL pointing to a green website): **Unit=Total (full counting)**;

(PAP) Total number of publications: **Unit=Total (full counting)**.

Source of data

For *(PAP_{OA}, PAP_{Gold}, PAP_{Green})*: *1findr (https://1findr.1science.com/home) matched to the WoS™;*

For *(PAP)*: *WoS™ (Clarivate Analytics).*

Specifications

$$Share\ (\%)\ of\ Total\ OA\ publications = \frac{PAP_{OA}}{PAP} \times 100$$

$$Share\ (\%)\ of\ Gold\ OA\ publications = \frac{PAP_{Gold}}{PAP} \times 100$$

$$Share\ (\%)\ of\ Green\ OA\ publications = \frac{PAP_{Green}}{PAP} \times 100$$

Comments/critical issues

The share of publications available in OA can be provided by the publication year of the papers. However, a 2005 publication might only become available in OA years after its original publication date. This phenomenon, referred to as 'delayed OA' or the 'backfilling effect', makes it impossible to study the growth in the share of OA publications using a single snapshot (e.g. Summer 2018 in the case of this study) of those papers in the WoS™ that are available in OA. Although an analysis of the trend in the share of papers available in OA based on their publication year shows a strong increase based on this study's 2018 snapshot, the yearly shares (even those of earlier publication years) will continue to change with future snapshots; it is also normal for older papers to be less accessible via OA. To adequately study the growth of OA availability, it would be necessary to use trends based on the production year (or date) of the snapshots instead of only the publication year of the papers. Unfortunately, since the sources of OA harvesting for 1findr changed since the last ERA report (see definition section of this indicator) the two snapshots from 2016 and 2018 are not comparable and a growth analysis is not yet possible.

Nevertheless, in this study the analysis of trends based on the publication year revealed a striking drop in the share of OA papers in the most recent year (i.e. 2016, refer to the study's technical report for more details). This drop is particularly pronounced for green OA and appears to be due to short-term delayed OA, which is mostly attributable to embargo periods. These embargoes are a period following publication, after which publishers release the copyright of traditional subscription-based journals, thereby either making their full content directly available to the public, or making the content partially available by allowing researchers to post their papers online on various archives or personal websites. However, even after an embargo period elapses, it often still requires some further time before a paper will be available in green OA. The slightly lower levels of OA measured for recent years is a very common finding, known as the 'embargo effect'.

Finally, note that the proportions of OA papers computed in this study are slightly underestimated since, like any harvester, the 1findr database does not capture 100 % of all OA papers. A 2016

study estimated that the recall of the 1findr harvesting technology was approximately 75% (Archambault et al., 2016), though a similar study conducted in the past year showed that the recall has increased to roughly 80% with slight variations across subject areas (Science-Metrix, 2018). The figures presented in this study are unadjusted measurements; no correction factor has been applied.

2.9.4 P5b – EMM indicator – Share RFOs' (i.e. members of Science Europe or other important sources of national funding) publications that are available in OA

Definition of indicator

The indicator is the share of the publications supported by an RFO (identified through the funding acknowledgements) that are available in OA.

Rationale

This indicator pertains to sub-priority 5b (optimal access to and circulation and transfer of scientific knowledge) and relates to the open access of publications resulting from publicly funded research. It complements the indicator presented below (Section 2.10.1: Main RFOs that provide funds to cover the costs of making publications available in OA) by providing an output measure that can be used to assess whether the provision of funding to offset costs of OA publishing are contributing to the objective of higher levels of OA. This indicator, along with the identification of the RFOs (i.e. members of Science Europe or other important sources of national funding) that provide funds to cover costs of OA publishing replaced the indicator "share of RFOs that provide funds to cover the costs of making publications available in OA" originally identified by the ERAC as an EMM indicator for priority 5b.

Computation method

Data needed

(RFO_PAP_{OA}) Number of RFO-supported publications in total OA (includes gold and green OA publications): **Unit=Total (full counting)**;

(RFO_PAP_{Gold}) Number of RFO-supported publications in gold OA (Publication that can be retrieved through at least one URL pointing to a gold website): **Unit=Total (full counting)**;

(RFO_PAP_{Green}) Number of RFO-supported publications in green OA (Publication that can be retrieved through at least one URL pointing to a green website): **Unit=Total (full counting)**;

(RFO_PAP) Number of RFO-supported publications: **Unit=Total (full counting)**;

Source of data

For *(*RFO_PAP_{OA}*,* RFO_PAP_{Gold}*,* RFO_PAP_{Green}*)*: *1findr (https://1findr.1science.com/home) matched to the WoS™;*

For *(*RFO_PAP*)*: *WoS™ (Clarivate Analytics).*

Specifications

$$Share\ (\%)\ of\ RFO\ publications\ in\ OA = \frac{RFO\_PAP_{OA}}{RFO\_PAP} \times 100$$

$$Share\ (\%)\ of\ RFO\ publications\ in\ Gold\ OA = \frac{RFO\_PAP_{Gold}}{RFO\_PAP} \times 100$$

$$Share\ (\%)\ of\ RFO\ publications\ in\ Green\ OA = \frac{RFO\_PAP_{Green}}{RFO\_PAP} \times 100$$

Comments/critical issues

The publications that were supported by an RFO were identified through *WoS™* funding acknowledgements. Note that the coverage of funding acknowledgement by *WoS™* is not

exhaustive and may vary across disciplines. However, recall rates (i.e., papers with a funding acknowledgement section that are actually found in WoS funding acknowledgement table) of more than 90% were observed in one study of UK researchers by Science-Metrix in 2018 (unpublished data) and in another study on UK cancer research in 2011 (Rotolo et all, 2016). One of the main concerns with funding acknowledgements is that the funding organisation names are sometimes misspelled, or a name variant was used. To maximize recall Science-Metrix performed a fuzzy search of the RFOs' names and acronyms in WoS' acknowledgements data.

2.9.5 P5b – EMM indicator – Share of life sciences papers to which a country contributed and that have at least one open dataset in Figshare

This indicator replaces the indicator "Share of RPOs making their research data available in OA" originally identified by the ERAC as an EMM indicator for priority 5b. The computation of the original indicator was not possible without an exhaustive list of RPOs for each country of the ERA as well as an assessment of open data availability for each of them. The new indicator covers a part of the open access data dimension that should have been captured by the original indicator.

Definition of indicator

The indicator is the proportion of life science papers to which a country contributed and that have at least one open access dataset available through the Figshare repository.

Rationale

This indicator pertains to priority 5b (optimal access to and circulation and transfer of scientific knowledge) and focuses on the open access status of the data used by researchers to perform their research. Research data is an integral part of scientific research ecosystem and the principles of access, circulation and transfer under priority 5b should also apply to research data. It is therefore relevant to track this dimension of open access.

Computation method

Data needed

(PAP_{OA_data}) Number of publications for which a dataset is available in OA on FigShare (note that the paper itself does not have to be available in OA): **Unit=Total (full counting)**;

(PAP) Total number of publications in the life sciences: **Unit=Total (full counting)**.

Source of data

For *(*PAP_{OA_data}*)*: DOIs of peer-reviewed papers linked to open datasets (type = dataset) in FigShare (https://figshare.com/account/home) matched to the *WoS™;*

For *(PAP)*: *WoS™ (Clarivate Analytics) with Science-Metrix' subfields (Archambault, Caruso and Beauchesne, 2011) set to: Agronomy & Agriculture, Dairy & Animal Science, Fisheries, Food Science, Forestry, Horticulture, Veterinary Sciences, Bioinformatics, Biotechnology, Biomedical Engineering, Medical Informatics, Anatomy & Morphology, Biochemistry & Molecular Biology, Biophysics, Developmental Biology, Genetics & Heredity, Microbiology, Microscopy, Mycology & Parasitology, Nutrition & Dietetics, Physiology, Toxicology, Virology, Allergy, Anesthesiology, Arthritis & Rheumatology, Cardiovascular System & Hematology, Complementary & Alternative Medicine, Dentistry, Dermatology & Venereal Diseases, Emergency & Critical Care Medicine, Endocrinology & Metabolism, Environmental & Occupational Health, Gastroenterology & Hepatology, General & Internal Medicine, General Clinical Medicine, Geriatrics, Immunology, Legal & Forensic Medicine, Neurology & Neurosurgery, Nuclear Medicine & Medical Imaging, Obstetrics & Reproductive Medicine, Oncology & Carcinogenesis, Ophthalmology & Optometry, Orthopedics, Otorhinolaryngology, Pathology, Pediatrics, Pharmacology & Pharmacy, Psychiatry, Respiratory System, Sport Sciences, Surgery, Tropical Medicine, Urology & Nephrology, Behavioral Science & Comparative Psychology, Clinical Psychology, Developmental & Child Psychology, Experimental Psychology, General Psychology & Cognitive Sciences, Human Factors, Psychoanalysis, Social Psychology, Epidemiology, Gerontology, Health Policy & Services, Nursing, Public Health, Rehabilitation, Speech-Language Pathology & Audiology, Substance Abuse,*

Ecology, Entomology, Evolutionary Biology, Marine Biology & Hydrobiology, Ornithology, Plant Biology & Botany, Zoology, Medicinal & Biomolecular Chemistry, Environmental Sciences, Oceanography, Paleontology.

Specifications

$$\text{Share of life sciences papers that have at least one open dataset in Figshare} = \frac{PAP_{OA\_data}}{PAP} \times 100$$

Comments/critical issues

FigShare is a digital repository where researchers can store and share their datasets, figures, papers or other digital materials. For the computation of this indicator, only the dataset file type was used. Most datasets contain a DOI that links them to a published paper. Using the DOIs, the papers associated to a dataset were matched to the *WoS™* database. Roughly 70% of the DOIs were matched to the *WoS™* database*;* the remaining 30% were either recent papers not yet indexed in *WoS™* or papers from sources that are not covered by the *WoS™*.

In total, 78 318 papers linked to at least one OA dataset were matched to *WoS™* for the 2013–2017 period. Note that the majority of these papers (94%) were published in PloS journals such as PloS One (88%), PLoS Neglected Tropical Diseases (2.4%), PLoS Genetics (1.3%) and PLoS Computational Biology (1.3%). Since all these journals focus on the life sciences,[11] it is fair to say that the indicator based on this data focuses on life sciences as well. Note that the share of papers in the life sciences for each country is highly correlated (r^2 = 97%) with the share of papers with an OA dataset, and therefore there is no notable bias against countries that publish less in life science. Although Figshare is a generalist repository for datasets in any field of science, it does not equally cover all areas of science and the number of papers with at least one OA dataset in Figshare must therefore be normalised by the total number of a country's papers in the life sciences.

The predominance of PloS One in Figshare is likely due to its policy requiring researchers to share the data underlying their papers (Federer et al., 2018). Thus, before the proposed indicator on OA datasets can be applied more broadly to all fields of science in monitoring progress on Priority 5b of the ERA, governments will likely need to take actions to substantially increase the adoption of policies similar to those of PloS One among a wide range of publishers. Ideally, these policies should specify the preferred pathway to release research data in OA. Such a pathway should ideally be uniform across publisher to centralise access to open research data. The use of a common platform across all fields of science would carry many benefits such as: uniformity of quality (e.g. standard format) of OA datasets and a centralised repository to track progress. To ease the process for researchers, the publishers could offer an integrated submission system to the centralised repository. Since Figshare provides almost 90% of OpenAire—a network of OA repositories—content on research data, and because OpenAire was developed to implement the European Commission's and the European Research Council's OA policies, Figshare appears as a key choice for such a centralised repository for all fields of science.

2.9.6 P6 – Headline indicator – International co-publications with non-ERA partners per 1 000 researchers in the public sector

Definition of indicator

Using fractional counting (refer to Annex 1 for a definition of fractional counting), this indicator measures the number of publications of an ERA country (or region within the ERA) involving at least another co-author from a non-ERA country. The number is presented relative to the given country's (or region's) researcher population size.

Rationale

This indicator pertains to priority 6, which promotes the openness of MS/AC for international cooperation beyond the ERA. The number of international co-publications with non-ERA partners per 1 000 researchers in the public sector is a good proxy to measure the outcomes resulting from

[11] While PloS One is a generalist journal, its content is mostly concentrated in the life sciences.

actions designed to achieve this priority. The normalisation by the number of researchers accounts for size differences across countries, allowing their direct comparison.

Computation method

Data needed

($PAP_{NON\text{-}ERA.COLLAB}$) Number of co-publications with non-ERA countries: **Unit=Total (fractional count)**;

(RES_{HES}) Researchers in the higher education sector: **Unit=Full time equivalent (FTE)**;

(RES_{GOV}) Researchers in the government sector: **Unit=Full time equivalent (FTE)**.

Source of data

For *($PAP_{NON\text{-}ERA.COLLAB}$)*: *WoS™ (Clarivate Analytics);*

For *($RES_{HES\ or\ GOV}$)*: *Eurostat—Statistics on research and development (online data code rd_p_persocc).*

Filters applied

For *(RES_{HES})*:
SECTPERF set to "Higher education sector"
OCCUP set to "Researchers"
SEX set to "Total"
UNIT set to "Full-time equivalent (FTE)"

For *(RES_{GOV})*:
SECTPERF set to "Government sector"
OCCUP set to "Researchers"
SEX set to "Total"
UNIT set to "Full-time equivalent (FTE)"

Specifications

$$Intl.co-publications\ with\ non-ERA\ partners\ per\ 1\,000\ researchers = \frac{PAP_{NON-R\ .Collab}}{\left(\frac{RES_{GOV}+RES_{HES}}{1000}\right)}$$

EU-28 computation

Numerator is the sum of all Member State's number of co-publications with non-ERA countries. Note that since fractional count is used this calculation does not lead to double counting.

Denominator is the sum of Eurostat pre-computed EU-28 scores for researchers in the higher education sector and researchers in the government sector.

No MS are missing from the EU-28 score.

Comments/critical issues

As most peer-reviewed scientific publications involve an actor from the public sector (at least 97 % in recent years; Science-Metrix, unpublished data), the denominator for this indicator was limited to the government and higher education sectors.

2.10 Directory and registry of open access policies (MELIBEA & ROARMAP)

2.10.1 P5b – EMM indicator – RFOs (i.e. members of Science Europe or other important sources of national funding) providing funds to cover costs of OA publishing as of August 2018

The ERAC originally identified the "Share of RFOs that provide funds to cover the costs of making publications available in OA" and the "Share of RPOs making their research data available in OA" as the two input indicators for priority 5b. However, to compute these shares for each ERA country,

one would need the list of all RFOs and RPOs in each country as well as the status of OA publications fund provision for all RFOs and OA data availability for all RPOs. Such data was impossible to obtain at reasonable cost and in a timely manner when the ERA progress report 2016 was produced. Therefore, these two indicators were not computed.

In the 2018 edition, the "Share of RPOs making their research data available in OA" was replaced with the "Share of life sciences papers to which a country contributed and that have at least one open dataset in Figshare" (see Section 2.9.5). The "Share of RFOs that provide funds to cover the costs of making publications available in OA" was replaced with "RFOs (i.e. members of Science Europe or other important sources of national funding) providing funds to cover costs of OA publishing as of August 2018".

Definition of indicator

The indicator is reported as a list of 58 RFOs with a binary value (yes/no) that indicates if the RFOs provide funds to cover the costs of OA publishing. Other information is also reported, such as membership of Science Europe, presence or absence on MELIBEA and ROARMAP databases and mechanisms of OA publishing cost coverage.

Rationale

This indicator pertains to sub-priority 5b (Open Access) under priority 5 (Optimal circulation, access to and transfer of scientific knowledge). In order to fulfil priority 5, researchers are encouraged to publish their research results in open access venues (see rational indicator 2.9.2). However, publishing in such venues is usually more expensive than publishing in a traditional journal. There are many reasons for these increased costs, but the chief concern is that the fees required to publish in these venues represent a shift in financial burden from those who read journals to those who publish in them. It is therefore of primordial importance that researchers are given the incentives and tools to publish in OA venues, including measures to help them offset increases to the cost of publishing their work. Accordingly, it is highly relevant to track the RFOs across the ERA that financially support OA publishing for their researchers.

Source of data

Registry of Open Access Repository Mandates and Policies (ROARMAP) database (https://roarmap.eprints.org/)

Directory of institutional open access policies (MELIBEA) database (http://www.accesoabierto.net/politicas/?idioma=en)

Science Europe Open Access Survey Report (https://www.scienceeurope.org/wp-content/uploads/2016/10/SE_OpenAccess_SurveyReport.pdf)

Specifications

MELIBEA and ROARMAP were the main sources of data for this indicator. Complete extractions from each source were made in August 2018.

The "State of Play" table in annex to the 2016 *Open Access Survey Report* from ScienceEurope (https://www.scienceeurope.org/wp-content/uploads/2016/10/SE_OpenAccess_SurveyReport.pdf) was used as a supplemental source. It was used primarily to fill in fields still empty after the analysis of MELIBEA and ROARMAP. Additionally, it provided a tiebreaker in the case of the Netherlands Organisation for Scientific Research (NWO), about which MELIBEA and ROARMAP disagreed; it also referenced a more recent policy for the Research Council of Norway (RCN), and therefore trumped the older information extracted from MELIBEA.

Finally, manual web searching was used to fill in empty fields and to validate data collated from the sources discussed above. This manual searching included the names of the funders (in English as well as in the local language of the funder, when that language used the Latin alphabet), along with terms such as "open access" + "policy" + "APC" + "article processing charge" + "author publishing cost" and so forth.

Comments/critical issues

It is worth considering that reducing policy mechanisms to binary variables often levels off interesting variations among them. For instance, among the funders that provide supplemental funding, some accept researcher applications directly to offset their article processing charges (APCs), whereas other funders have the application process managed locally through the institutions at which the researchers are working. Variation of these types cannot be reflected in such a condensed format.

3 GENERAL APPROACH TO THE ANALYSIS AND PRESENTATION OF QUANTITATIVE INDICATORS

The general time frame to be assessed was the 2007-2017 period, with each results table providing an assessment of static performance in the most recent year for which high-quality data was available across countries, as well as a longitudinal assessment of evolving performance, where the length of this assessment period was again determined by quality of available data. As very up-to-date data was often unavailable to compute a given indicator for certain countries, the selection processes for performance snapshots required balancing country coverage with the timeliness of assessment, to ensure that the need for a very timely snapshot did not exclude the coverage of too many countries, and that the need for exhaustive coverage across countries did not lead to the assessment of outdated results.

The quantitative results tables present two growth measures; one covers the long-term period, i.e., 2007-2017 when the data is available, and the second growth measure covers a short-term period which intends to assess the evolution of a country performance since the 2016 ERA monitoring exercise up to the most recent available year. Both growth measures are displayed as a compound annual growth rate (CAGR), which shows the average year-over-year change in a country's performance, taking compounding effects into account. The CAGR assumes an exponential growth between the starting and ending year of a reference period, which is rarely the case across all countries, especially for the smaller ones. Additionally, there is some temporal heterogeneity among the selected indicators: some measure the structural aspects of a nation that change in the long term, whereas others show high short-term fluctuations in many countries. The long-term CAGR measures growth using the longest available period for each indicator (from 2007 onward) and therefore, it might indicate an upward or downward trend that no longer holds in the most recent years, especially for the smaller countries and indicators subjected to short-term fluctuations. The short-term growth addresses this issue by indicating the most recent trend of a country along an indicator. In this ERA Progress Report's tables, a micro bar chart showing the actual trend for each country is presented next to the CAGR to help detect both long-term and short-term progress towards realising the ERA.

As no explicit, quantitative targets have been established as a definition of having 'achieved the ERA', the static assessment of performance in the ERA Progress Report cannot meaningfully speak of how well one country or region is standing relative to that target, nor how fast one country or region is progressing or regressing relative to that target in the longitudinal assessment. This issue stems from the fact that the goals to be reached in achieving the ERA constitute moving targets (e.g. ERA priorities and actions to achieve them are continuously evolving along with the needs of European societies). As such, it is difficult to establish reference values to be attained in relation to specific ERA policy actions; some of these targets could become obsolete in between each EMM round. Thus, both the performance and progress of countries are benchmarked against one another and against the EU-28 average ([12]), displayed in percentage point difference for the CAGR (displayed in the ERA Progress Report's tables). This lead/gap analysis for growth has been colour-coded, from blue for the lowest scores to orange for the highest scores, to facilitate visual identification of patterns in performance ([13]). Performance scores in the most recent available year are colour-coded in a similar fashion from blue for the lowest scores to orange for the highest

[12] Weighted averages are usually used to ensure representativeness of the whole (i.e. as if the EU-28 was a single country). Refer to Section 2 for details on how EU-28 scores were computed by indicator.

[13] Assuming progress is reflected by increased scores over time for all indicators, except those characterised by a tipping point after which further increases lead to greater imbalance (e.g. share of women researchers).

scores. Additionally, performance in the most recent year is also benchmarked relative to each ERA member. This benchmarking is conveyed through the clustering approach implemented throughout the ERA Progress Report ([14]). As mentioned above, because explicit targets are not defined for these indicators, the distance to such a target cannot be measured. When country-level performance is compared to the ERA (unweighted) and EU-28 (weighted) averages, these averages should not be conflated with targets. For instance, the EU-28 (weighted) averages is close to 20 % for some gender parity indicators, while a reasonable target would likely lie between 40 % and 60 %, which would reflect absolute parity.

The following guide to reading the quantitative results tables was added to the technical report of the 2018 ERA Progress Report.

Guide to reading the quantitative results tables

Because the goals to be reached in achieving the ERA constitute moving targets (e.g. the ERA priorities and actions to achieve them are continuously evolving along with the needs of European societies), it is difficult to establish reference values to be attained in relation to specific ERA policy actions; some of these targets could become obsolete in between each EMM round. Consequently, it is not possible to directly speak of a country's level of compliance in achieving each of the six priorities towards realising the ERA. Instead, the current state of play, as well as trends, are presented for all indicators in order to monitor the performance and progress ([15]) of countries relative to one another, and to the ERA average (unweighted) — instead of relative to country-specific targets. This is done for each ERA priority, or more specifically the ERA action, they each intend to measure.

Thus, each table shows country-by-country scores for national performance based on the indicator in question. The average of performance for the EU-28 ([16]) is also presented, as is a lead/gap analysis showing how much further ahead or behind a given country is relative to the EU-28 performance. The lead/gap in performance is presented as a percentage of the EU-28 score by which a given country is ahead/behind that score. Countries are sorted in descending order of performance, meaning that the strongest performers appear at the top, with softer and softer performance results as one reads down the table. Note that the EU-28 score might not represent an appropriate target for many of the smaller countries, although care was taken to use normalised indicators, usually by incorporating the size of a country's population, researcher population or economy in the denominator of an indicator. Also, the EU-28 score might in some cases be lower than the level of performance that would be optimal towards achieving the ERA; for instance, gender equality might not have been reached in all relevant aspects at the EU-wide level. Thus, the comparisons to the EU-28 score are intended to help individual countries situate themselves relative to the core of the EU, so as to inform their decisions on which targets are most appropriate to them and on the ways to achieve them.

[14] The strongest performances are found in Cluster 1, which is more than one standard deviation above the ERA (unweighted) mean; the next strongest performances are found in Cluster 2, which is above the ERA mean, but within one standard deviation of it; performances listed in Cluster 3 are below the ERA mean, but within one standard deviation thereof; and finally the performances listed in Cluster 4 are the lowest, being more than one standard deviation below the ERA mean. Under this clustering approach, and assuming a normal distribution of the scores, 16 % of the countries should fall in each of Cluster 1 and Cluster 4, while there should be 34 % of countries in each of clusters 2 and 3. This approach therefore aims to highlight the few countries that really stand out above or below the ERA average (i.e. respectively those in Cluster 1 and Cluster 4). In some cases where results are highly skewed (i.e. with a few countries showing very high scores and the rest being concentrated in the low scores; in other words, the distribution is not normally distributed), it would be mathematically impossible to be more than one standard deviation below the mean, and in these cases, there is no Cluster 4. In such cases, Cluster 3 can in fact be interpreted as a merge of clusters 3 and 4. In exceptional circumstances, some data points (i.e. outliers) were presented and categorised, although they were not used in computing the ERA average (and the associated standard deviation) to determine the clusters' boundaries. Data points were considered as outliers if they were more than four standard deviations away from the ERA average. In a normal distribution, 100 % of data points must lie within four standard deviations of the average.

[15] Assuming progress is reflected by increased scores over time for all indicators, except those characterised by a tipping point after which further increases lead to greater imbalance (e.g. share of women researchers).

[16] In cases where data for EU-28 Member States were not available, the weighted average (see Footnote 12 for explanation on the choice of a weighted average) is based on fewer countries and footnoted accordingly, though still labelled 'EU-28' for consistency. For some indicators, the EU-28 score is not a weighted average (see Section 2).

For the same purpose, the countries are also clustered into groups based on performance. This clustering operation is based on the distribution of scores for all ERA countries for which data are available; countries more than one standard deviation above the ERA average (unweighted (see Footnote 14) average across the MS/AC for which data are available) for a given indicator are in Cluster 1, the strongest cluster; those at or above the ERA average but within one standard deviation are in Cluster 2; those below the average but within one standard deviation are in Cluster 3; those more than one standard deviation below the ERA average are in Cluster 4, being the least performing cluster ([17]). For each country and cluster, the percentage of the ERA GDP that is accounted for by each country and cluster is provided as a reference of the country/cluster GDP weight among the ERA countries ([18]); at the cluster level, this helps in appreciating the share of the ERA's global economy that is found in each performance cluster, as well as the importance of the progress — from an ERA-wide perspective — made in each cluster ([19]).

In addition to a measurement of performance in 2017 (or the most recent reference year for which sufficient data were available at the time of producing this report ([20])), the indicator tables also assess changes in national performance over time, computed as a Compound Annual Growth Rate (CAGR). Note that progress is measured both in the long and short term. The long-term CAGR is obtained by comparing the latest available data to 2007 — that is, at the same time as the launch of the European Commission's Seventh Framework Programme for Research and Technological Development (FP7) — or the earliest available year for each indicator, rather than in relation to achieving a specific target. The short-term CAGR aims to assess recent progress made since the ERA *Progress Report 2016*. Accordingly, it compares the latest available year in the 2016 report to the latest available year in this report using the updated time series (for some indicators, there have been retrospective changes in the data). As with the analyses on the performance of countries, a lead/gap analysis for short-term growth shows the difference between each country's CAGR and the CAGR of the EU-28 score. This comparison in growth is intended to inform individual countries on the extent to which the gap between their level of performance and that of the EU-28 is closing or widening so that they can better assess the extent to which new actions are required to help them achieve their respective targets.

The CAGR assumes an exponential growth between the starting and ending year of a reference period, which is rarely the case across all countries, especially for the smaller ones. Additionally, there is some temporal heterogeneity among the selected indicators: some measure the structural aspects of a nation that change in the long term, whereas others show high short-term fluctuations in many countries. Since the long-term CAGR measures growth using the longest available period for each indicator (from 2007 onward, where data were available), it might indicate an upward or downward trend that no longer holds in the most recent years, especially for smaller countries and indicators subjected to short-term fluctuations. In the ERA Progress Report's tables, a micro bar chart showing the actual trend for each country is presented next to the long-term CAGR to help detect both long-term and short-term progress towards realising the ERA. For the indicator on Gender dimension in research content, where short-term fluctuations were particularly pronounced, moving averages have been used to measure performance and growth (e.g. average scores across 2007-2009, 2008-2010 … 2015-2017). In such cases, the CAGR measures the year-on-year per cent change in the rolling average of an indicator between the starting and ending periods (e.g. between 2007-2009 and 2015-2017).

Note that the lead/gap analysis in growth is simply the percentage point difference between a given country and the EU-28 short-term CAGR (directly shown in the ERA Progress Report's tables). For example, if a given country has a performance score of 0.75 and the EU-28 average is 0.50, the country's lead would be 50 %. However, if a country's short-term CAGR is 7.5 % and the EU-28 average is 5.0 %, the country's lead would be 2.5 percentage points.

Country-by-country results for performance and short-term growth have been colour-coded to ease the reading of tables, with blue representing the lower scores and orange representing the higher scores. The connection between performance and short-term growth is a point of interest to follow throughout the ERA Progress Report,

[17] For each indicator, countries for which sufficient data were not available have not been included in the respective results table. Furthermore, these countries have not been integrated into the calculation of averages or standard deviations, which are used to delineate the thresholds between the clusters. For further information on the clustering methods, refer to Footnote 14.

[18] The ERA GDP is equal to the sum of GDP across the countries for which data are available for each indicator. Because this set of countries varies across indicators, the percentage of the ERA GDP that is accounted for by each country/cluster varies slightly across indicators. Also, the reference year used for the GDP matches that of the presented indicator; in cases where no GDP data are available for the reference year of an indicator, 2016 was used for computing the GDP weight.

[19] It is worth noting that the clustering is based on ERA averages (unweighted), while the lead/gap analysis is relative to the EU-28 scores (weighted); accordingly, it is possible for a country to be in Cluster 2 but have a negative lead/gap score, signifying that they are above the ERA average, but below the EU-28 average.

[20] Refer to Table 9 for the extraction dates of the presented data.

as it shows whether countries lagging somewhat behind are catching up to their stronger counterparts in progressing towards the ERA, or whether the stronger performers are pulling further away from the pack.

The performance–short-term growth connection for each indicator can be assessed visually based on the colour-coding of results: performance scores will always be sorted from orange at the top to blue at the bottom, so if short-term growth scores are predominantly orange at the top and blue towards the bottom, one can conclude that the leaders are pulling away from the pack; contrarily, if short-term growth scores are predominantly blue at the top and orange towards the bottom, this finding shows that those behind are catching up, closing the gap to the leaders.

An example of a typical indicator table that is used throughout the ERA progress report 2018 is shown in Table 2. In this table, the current performance (i.e., most up to date data that was available for most of the countries) is reported for 2016, the short-term growth spans from 2014 (performance year reported in the ERA progress report 2016 for this indicator) to 2016 and the long-term growth covers 2009 to 2016. There are some exceptions, for example, the situation for Iceland (IS) is particular; in 2014 there was a break in time series that resulted in a drastic change of the indicator value for the following years. The short-term growth was not affected, but the long-term growth was not computed because the change was too drastic and would induce a false impression of negative growth. Poland (PL) is also a great example of how the micro bar chart can show a different situation than what is conveyed by both the short and long-term growth. Indeed, Poland score for the last reported year (2016) is drastically lower than in all previous years (it was flagged as a potential outlier, see table's note) resulting in negative CAGRs. However, a visual examination of the micro bar chart shows that the country has actually increased its score if we only consider years up to 2015. Therefore, the picture for Poland is probably not as bad as the values show (except if the 2016 data point, as well as the preceding data points, are accurate) and interpretation of this result must be done cautiously.

Table 2 Sample table showing the presentation layout used to report the data for each indicator — GBARD as a percentage of GDP (2009–2016)

Country	Weight in GDP	Score (2016)	CAGR			
			Short-term (2014-16)	Lead/Gap to EU-28 CAGR	Long-term (2009-16)	Trendline
EU-28		**0.64%**	**-2.4%**	**N/A**	**-2.3%**	
Cluster 1	30.6%	0.89%	-0.5%	1.8	0.2%	
Cluster 2	56.9%	0.62%	-0.7%	1.6	-0.8%	
Cluster 3	9.3%	0.34%	0.5%	2.8	-4.1%	
Cluster 4	3.2%	0.14%	-9.7%	-7.3	-3.0%	
Cluster 1						
NO	2.0%	0.99%	7.7%	10.1	2.3%	
DK	1.7%	0.92%	-4.0%	-1.6	-0.9%	
PT	1.1%	0.91%	-1.8%	0.5	-1.4%	
CH	3.6%	*0.90%*	:	:	*3.3%*	
DE	18.8%	0.87%	0.2%	2.6	-0.1%	
FI	1.3%	0.85%	-6.5%	-4.1	-3.2%	
AT	2.1%	0.81%	1.2%	3.6	1.2%	
Cluster 2						
SE	2.8%	0.78%	-3.3%	-0.9	-1.4%	
HR	0.3%	0.74%	2.0%	4.4	0.9%	
NL	4.2%	0.70%	-2.1%	0.3	-1.6%	
EE	0.1%	0.69%	-2.1%	0.3	0.1%	
BE	2.5%	0.64%	-3.5%	-1.1	-0.5%	
FR	13.3%	0.63%	-4.4%	-2.0	-5.0%	
LU	0.3%	0.61%	-1.9%	0.5	1.9%	
CZ	1.1%	0.59%	-3.7%	-1.3	0.0%	
IS	0.1%	0.57%	2.5%	4.9	:	
EL	1.0%	0.54%	11.4%	13.8	6.2%	
ES	6.7%	0.54%	-1.4%	1.0	-5.5%	
UK	14.4%	0.52%	-3.2%	-0.8	-2.3%	
IT	10.0%	0.52%	-0.1%	2.2	-2.5%	
Cluster 3						
SI	0.2%	0.40%	-3.1%	-0.7	-7.2%	
HU	0.7%	0.40%	19.0%	21.4	-1.9%	
RS	0.2%	0.38%	-3.9%	-1.6	:	
SK	0.5%	0.37%	-1.0%	1.4	0.6%	
CY	0.1%	0.33%	-3.4%	-1.0	-4.4%	
LT	0.2%	0.32%	-4.2%	-1.9	-6.8%	
TR	4.7%	0.29%	2.4%	4.8	-3.2%	
RO	1.0%	0.28%	14.8%	17.2	-0.5%	
IE	1.6%	0.26%	-16.4%	-14.0	-9.5%	
Cluster 4						
LV	0.1%	0.21%	14.2%	16.6	0.6%	
BG	0.3%	0.20%	-10.2%	-7.8	-6.4%	
MT	0.1%	0.20%	-6.3%	-4.0	3.7%	
PL	2.5%	0.16%	-39.1%	-36.8	-9.9%	
BA	0.1%	0.04%	-6.8%	-4.5	:	
MK	0.1%	*0.01%*	:	:	:	

Note: Break in time series: EE (2016); PL (2012); RO (2013); IS (2014)
Definition differs: AT (2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016)
Estimated: DK (2015, 2016); EE (2009, 2010, 2011, 2012, 2013, 2014, 2015)
Provisional: 2016 (CY, FR, PT, RO, MK); EL (2011, 2012, 2013, 2014, 2015, 2016); ES (2015, 2016)
Potential outlier: HU (2013); PL (2016)
Exception to reference year: MK (2014); CH (2015)
Exception to long-term reference period: CH (2010-2015)
Data unavailable: AL, AM, FO, GE, IL, MD, ME, TN, UA
(:) = missing data

Source: Computed by Science-Metrix using Eurostat data (online data codes: gba_nabsfin07 and nama_10_gdp)

4 ADDITIONAL RELEVANT DETAILS

Computation of EU-28 aggregate scores

When reporting EU-28 aggregates, two core methods have been used to compute the score for the EU-28, depending on the data composing the reported indicator. If an EU-28 aggregate was already available from the data source, then the already aggregated score was used. It is often the case for data produced by Eurostat. For example, Eurostat provides EU-28 aggregate scores for GBARD and GDP that are used in computing the *"GBARD as a percentage of GDP"* indicator.

When a pre-aggregated score was not available, Science-Metrix computed it by summing the score of each MS separately for each part of the indicator (i.e. the numerator and the denominator). For example, when an indicator is a ratio between two values, the EU-28 numerator will be the sum of all MS numerators and the EU-28 denominator will be the sum of all MS denominators resulting in a weighted average across MS. This is the case for the indicator *Share of doctoral candidates with a citizenship of another EU Member State* for the year 2013. Also, since a trend analysis is provided, special care was taken to ensure that the MS constituting the EU-28 score stayed the same throughout the presented period; for a few indicators, some MS are excluded from the EU-28 aggregate scores due to missing data. The reporting periods were chosen to maximise the number of MS with available data. The footnote of each table describes which MS were excluded from the EU-28 score, if any.

Note that in some cases, when a Member States was missing a year or two of data, the missing scores were imputed from the previous or subsequent year. This way, the EU-28 aggregate includes data from all MS for all years. Note that imputation was performed only when one or two data points were missing, otherwise the MS was not included in the EU-28 average. In those cases, the tables' notes clearly state which MS is missing or which MS and year were imputed. The imputation was done according to the same rules as in the EIS, that is:

- missing data point at the beginning of series -> set to the next available year;
- missing data point at the end of series -> set to the latest available year; or
- missing data point between two available points -> set to prior year.

Some indicators may also include both methods — that is, a part is computed by summing each MS value and the other part comes from a pre-aggregated score. This is the case for the indicator *Member States participation in Public-to-public partnerships per researcher in the public sector*, the numerator was computed by summing all MS participation in public-to-public partnerships and for the denominator, the EU-28 aggregated score from Eurostat was used.

There are a few other instances where the EU-28 score is an unweighted, rather than a weighted, average of the MS scores. One such example is the *Share of developing ESFRI projects and operational ESFRI Landmarks in which a Member State or an Associated Country is a partner* (Section 2.1.2). In that case, a weighted average is not applicable since all MS share a fixed value in the denominator.

Limits and possible biases in Headline and EMM indicators

Although the Headline and complementary EMM indicators were chosen as those most relevant in measuring progress towards the ERA, and as those most objective and impartial in performing cross-country comparisons among MS/AC, it is possible that some indicators present some biases favouring specific countries to the detriment of others. Among the possible biases, it is recognised that a country's size, geographic location and home language can exert a significant effect on, for example, the extent to which a country gets involved in various types of cross-country partnerships. Table 3 lists the biases that can most likely affect the selected EMM indicators (including the Headline indicators). In Table 4 the reader will find a matrix of the Headline and complementary EMM indicators organised by priority and type. The coloured capital letter or letters at the end of each indicator indicate which biases from those listed in Table 3 may apply to the indicator.

Table 3 List of possible biases applicable to the headline and EMM complementary indicators

Problem	Definition
Question of optimum **O**	What is the optimum? It is not necessarily 100 % for project-based funding or 100 % for the share of females.
Question of balance **B**	As regards gender, one should aim at gender balance, not at maximising the share of one gender. Is a perfect balance/an optimum 50 %? (Women are, however, more than 50 % of the population, but below 50 % in the younger cohorts.) One might need to develop an indicator that reaches its maximum at 50 %. For PhD graduates, the share of female graduates might soon exceed 50 %.
Country size bias (in favour of small countries) **CS**	Small countries tend to be more international than larger countries, especially if they share a common language with a larger country.
Country size bias (in favour of large countries) **CL**	Some indicators make use of a fixed denominator across countries resulting in an advantage for the larger economies.
Country location bias **L**	Countries at the geographic centre of the EU might have a higher share of intra-EU cooperation, while countries at the periphery of the EU or bordering non-EU countries might have a higher share of non-EU cooperation. There may be additional linguistic/historical biases: countries with international languages or countries that have been colonial powers might have a higher share of non-EU cooperation.
Economic structure bias **S**	Countries with a high share of manufacturing industry tend to have a higher propensity to commercialise product than countries with a lower share of manufacturing. Countries that host the headquarters of large companies tend to have a higher level of patenting than countries that do not. Countries with a high share of pharma, biotech, ICT, software and electrical machinery companies tend to have more scientific publications issued from the private sector than countries without such industries.
Country level data only in binary form **BI**	In some cases, indicators can take a binary form (e.g. 0/1 or yes/no), such as for the availability of national roadmaps with identified ESFRI projects and corresponding investment needs (ESFRI). This is too little information for benchmarking countries.
Periodicity of data collection **P**	Data might not be updated annually (for example, results of the MORE study, She Figures is 3-yearly only, some of the She Figures data might, however, be available annually, Cooperation innovative survey is biannual).
Historical factors **H**	Some data might be influenced by historical factors; e.g. the UK and France have many non-ERA students and PhDs from former colonies.

Note: The coloured capital letters are matched to headline and EMM indicators in Table 4.
Source: Assembled by Science-Metrix from ERAC documentation

Table 4 Matrix of Headline and complementary EMM indicators with potential bias(es) identified

Priority	Input Indicator	Output Indicator	Outcome/Impact Indicator
Priority 1: More effective national research systems	GBARD as percentage of GDP (Eurostat)	Adjusted Research Excellence Indicator (REI) (source: JRC)	European Innovation Scoreboard Summary Innovation Index (SII) (source: EIS)
Sub-priority 2a: Optimal transnational cooperation	Member States participation in public-to-public collaborations per FTE researcher in the public sector (Eurostat and ERA-Learn 2020 report on P2P) **CS**	GBARD allocated to Europe-wide transnational, as well as bilateral or multilateral, public R&D programmes per FTE researcher in the public sector (Eurostat) **CS**	International co-publications with ERA partners per 1 000 researchers in the public sector (WoS and Eurostat) **CS, L**
Sub-priority 2b: European Strategy Forum on Research Infrastructures (ESFRI)	Share of developing ESFRI Projects in which a Member State or an Associated Country participates (ESFRI) **CL**	Availability of national roadmaps with identified ESFRI projects and corresponding investment needs (ESFRI) **BI**	Share of operational ESFRI Landmarks in which a Member State or an Associated Country is a partner (ESFRI) **CL**
Priority 3: Open Labour Market for Researchers	Share of doctoral candidates with a citizenship of another EU Member State **CS, L**	Researcher's posts advertised through the EURAXESS job portal per 1 000 researchers in the public sector (EURAXESS and Eurostat)	Share of researchers expressing satisfaction that the hiring procedures in their institution are open, transparent and merit based (MORE2 and MORE3 Survey) **P**
Priority 4: Gender equality and gender mainstreaming in research	Share of female PhD graduates (Eurostat) **B**	Gender dimension in research content (WoS) **O**	Share of women in grade A positions in HES (WiS—Women in Science database) **B, P**
Sub-priority 5a: Knowledge circulation	Share of product and/or process innovative firms cooperating with higher education institutions or public/private research institutions (Eurostat) **S**	Share of public research financed by the private sector (Eurostat) **S**	Number of public-private co-publications per million population (EIS) **S**
Sub-priority 5b: Open access	RFOs providing funds to cover costs of OA publishing and share of RFOs' publications available in OA **BI** Share of life sciences papers to which a country contributed and that have at least one open dataset in Figshare	Share of publications available in open access (green and gold) (1findr and WoS)	Qualitative assessment of OA policies in NAPs and other information sources
International dimension outside ERA (Priority 6)	International co-publications with non-ERA partners per 1 000 researchers in the public sector (WoS and Eurostat) **CS, L, H**	Non-EU doctorate students as a share of all doctorate students (EIS) **CS, L, H**	Exports of medium and high technology products as a share of total product exports and Knowledge-intensive services exports as percentage of total services exports (EIS) **S**

Note: The capital letters in colour refer to Table 3. The cells in light green represent Headline indicators while the cells in light grey hold EMM complementary indicators.

Source: Assembled by Science-Metrix from ERAC documentation

Aside from the biases, indicators may also contain drawbacks or limits inherent to the data used in their construction or by their relevancy to effectively represent and monitor the progress of ERA

members toward the achievement of an ERA priority. The remaining part of this section aims to highlight the limits of each headline indicator and some of the EMM indicators.

The Headline indicator for priority 1, the adjusted research excellence, is a composite built of four components: highly cited publications, PCT patents, ERC grants and number of Marie Skłodowska-Curie Actions (MSCA) grants. Although the four components capture the main aspects of research effectiveness and excellence it can be argued that priority 1, more effective national research systems, needs more than these four components to be fully represented and evaluated. Moreover, the component highly cited publications have an intrinsic lag associated with it; a time window of two or three years is necessary to record the citations to scientific articles. Consequently, the latest available year for this indicator is 2015 while the reported year for the AREI is 2016. One of the EMM indicators associated with priority 1 is the Summary Innovation Index (SII) from the European Innovation Scoreboard. This indicator provides an innovation performance score of the MS based on 27 indicators, which are divided across the following categories: framework conditions, investments, innovation activities and impacts. The principal concern about using this indicator to monitor priority 1 is that it includes many dimensions that are not covered by priority 1. Moreover, the primary goal of the SII is to measure the performance of both research and innovation systems rather than to measure the effectiveness of research systems alone.

Sub-priority 2a is represented by the Headline indicator GBARD allocated to Europe-wide transnational, as well as bilateral or multilateral, public R&D programmes per FTE researcher in the public sector. This indicator informs on the budgetary effort of governments toward joint programming processes and it reflects the transnational cooperation between governments. However, it might undervalue the real amount of transnational research budgets as many research programmes might include a transnational dimension while their associated funding might not be tagged with a transnational component. The funding of such research programmes will not be taken into account by the transnational GBARD. In addition, the indicator does not show how the transnational funding directly links with the European grand challenges. It also does not provide information on increases in government research expenditure. Lastly, this indicator may suffer from a potential country-size bias, as the lack of RIs or expert knowledge within the small countries may make them turn to larger countries in order to carry out research projects. Hence smaller countries tend to collaborate more internationally than larger ones, and thus their need for budget allocations to transnational R&D programmes may be different.

A similar country-size bias is applicable to the EMM indicator on internal co-publications with ERA partners, and in this case another country bias related to the location of a country may apply. When a country is centrally located in Europe, it will likely show a preference, in relative terms, towards cooperation with European (or ERA) rather than with non-European countries; alternatively, a country located on the periphery of Europe will likely show a more even preference, in relative terms, towards cooperation with European or non-European countries.

Sub-priority 2b focuses on a coordinated approach to transnational research infrastructures. In this context MS/AC are encouraged to actively participate in ESFRI projects and landmarks and reflect this participation in their RI national roadmap. The headline indicator of sub-priority 2b seeks to identify the MS/AC that have (a) a national roadmap, (b) identified ESFRI projects, and (c) corresponding investment needs. Although this indicator is very useful to identify MS/AC who effectively provided a roadmap regarding their RIs and who provide information on ESFRI projects in addition to their national RI, it does not cover the financial details of ESFRI investment needs such as the quantity or the progress of financial investment. It is only a binary indicator. The availability of such roadmaps is a good starting point, but they are more a measure of communication effort than investment effort. Moreover, this indicator does not inform on the transnational accessibility to RIs, which is an important point when assessing optimal use of public investment in RIs. Regarding the complementary indicators (participation to ESFRI projects and landmarks), there is a clear bias in favour of countries with large economies. Since these indicators are normalised by the total number of ESFRI Projects and/or Landmarks across Europe rather than by the size a country's population/GDP, the largest countries will dominate as they naturally participate in a larger number of RIs. See the following sub-section for a suggestion on how to improve these indicators for future ERA Progress Reports.

As the Headline indicator for priority 3, the ERA committee selected Researcher's posts advertised through the EURAXESS job portal per 1 000 researchers in the public sector. This indicator fits very well with the priority, as EURAXESS is an open and transparent recruitment system. Moreover, it can serve to directly measure a country's institutions' willingness to be open about recruitment. However, since the portal only displays the job vacancies, there is no information to assess if the

recruiting procedures are really merit based. In addition, some MS institutions may prefer to use national job portals and these vacancies will not be reported in EURAXESS. The jobs posted by private companies will also not show up on the portal. One of the accompanying EMM indicators for this priority is the share of researchers expressing satisfaction that the hiring procedures in their institution are open, transparent and merit based. This indicator, constructed using data from the MORE2 and MORE3 surveys, directly measures the extent to which recruitment mechanisms are perceived as open, transparent and merit-based by the researchers from the HEI themselves. With more than 10 000 respondents, the MORE2 and MORE3 surveys were designed to provide maximum accuracy at the EU and country levels. The downsides of using this data are that they only cover researchers from the HEI (GOV not covered), and the survey is not carried out periodically, so data availability is limited. The second EMM complementary indicator under priority 3 is the Share of doctoral candidates with a citizenship of another EU Member State. It was pointed out by the ERAC that this indicator is loosely connected to the priority (Open labour market for researchers); it does not refer directly to open, transparent and merit-based recruitment procedures but rather to the training of students from other EU countries. In this sense, it is somewhat more of a mobility measure than an open, transparent and merit-based recruitment measure. That said, the cross-border mobility of highly qualified personnel indirectly reflects the openness of national research systems.

Moving to priority 4, gender equality and gender mainstreaming in research, the Headline indicator is Share of women in grade A positions in HES. This indicator illustrates well the priority action of addressing gender imbalances in research institutions and decision-making bodies. It focuses on senior-level positions, which are positions that women may have more difficulty accessing than men. Also, the methodology to gather the data behind this indicator has been refined for more than a decade so one can expect the data to be very accurate and representative of the reality. On the downside, this indicator only covers positions in HEI and, accordingly, it does not provide information on the government or business enterprise sectors.

In addition, the interpretability of this indicator may not be obvious, because a higher score does not necessarily translate to a better situation. For example, a score above 50% may indicate a bias in the recruitment process for men. This raises the question of balance: What is the right balance? 50 %/50 %? Or should women in grade A positions be represented in the same proportion as women in the population? The answer is still unclear. Also, this indicator does not take into account or act as a proxy for monitoring the inclusion of the gender dimension in research content, which is another part of the top action priority. However, this aspect is covered by the EMM indicator Gender dimension in research content. Note that this indicator uses research articles (from the *WoS™*) in which a gender dimension has been identified by a keyword query. The keyword query is not flawless (as is always the case when identifying articles by keywords queries) and a vocabulary bias might in practice affect the results. For example, if a keyword connected to the gender dimension has been omitted in the query, and if this word is used more often in one country relative to another country, then this might result in country biases. In addition, although the *WoS™* databases used in this study cover a wide range of scientific journals, they almost exclusively index articles written in English, which may lead to a language bias (resulting in underrepresentation) for countries publishing more heavily in local- and non-English-language journals. The next EMM indicator of priority 4 is the Share of female PhD graduates. This indicator does not cover the full aspect of gender imbalance since it accounts only for students and not working positions. Yet, it is a good complement to the Headline indicator.

The Headline indicator for sub-priority 5a (knowledge circulation) is Share of product and/or process innovative firms cooperating with higher education institutions or public/private research institutions. This indicator acts as a good proxy to measure the collaboration level between private firms and HEI or research institutions. Moreover, it is readily available through the biannual Community Innovation Survey (CIS). One of the issues with this indicator is that the data do not distinguish between large and small or medium firms; however, larger firms are known to collaborate more with HEI or research institutions because of their larger R&D capacities. Hence countries with a higher proportion of SMEs are likely to observe a bias linked to this indicator. In addition, the data from CIS do not distinguish the level or extent of cooperation and record the cooperation in a binary form (yes/no). The two EMM indicators for this priority are Number of public-private co-publications per million population and Share of public research financed by the private sector. Although the first of these is interesting in terms of public-private cooperation, it covers only one type of knowledge transfer: that which ends up in a co-publication. It misses other types of knowledge transfer such as that used for the creation of a new product or new process. The second EMM indicator may convey a misleading picture as MS/AC may have different approaches

to bring R&D to industry. For example, some countries have put in place an established system with private (or semi-private) research organisations to provide commissioned R&D to industry.

Priority 5b, open access, is represented by the headline indicator Share of publications available in open access (green and gold). This indicator is produced by matching OA papers to the *WoS™* database; as a result, most limits of the *WoS™* database are applicable here (e.g. coverage and language bias). In addition, a field of science bias may also apply; if OA is more predominant in a particular field of science. In this case, countries that publish in this field in greater proportion will benefit from a higher score. Although the data behind the indicator can easily be obtained annually (or even more frequently), there is a certain OA lag that obscures the most recent years. Indeed, some journals impose an embargo of a fixed time period (usually between 6 months and 2 years) on scientific publications before they officially become open. The maximal availability of OA paper is thereby shifted back by one or two years. One of the accompanying EMM indicator under this priority is RFOs (i.e. members of Science Europe plus other important sources of national funding) providing funds to cover costs of OA publishing. While this indicator covers a large portion of a country's main RFOs, some RFOs will inevitably be excluded. Since the portion of uncovered RFOs is unknown, this indicator cannot be extrapolated to the country level. The next EMM indicator of priority 5b is the Share of RFOs' (i.e. members of Science Europe or other important sources of national funding) publications that are available in OA. Again, this indicator focuses on a subset of a country's RFOs such that the scores can hardly be extrapolated at the country level. That said, this information is already embodied in the Headline indicator. With this complementary EMM indicator, the goal is to assess whether RFOs covering the cost of OA publishing outperform those who do not. Also note that the RFOs publications were identified through WoS funding acknowledgements which can also result in some biases. For example, the coverage of funding acknowledgements might not be equal across the disciplines. Therefore, if a RFO funds more research in disciplines for which the funding acknowledgements are less covered, and if the share of OA is higher in those disciplines, its share of OA papers could be underestimated. Also, some RFOs require the supported researchers to report the source of their funding, while for other RFOs it might not be required. The different acknowledgement requirements and the level of compliance of the supported researcher to these requirements will also impact the retrieval of RFOs' publications.

Lastly, the Headline indicator of Priority 6, international co-publications with non-ERA partners per 1 000 researchers in the public sector, deals with the international dimension. This headline indicator is well suited to act as a proxy for scientific cooperation at the international level. Because it is built upon the *WoS™* database, the WoS limitations introduced above must also be taken into consideration. Adding to these limitations, we can add the small-country bias (usually, smaller countries tend to be more international than larger ones), the location bias (countries situated at the periphery of Europe will have a larger propensity to collaborate with non-European countries) and the language bias (English-speaking countries may collaborate more internationally). Additionally, this indicator does not provide any information about the impact of the scientific publications. Finally, it was also pointed out by the ERAC that this indicator will react slowly to policy change since there is usually time lag between a policy being implemented, the funding mechanism engaging, and the publication of a research article.

Fluctuating denominators — Recommendations for future improvement

Most of the 24 EMM indicators presented in this study are computed either as a share or as a normalised indicator. This ensures comparability between countries with economies/populations of different size. The majority of indicators are normalised by the number of FTE researchers in the public sector. Researchers from the public sector are the vehicles from which public research is performed in a nation and therefore, from a logical point of view, it makes perfect sense to use this normalisation unit when assessing the research landscape. However, from a practical standpoint, the situation might be a little more hazardous than it seems. Indeed, the research team noticed that historical trends of researcher counts are often fluctuating, diverging or incomplete. For some countries, the fluctuations are so pronounced that, when used as a denominator to normalise an indicator, they may end up obscuring the signal that was meant to be measured. For example, Greece's number of public sector researchers dropped by 20% from 2015 to 2016, Iceland saw a bump of 36% between 2008 and 2009 and Finland's number of researchers increased by 7% in 2010 to decrease back to 7% in 2011. One of the countries whose trend in number of researchers is the most impacted is Ireland. This member state experienced a drastic increase of more than 60% of its public-sector researchers from 2013 to 2014 and the increase continued in 2015 at roughly the same rate. Therefore, for all indicators that were normalised by the number of FTE researchers from the public sector, Ireland will appear to significantly drop when compared to its

pre-2014 scores (ERA progress report 2016) and this, even if the indicator numerator remained stable or slightly increased. This information does not necessarily indicate that Ireland regressed in its effort to achieve ERA objectives if, for example, there was a non-documented change in the definition applied to count its public-sector researcher. Special care was taken when analysing the results normalised by FTE number of public researchers to ensure that the signal observed is not a consequence of a drastic change in the denominator.

For future editions of the ERA Progress Report, it would be worth considering normalization by an indicator of the structural aspect of a nation that is less prone to short-term fluctuations. For example, normalising by the population or GDP of a country would ensure a smooth historical trend, and it would increase the availability of data for many countries in the most recent years. Another benefit of this approach is that it would be easier to detect countries whose growth in the numerator of a given indicator does not follow their overall growth (i.e. in population or GDP). The main downside of this approach is that such a normalisation would convey less information on the relative effectiveness of national research systems. The normalization per capita or GDP would also be very useful for the priority 5b indicator *Share of developing ESFRI Projects and operational ESFRI Landmarks in which a Member State/Associate Country is a partner*. For this indicator, the large economies are all the top performing countries since a fixed denominator is currently applied across countries (see Sections 2.1.2 to 2.1.4). This is not surprising as countries with more financial resources will participate in more research infrastructures.

Additionally, for indicators related to scientific publications (i.e., international co-publication with ERA and non-ERA partners per thousand FTE researchers in the public sector), the total number of publications could be used as the normalization unit instead of the public-sector researchers. This normalization was applied to the indicators of priority 5b (e.g., share of publication available in open access, share of RFOs' publications that are available in OA and Share of life sciences papers to which a country contributed and that have at least one open dataset in Figshare).

5 QUALITY PLAN: VERIFICATION AND VALIDATION OF DATA

During the data gathering phase, the data quality was assured via a multi-faceted quality framework. The data quality framework involves various tests applicable on three dimensions: data relevance, data accuracy and data availability. Each indicator was evaluated by grading it for each dimension and by an overall assessment.

Relevance: Compared to the 2016 ERA Progress Report, the 2018 monitoring exercise only covers the 24 EMM indicators identified by the ERAC to assess progress towards realising the ERA. These indicators were specifically chosen to maximize the relevance to the six ERA priorities, the comparability between countries, and the availability of data across years and countries. By reducing the number of indicators to those that are most relevant to the ERA, it was possible to simplify the reporting mechanism leading to a more convivial presentation of progress.

Accuracy: the accuracy of an indicator may be seen as the capacity of the indicator to adequately represent or describe the quantities it is designed to measure. We define two dimensions related to data accuracy: the data collection method and the degree of cross country standardisation. The former dimension was deemed fit if the data correctly estimated the quantities it was designed to represent. In other words, the accuracy of the data collection method evaluates how close the given values represent the (unknown) true values.

Since most of the data were collected from high-quality databases originating from international organisations, the European Commission and its agencies, or well-established bibliographic sources (i.e. WoS™), one can expect the accuracy of the data collection method to be on par with the highest standard.

Next, data accuracy was also assessed for cross-country comparability. Data are said to be comparable across countries when the methods of data collection were the same or very similar across the countries of interest and when they do not introduce biases. Some biases are inevitable and these biases are documented in Section 4 (under the "Limits and possible biases in Headline and EMM indicators" sub-section).

To ensure data quality over the course of the project, additional validity checks were performed once the data were gathered and the indicators were computed. The two tests that were

implemented — namely, the detection of unreliable data point and coherence check — are explained below.

Availability: The availability of a particular dataset can be defined as the accessibility to data points for each country for a given time frame. Ideally, data would be available for each Member State at the benchmark year (2017).

Table 5 Dimensions of the data quality framework

	Depends on	Addressed by
RELEVANCE	• Relevance of indicator to the six ERA priorities in terms of content/policies perspective	• Discussions with the Commission's officials
ACCURACY OF DATA COLLECTION METHOD/COMPARABILITY	• Alignment between countries in reporting system, classifications used, etc., by data source	• Trying to rely as much as possible on existing official classifications and manuals for data collection (e.g. Frascati Manual); international standards; etc. • Validity/coherence checks after data gathering and computation of indicators
AVAILABILITY	• Availability of data up to benchmark year across ERA countries	• Relying on international databases offering EU coverage • Flagging system (to systematically register missing data and other issues in the data)

Identification of unreliable data points through detection of outliers

Non-sampling errors (e.g. processing errors such as cleaning errors, wrong denominator in normalising an indicator, wrong units) could lead to inaccurate data points. In order to detect aberrations in the time series, an automated test for detecting potential outliers was applied to the time series of each MS/AC for each indicator. A linear regression model was fitted on the time series of each country. Subsequently, a statistical procedure was applied to test the null hypothesis that the studentised residual of each data point could have been generated by the fitted model; when the *p*-value of a test was smaller than 0.05, the hypothesis was rejected implying that the data point is likely an outlier. Subsequently, the potential outliers were visually inspected by a seasoned analyst to assess the degree to which they may represent real variations; in other words, the potential outliers automatically identified using the above statistical test were validated manually to differentiate real outliers (bad data or incorrect definition) from false outliers (data points likely representing real fluctuations). Note that this exercise is very complex, as some outliers may naturally arise as a result of a precise political and/or economic condition unknown to the analyst performing the manual validation. Therefore, actions were only taken on data points for which there was no ambiguity regarding their outlier status. When outliers were identified, the data source(s) used for the computation of the indicator was analysed to detect where the aberrant values might come from. Subsequently, the faulty data points were labelled with a flag (identified in the tables' notes as "potential outlier"). Note that only a small proportion of the outliers detected with the automated method were flagged as such.

Next, a method was applied to identify breaks in a time series and other possible outliers. A stepwise analysis was conducted via a script that compares the (y axis) difference between two successive points to the average (y axis) difference of the points before and after. The analysis highlighted undocumented breaks in a time series or changes of regime that were not detected through the

first method. Again, when the result was above a particular threshold, a manual validation was applied to each point before flagging them.

Special care was taken when analysing data points flagged by the above validation procedures. For example, if a severe break in time series was detected, the reference period in the growth analysis could be shifted or reduced in order to avoid using data points that would lead to inaccurate results. Whenever a change was applied either in the reference period (for growth) or reference year (for performance), it was clearly indicated in the corresponding table notes.

Coherence checks

For data broken down in sub-categories, the sum of sub-categories should add up to the corresponding total. When data for all sub-categories and totals across sub-categories were available, coherence checks were computed by summing across sub-categories and comparing the sum to the corresponding total. This was mostly feasible for data coming from Eurostat. For example, the sum of the GBARD funding modes should be equal to the total GBARD. Sub-categories that were used in the coherence checks can be defined along the following dimensions:

- Sex
- Institutional sectors
- Country aggregate (i.e. EU-28)

Table 6 lists the coherence checks that were applied to each dataset before the production of the indicators.

Table 6 List of coherence checks

Tables	Dimensions	Computations
educ_uoe_enrt01	Verify doctoral enrolment EU28 totals	{AT} + {BE} + {BG} + {CY} + {CZ} + {HR} + {DE} + {DK} + {EL} + {EE} + {ES} + {FI} + {FR} + {HU} + {IE} + {IT} + {LT} + {LV} + {LU} + {MT} + {NL} + {PL} + {PT} + {RO} + {SE} + {SI} + {SK} + {UK} = {EU-28}
educ_uoe_mobs02	Verify doctoral enrolment EU28 totals	
gba_nabsfin07	Verify GDP EU28 totals	
gba_nabsfin07	Verify GBARD EU28 totals	
gba_tncoor	Verify funding for all transnationally coordinated R&D	{National contributions to transnational public R&D performers} + {National contributions to Europe-wide transnational public R&D programmes} + {National contributions to bilateral or multilateral public R&D programmes} = {National public funding to transnationally coordinated R&D}
Inn cis9 coop	Verify the EU28 enterprises totals	{AT} + {BE} + {BG} + {CY} + {CZ} + {HR} + {DE} + {DK} + {EL} + {EE} + {ES} + {FI} + {FR} + {HU} + {IE} + {IT} + {LT} + {LV} + {LU} + {MT} + {NL} + {PL} + {PT} + {RO} + {SE} + {SI} + {SK} + {UK} = {EU-28}
inn_cis9_type	Verify the EU28 enterprises totals	
nama_10_gdp	Verify GDP EU28 totals	
rd_p_persocc	Verify EU28 researchers totals	
rd_e_gerdfund	Verify funding from all sectors	{Business enterprise sector} + {Government sector} + {Higher education sector} + {Private non-profit sector} = {All sectors}
rd_e_gerdfund	Verify funding from all sectors	{Abroad} + {Business enterprise sector} + {Government sector} + {Higher education sector} + {Private non-profit sector} = {All sectors}
rd_e_gerdfund	Verify EU28 funding totals	{AT} + {BE} + {BG} + {CY} + {CZ} + {HR} + {DE} + {DK} + {EL} + {EE} + {ES} + {FI} + {FR} + {HU} + {IE} + {IT} + {LT} + {LV} + {LU} + {MT} + {NL} + {PL} + {PT} + {RO} + {SE} + {SI} + {SK} + {UK} = {EU-28}
rd_e_gerdfund	Verify EU28 funding totals disagragated by dimension	
educ_uoe_grad02	Pre-calculated totals equal sum of individual gender figures	{Women}+{Female} = {Total}
Grade A position / She Figures 2018 data	Pre-calculated totals equal sum of individual gender figures	

Source: Compiled by Science-Metrix

Most of the tables passed the coherence checks. Note that some very small discrepancies (0.999 < ratio between expected value and real value < 1.001) were not reported as the impact associated with them is minimal. The following section lists the table and the coherence checks applied to each of them with the results. For the values that did not pass the coherence checks, an explanation or the action taken to correct the table is given.

Educ_uoe_enrt01

The sum across MS in the number of doctoral students for 2015 differs from the EU-28 total reported by Eurostat by 9 044. The ratio of the sum across MS to the Eurostat pre-aggregated figure equals 1.012 (734 582 over 725 538).

Action: Science-Metrix calculated EU-28 totals by adding individual country counts so the incoherence had no effect.

educ_uoe_mobs02

Numbers of foreign doctoral students by individual country seldom add up to the aggregate levels provided by Eurostat.

Action: Science-Metrix calculated EU-28 totals by adding individual country counts so the incoherence had no effect.

gba_nabsfin07

Member States GDP and GBARD figures add up to the pre-calculated EU-28 totals.

gba_tncoor

The aggregated category "national public funding to transnationally coordinated R&D" is generally equal to the addition of the contributing sub-categories. Three inconsistencies in the dataset have nonetheless been detected (see Table 7 below).

Table 7 Incoherence for sum of transnational and multilateral public R&D (gba_tncoor), in Million Euro

Country	Year	National contributions to bilateral or multilateral public R&D programmes	National contributions to Europe-wide transnational public R&D programmes	National contributions to transnational public R&D performers	National public funding to transnationally coordinated R&D	Difference	Ratio
Latvia	2009	0.011	0.806	0	0.818	-0.001	0.999
Lithuania	2014	0.037	1.978	0.009	2.015	0.009	1.004
Poland	2012	2.581	5.114	33.694	41.413	-0.024	0.999

Source: Science-Metrix

Action: No action taken, the differences are very small and had no impact on the indicators.

inn_cis9_type

The sum of individual enterprise counts for Member States equals the Eurostat pre-calculated score for EU-28.

inn_cis9_coop

The sum of counts of "Enterprises co-operating with universities or other higher education institution" for individual Member States equals the Eurostat pre-calculated score for EU-28. Eu-28 totals are not provided for the two other categories of enterprises.

nama_10_gdp

The sum of Member States GDP roughly equals to the Eurostat pre-calculated EU-28 score across years.

Action: No action taken has the observed differences were outside the reportability thresholds.

rd_p_persocc

The sum researcher counts across MS is close to (outside the reportability thresholds) or equal to the Eurostat pre-calculated EU-28 score.

Action: No action taken, the differences are very small and had no impact on the indicators.

rd_e_gerdfund

Sum of sectors (for SECTPERF): minor differences (see Table 8).

Action: No action taken, the differences are very small and had no impact on the indicators.

Table 8 Incoherence for sum sector (SECTPERF) (rd_e_gerdfund)

GEO	SECTFUND	TIME	Business enterprise sector	Government sector	Higher education sector	Private non-profit sector	All sectors	Sum sectors	Diff	Ratio
Former Yugoslav Republic of Macedonia, the	Abroad - Business enterprise sector	2015	0.000	0.003	0.033	0.002	0.037	0.038	0.001	1.027
Estonia	Higher education sector	2015	0.020	0.020	0.560	0.060	0.650	0.660	0.010	1.015
Poland	Higher education sector	2007	0.408	1.322	1.771	0.026	3.515	3.527	0.012	1.003
Slovakia	Higher education sector	2007	0.042	0.039	0.326	0.000	0.406	0.407	0.001	1.002
Bosnia and Herzegovina	All sectors	2014	6.811	6.903	22.410	0.516	36.686	36.640	0.046	0.999
Montenegro	Government sector	2015	0.100	2.540	5.230	0.020	7.900	7.890	0.010	0.999
Montenegro	All sectors	2015	4.160	2.620	6.390	0.480	13.670	13.650	0.020	0.999
Bosnia and Herzegovina	Business enterprise sector	2014	6.136	2.301	6.800	0.026	15.288	15.263	0.025	0.998
Bulgaria	Higher education sector	2011	0.023	0.265	0.149	0.000	0.438	0.437	0.001	0.998
Montenegro	Business enterprise sector	2015	4.050	0.000	0.020	0.000	4.080	4.070	0.010	0.998
Bosnia and Herzegovina	Abroad	2014	0.077	3.017	0.972	0.031	4.116	4.097	0.019	0.995

Source: Science-Metrix

Sum of sectors (for SECTFUND): minor differences (data not shown).

Action: No action taken, the differences are very small and will have no impact on the indicators.

The sum of MS' figures corresponds to the Eurostat pre-calculated EU-28 score.

educ_uoe_grad02

Sum of MS, both for women and total, differs by 2% or less from the Eurostat pre-calculated EU-28 score. However, this table was used only to compute the share of female PhD graduates and both the numerator (number of women PhD graduates) and the denominator (number of total PhD graduates) were affected. In the end, the difference of the indicator values for EU-28 calculated by summing each MS or by using pre-calculated Eurostat data differs only by 0.1% or less (e.g., 2018 EU-28 share of female graduates by summing the MS = 0.48002 VS 0.47895 when using the Eurostat pre-calculated EU-28 scores). Given this small difference, no action was taken to correct the data. The Eurostat pre-calculated EU-28 scores were used for the years 2014-2016. For 2013, the sum across MS was used (see Section 2.5.4).

Data on Women in Grade A positions

The sum of women and men counts were comparable to the pre-calculated total across sex. There was only one negligible (outside the reportability thresholds) inconsistency.

Action: None taken, differences are too small to impact the headline indicator of Priority 4.

Additional data considerations

Rounding error

In some cases, the row or column totals do not match the sum of the data. This may be due to rounding error.

Cut-off date

At the beginning of the project, a cut-off date for each data source was established in collaboration with the Commission in order to maximise the chance of having the most up-to-date data while not delaying the project. All data were extracted at a time past, but near, the cut-off date; the actual extraction dates are provided in Table 9. The project lasted for several months. It is therefore possible that some data sources will have been updated between the time the data was extracted (slightly passed the cut-off date originally planned) and the release of the ERA Progress Report.

Table 9 Data source extraction dates

Data source & table name	Extraction date	Exception
Eurostat		
online data code educ_uoe_enrt01	25-Jul-18	
online data code educ_uoe_grad02	04-Oct-18	
online data code educ_uoe_mobs02	20-Aug-18	
online data code gba_nabsfin07	03-Jul-18	For GBARD as a share of GDP: 11/23/2018
online data code gba_tncoor	03-Jul-18	
online data code rd_e_gerdfund	18-Jul-18	
online data code rd_p_persocc	03-Jul-18	
online data code inn_cis8_coop	10-Jul-18	
online data code inn_cis8_type	03-Jul-18	
online data code inn_cis9_coop	03-Jul-18	
online data code inn_cis9_type	03-Jul-18	
online data code nama_10_gdp	03-Jul-18	For GBARD as a share of GDP: 11/23/2018
ESFRI Executive Secretary		
National roadmap	21-Sep-18	
MS/AC participation in ESFRI project and Landmarks	09-Aug-18	
Women in Science database		
Share of women heads of institutions in the higher education sector	21-Aug-18	
Other sources		
EURAXESS historical data	26-Jun-18	
Funds committed to Cofunds, Art. 185s, JPIs, FP7 ERA-NETs and self-sustained networks and budgets for joint calls (from Optimat)	21-Jun-18	
Figshare	05-Sep-18	
Directory of institutional open access policies (MELIBEA)	30-Aug-18	
Registry of Open Access Repository Mandates and Policies (ROARMAP)	30-Aug-18	

Source: Science-Metrix

6 DESK RESEARCH AND DOCUMENT REVIEW

Desk research and document review provided the framework for the ERA Progress Report 2018, situating the assessment exercise in the policy context of the movement towards an ever-more integrated European Research Area. Desk research consisted of review of relevant documents that allowed ERA progress to be monitored for each of the ERA priorities at EU and country level as well as level of research organisations.

Refer to Table 10 for a list of the main sources used in the desk research and document review (additional documents are listed in this report's bibliography). To explore the situation in each country regarding each ERA priority, we looked at national R&I strategies as of 2018, national roadmaps for research infrastructures, National Action Plans, different country reports and profiles (e.g. RIO, European Semester, OECD STI), country specific recommendations (e.g. European Semester), and country specific information provided by various EU agencies (e.g. EIGE). Progress at the level of research organisations towards the implementation of the ERA were examined by analysing publications of the Commission and the OECD, position papers and reports of the stakeholders involved in the ERA Stakeholder Platform and documents covering EU and country level (e.g. Innovation Union Country Profiles, European Semester documents and ERAWATCH country reports). A number of more general studies, evaluations and reports helped the study team understand the general EU level trends. Such reports covered topics related to ERA priorities, for example, research funding, gender equality in science, researchers' mobility and careers, and open access. Via desk research, efforts were also made to identify and document examples of good practice, in particular for assessing institutional changes at the organisational level, as required for the completion of the ERA.

Table 10 Main sources used in the desk research and document review

Category	Number of documents
National Level	
National Action Plans	28
Research and Innovation Observatory (RIO) Country Reports	25 (2017) 27 (2016) 5 (2015)
OECD Policy Reviews	29
National R&I Strategies	15
National Roadmaps for Research Infrastructures	24
European Semester Country Reports	26 (2017) 27 (2016)
European Semester Country specific recommendations	12
European Innovation Scoreboard	36 (2018) 37 (2017)
Organisation level	
ERAC	5
EIGE	4
Science Europe	6
ERA-LEARN	2
League of European Research Universities	2
European University Association	5
European Parliament	1
European Commission	31
Other	1

Source: Compiled by PPMI Group.

Note that the document review has also established important contextual components for the subsequent interviews with key stakeholders and RPOs/ RFOs, as well as the quantitative measurements of national- and ERA-level performance; one primary focus of the desk research was to deepen understanding of the ERA priorities, as these provide the primary structure for the assessment exercise at hand.

We are proud that desk research and documentary review implemented for this ERA Progress Report 2018 was the most extensive and systematic yet. Desk research was done systematically on the basis of the coding framework structured according to themes of the ERA priorities. The coding framework was developed based on ERA Communication and Roadmap. There were three types of codes:

- Country codes, which allowed us to assign certain segments of text to specific countries;
- Thematic codes, which allowed us to assign certain segments of text to ERA priorities, sub-priorities and very specific themes indicated by ERA Communication and Roadmap;
- Good practice codes, which allowed us to indicate that a certain segment of text is speaking about a good practice.

The desk research was supported by a qualitative data analysis software NVivo 10, which helped classify, sort and arrange large amounts of data; examine relationships in the data; and combine analysis with text modelling. All textual data were uploaded and coded according to the categories described above. As a result, we were able to classify and extract data by (1) country and (2) theme: ERA priority, sub-priority, specific action. The section below provides the coding framework that was used for analysing textual data for ERA Progress Report 2018.

6.1 Coding framework for software-supported desk research

[1st level coding node]
ERA priorities

[2nd level coding node]
P1 – More effective national research systems

[3rd level coding node]
P1 – Political context around ERA

P1 – National R&I strategies

P1 – National R&I reforms

P1 – Recommendations from RPOs and RFOs on improving national systems

P1 – (Non)alignment of national strategies with the European policies and goals

P1 – Funding allocation mechanisms

[4th level coding node]
P1 – Competitive funding

[5th level coding node]
P1 – Calls for proposals

P1 – Institutional assessments

P1 – Other funding mechanisms

P1 – Applying the core principles of international peer review in allocating research funds

P1 – Investment in wider education, research and innovation systems

P1 – Smart specialisation policies

P2A – Jointly addressing grand challenges

P2A – Context for international research collaboration

P2A – (Non)alignment of national strategies with the themes and priorities of the Joint Programming Initiatives

P2A – Funding for joint programming

P2A – Recommendations for joint programming

P2A – Application of common funding principles among RFOs

P2A – Models of cross–border cooperation among RFOs

P2A – Use of joint research agendas, synchronised calls, joint international peer reviews among RFOs

P2B – Make optimal use of public investments in research infrastructures

P2B – Research infrastructures at national level

P2B – Research infrastructures at organisational level

P2B – Cross border (non)access to research infrastructures

P2B – Compatibility between the ESFRI roadmap and national RIs

P2B – Other trends in investment in research infrastructures

P3 – An open labour market for researchers

P3 – EURAXESS Jobs portal

P3 – International mobility of researchers

P3 – Recommendations on open labour market for researchers

P3 – Career development of researchers

P3 – Policies/ strategies for the career development of researchers

P3 – Participation in the Human Resource Strategy for Researchers

P3 – Other trends in career development of researchers

P3 – Open recruitment of researchers in RPOs

P3 – Open, transparent, merit-based recruitment

P3 – Promotion and uptake of the Charter and Code

P3 – Existing barriers

P3 – Policies and initiatives to remove barriers

P3 – Other trends in open recruitment of researchers

P3 – Provision of doctoral training

P3 – Policies and initiatives for doctoral training

P3 – Alignment of doctoral training programmes with the Principles for Innovative Doctoral Training

P3 – Other trends in provision of doctoral training

P3 – Mobility between industry and academia

P3 – Policies/ measures to encourage/ support mobility

P3 – Other trends in mobility between industry and academia

P3 – Pensions of researchers

P4 – Gender equality and gender mainstreaming in research

P4 – Gender issues around research career

P4 – Policies to promote gender equality in research

P4 – Specific RPOs actions to promote gender equality

P4 – Recommendations on gender in research

P4 – Other trends in gender equality in the research and innovation field

P5A – Implementation of knowledge transfer policies to maximise the exploitation of scientific results

P5A – Knowledge transfer policies/ practices at RPOs (including monitoring)

P5A – Intellectual Property management policies/ practices at RPOs

P5A – Policies/ strategies fostering the collaboration between RPOs and the private sector

P5A – RPOs collaboration with the private sector

P5A – Other trends in knowledge transfer (including intellectual property management)

P5B – Promoting Open access to scientific publications

P5B – Policies to promote/ support Open Access

P5B – Open Access at RPOs

P5B – Policies to promote Open Innovation

P5B – Open Innovation at organisational level

P5B – Other trends in Open Access and Open Innovation

P5B – Recommendations on Open Access and Open Innovation

P6 – International Cooperation

P6 – Cooperation with third countries in the field of research and innovation

P6 – National strategies for cooperation with third countries

[1st level coding node]
Good practice examples

[2nd level coding node]
P1 – More effective national research systems

P2A – Jointly addressing grand challenges

P2B – Make optimal use of public investments in research infrastructures

P3 – An open labour market for researchers

P4 – Gender equality and gender mainstreaming in research

P5A – Implementation of knowledge transfer policies to maximise the exploitation of scientific results

P5B – Promoting Open access to scientific publications

P6 – International Cooperation

[1st level coding node]
Countries

[2nd level coding node]
EU level tendencies

Member States

[3rd level coding node]
Austria
Belgium
Bulgaria
Croatia
Cyprus
Czech Republic
Denmark
Estonia
Finland
France
Germany
Greece
Hungary
Ireland
Italy
Latvia
Lithuania
Luxembourg
Malta
Netherlands
Poland
Portugal
Romania
Slovakia
Slovenia
Spain
Sweden
United Kingdom

Associated countries
Albania
Armenia
Bosnia and Herzegovina
Faroe Islands
Georgia
Iceland
Israel
Moldova
Montenegro
Norway
Serbia
Switzerland
the former Yugoslav Republic of Macedonia
Tunisia
Turkey
Ukraine

7 INTERVIEWS

To inform the ERA Progress Report 2018, in total, 73 telephone interviews were conducted between mid-July and August 2018. The interviews involved 64 representatives of research funding organisations (RFOs) and research performing organisations (RPOs) from countries across the ERA and 9 representatives of member or observer organisations in the ERA Stakeholder Platform. Interviewees provided important findings from a variety of perspectives to facilitate interpretation of quantitative data, as well as the assessment of features of the ERA process that are not tracked by quantitative measures. Among other findings, these interviews provided insights into policy initiatives, as well as the benefits, difficulties and limitations that organisations are facing in implementing ERA initiatives and policies. The data collected through interviews was triangulated with documentary sources consulted during the desk research and literature review. Finally, interviews were extremely helpful in assessing the progress of ERA countries with the implementation of the National Action Plans. The discussion in this report uses the term 'qualitative data' to denote situations where there was convergence between interview data and the literature review/ desk research.

The interview questionnaire was based on the themes from ERA Communication and ERA Roadmap, which indicate necessary actions and contributions at the level of research organisations. The interview questionnaire unambiguously specified, which questions should be addressed to (1) RPOs, (2) RFOs and (3) research stakeholder organisations.

Interviews allowed us to better understand or clarify the results of the analysis derived from the document review, as well as to provide additional lines of evidence on the identified examples of good practices. Accordingly, more precise questions and evaluation issues were developed as findings from the preceding approaches to data collection became available.

The interviews helped collect evidence, perceptions and experiences from individuals who were directly knowledgeable about the processes underpinning the advancement of the ERA, and from the perspective of the actors ultimately responsible for implementing and sustaining many of the relevant initiatives and policies—namely, RPOs and RFOs. For the evaluation of progress towards the ERA, interviews were also helpful to better understand the wider economic, social and environmental factors that characterise the operation of these organisations.

Furthermore, interviews served as a powerful instrument for identifying major challenges, barriers, and concerns—as well as success factors and best practices—that quantitative data often fail to capture. In this case, some of the interviewees were well positioned to identify areas that needed improvement and to provide suggestions for appropriate adjustments to or reflections on future directions for the ERA.

Once the interviews have been completed, content analysis was applied, a technique designed to characterise a body of text in a systematic and qualitative manner. To systematically analyse interview information, we employed Nvivo 10 software using both the deductive and inductive approaches, as discussed in the section on desk research above. The resulting analysis and key quotes were compiled in a table or matrix, grouped by theme to feed into the lines of evidence collected through the desk research. The section below provides a detailed interview questionnaire that was used for gathering qualitative data for ERA Progress Report 2018.

7.1 Interview questionnaire for RFOs, RPOs and stakeholder organisations

Interviewee (name, position, organisation, organisation type [i.e. RFO, RPO, stakeholder organisation, etc.], country)	
Interview date	
Notes	

Introductory questions

Q1. Could you please provide a brief overview of your organisation?

Q1.1. Could you please provide a brief overview of your role within your organisation?

Q2. Please comment briefly on your level of familiarity with the six ERA priorities.

Institution's progress in the implementation of the ERA priority areas

ERA priority 1: More effective national research systems	- **Better alignment** of national and European policies, with the goal of making optimal use of public investments in research and innovation. - **Increased competition** for funding within national borders and sustained or greater **investment** in research and innovation. - Application of principles of **international peer review** in allocating research funds.

Q3. ERA strategic documents encourage RFOs to apply principles of international per review in allocating research funds.

[For RPOs] Please briefly comment on the current situation in your country regarding the application of international peer review in allocating research funds. How has the situation changed (improved/ deteriorated) in recent years?

[For RFOs] Please briefly comment on the current situation in your country regarding the application of international peer review in allocating research funds. How has the situation changed (improved/ deteriorated) in recent years? What specific actions has your organisation undertaken in this field from 2016 to 2018?

[For EU stakeholders] Please provide a broader picture on the current situation/ trends in Member States and Associated countries regarding the application of international peer review in allocating research funds. How has the situation changed (improved/ deteriorated) in recent years? What are the key regional/ country level differences? Could you identify any good practice examples?

Q4. ERA strategic documents encourage Member States to better align national research and innovation strategies with the European level policies and goals (i.e. i) Open innovation; ii) Open science; iii) Open to the world)[21]

[For RPOs and RFOs] In your opinion, are your country's national strategic documents well aligned with European policies and goals in research and innovation? Did your organisation play a role in designing the national strategies and ensuring their alignment with the EU policies? If yes, please elaborate on your role.

[For EU stakeholders] To the best of your knowledge, are Member States' national research and innovation strategies well aligned with European level policies and goals? What are the key regional/ country level differences? Could you identify any good practice examples?

[21] In 2015, Commissioner Carlos Moedas identified i) Open innovation; ii) Open science; iii) Open to the world as the three main policy goals for EU research and innovation. More information can be found https://ec.europa.eu/info/research-and-innovation/strategy/goals-research-and-innovation-policy_en

Q5. ERA strategic documents invite Member States to enhance competitive funding through calls for proposals and institutional assessments.

[For RPOs] Please briefly comment to what extent are the principles of competitive funding through calls for proposals and institutional assessments applied in your country? Whether the application of competitive funding principles has increased/ decreased from 2016 to 2018?

[For RFOs] Please briefly comment to what extent are the principles of competitive funding through calls for proposals and institutional assessments applied in your country? Whether the application of competitive funding principles has increased/ decreased from 2016 to 2018? What specific actions has your organisation undertaken in this field from 2016 to 2018?

[For EU stakeholders] What are the key trends/ differences among Member States in applying the principles of competitive funding through calls for proposals and institutional assessments. In your opinion, whether the prevalence of competitive funding has increased/ decreased from 2016 to 2018 across the EU?

ERA priority 2(A): Jointly addressing grand challenges	Defining and implementing common research agendas on grand challenges, raising quality through Europe-wide open competition

Q6. ERA strategic documents foresee that RFO's and relevant ministries should work more closely together to better align national strategies with themes and priorities of the Scientific Research and Innovations Agendas (SRIAs) of the Joint Programming Initiatives (JPIs)[22].

[For RFO's] What role has your organisation played in defining national research strategies? In your opinion, do these national strategies reflect the themes and priorities of the JPIs?

Q7. RFOs are invited to agree on common funding principles, including recognition and evaluation procedures, interoperability of selection procedures, common terminology and other rules and procedures.

[For RFOs] How well are your country's national funding principles and procedures aligned/ integrated with other Member States' funding systems for research and development? What specific actions has your organisation undertaken in this field from 2016 to 2018?

[22] The following JPIs have been launched to date: i) Alzheimer and other Neurodegenerative Diseases (JPND); ii) Agriculture, Food Security and Climate Change (FACCE); iii) A Healthy Diet for a Healthy Life; Cultural Heritage and Global Change: A New Challenge for Europe; iv) Urban Europe - Global Urban Challenges, Joint European Solutions; v) Connecting Climate Knowledge for Europe (CliK'EU); vi) More Years, Better Lives - The Potential and Challenges of Demographic Change; vii) Antimicrobial Resistance- The Microbial Challenge - An Emerging Threat to Human Health; viii) Water Challenges for a Changing World; ix) Healthy and Productive Seas and Oceans. More information can be found: http://ec.europa.eu/research/era/joint-programming-initiatives_en.html

[For RPOs] From your experience, how well are your country's national funding principles and procedures aligned/ integrated with other Member States' funding systems for research and development? Have you noticed any progress in this field during 2016-2018?

[For EU stakeholders] How well are funding principles in different Member States mutually aligned and integrated? Have you noticed any progress in this field during 2016-2018? What are the key differences among countries/ regions? Could you identify any good practice examples?

Q8. RFOs are invited to further develop and test various models for cross-border cooperation with other RFOs such as Money-Follows-Cooperation Line[23] or Money-Follows-Researcher[24].

[For RFOs] What kind of international cooperation models your organisation applies with other RFOs? Are you applying models such as Money-Follows-Cooperation Line or Money-Follows-Researcher? Has your organisation tested any new cooperation models from 2016 to 2018? If yes, please describe them briefly.

[For EU stakeholders] To the best of your knowledge, how prevalent are various international cooperation models such as Money-Follows-Cooperation Line or Money-Follows-Researcher among RFOs from different countries? What are the key challenges in developing such cooperation models? Could you identify any good practice examples?

Q9. RFOs are invited to pilot and use synchronised calls, including single joint international peer review evaluations.

[For RFOs] Did your organisation have any experience in using synchronised calls with other RFOs? If yes, please elaborate on it.

[For EU stakeholders] Could you briefly comment on the international cooperation among RFOs in using synchronised calls? Has been there any progress from 2016 to 2018? Could you identify any good practice examples?

ERA priority 2(B): Make optimal use of public investments in research infrastructures	Contributing and making optimal use of public investments in research infrastructures by setting national priorities compatible with the ESFRI priorities.

[23] **The Money-follows-Cooperation line** process is aimed at researchers who implement cross-border projects in which only a very small proportion of the work is carried abroad. With Money-follows-Cooperation line agreements RFOs in different countries can agree that RFO with larger financial burden would cover all project research expenses in both countries.

[24] **The Money-follows-Researcher process** is aimed at researchers who move abroad but would like to continue to carry out a research project funded by a national RFO. Such project can either be continued in a primary country while being managed from abroad or transferred to the new location in another country (including transfer of funds and employees)

Q10. ERA strategic documents call Member States and Associated Countries to ensure compatibility between the ESFRI roadmap[25] and their national roadmaps for research infrastructures (RIs)[26].

[For RFOs and RPOs] To the best of your knowledge, how well is your national roadmap for research infrastructures aligned with the ESFRI roadmap? Has your organisation played any role in developing the national roadmap? If yes, please elaborate on it.

[For EU stakeholders] To the best of your knowledge, how well are national roadmaps for research infrastructures, prepared by Member States and Associated Countries, aligned with the principles of the ESFRI roadmap? Could you identify any good practice examples?

ERA priority 3: Open labour market for researchers	Breaking down barriers to researcher mobility, training, and attractive careers to promote mobility, better working conditions, open and transparent recruitment improved careers of researchers and the removal of social security obstacles like non-transferability of pensions.

Q11. RFOs and RPOs are invited to advertise all vacancies on the EURAXESS Jobs portal.

[For RFOs and RPOs] Does your organisation regularly publish job offers on EURAXESS Jobs portal? When your organisation started to publish offers on this website? Would you agree that your organisation has started to publish more offers in EURAXESS portal in recent years?

[For EU stakeholders] To the best of your knowledge, do RFOs and RPOs regularly publish job offers on EURAXESS Jobs portal? What are the key differences among countries/ regions?

Q12. RFOs are invited to amend rules for national funding schemes to promote the uptake and implementation of the Charter and Code[27] principles such as openness, transparency and merit-based recruitment among RPOs.

[For RFOs] Would you agree that RPOs in your country apply recruitment practices based on the principles set in the Charter and Code such as openness, transparency and merit-based recruitment? Would you say that the uptake of these recruitment principles has increased or decreased in your country from 2016 to 2018? What specific actions has your organisation undertaken to promote the recruitment based on the aforementioned principles?

[For RPOs] Would you agree that your organisation's recruitment practices correspond to the principles set in the Charter and Code such as openness, transparency and merit-based recruitment? Has your organisation undertaken any actions from 2016 to 218 to better align its recruitment practices with the aforementioned principles?

[25] ESFRI Roadmap 2016 can be found here: http://www.esfri.eu/roadmap-2016.

[26] National roadmaps for research infrastructures can be found here: http://www.esfri.eu/national-roadmaps.

[27] The Researcher's Charter and the Code of Conduct for Recruitment of Researchers. These two documents, addressed to researchers as well as research employers and funders in both the public and private sectors, are key elements in the EU's policy to boost researchers' careers. The Charter and Code ensures researchers can enjoy the same rights and obligations in any European country. More information can be found at https://euraxess.ec.europa.eu/jobs/charter.

[For EU stakeholders] Please provide a broader picture on the current situation/ trends among RPOs in different countries regarding the uptake and implementation of the Charter and Code principles such as openness, transparency and merit-based recruitment in their recruitment policies.

Q13. RPOs are invited to develop strategies to support the career development of researchers in line with the Human Resource Strategy for Researchers.

[For RPOs] Does your organisation have a formal strategy for the career development of researchers? Is this strategy in line with the Human Resource Strategy for Researchers[28]?

[For EU stakeholders] To the best of your knowledge, do RPOs develop their own strategies to support the career development of researchers? How prevalent are such strategies among RPOs in different Member States and Associated countries? Are these strategies well aligned with the EU Human Resource Strategy for Researchers? Could you identify any good practice examples?

Q14. ERA strategic documents invite Member States and Associated Countries to remove legal barriers and other hindrances to open recruitment of researchers in public sector RPOs.

[For RFOs and RPOs] What are the key obstacles (if any) to open recruitment of researchers in public sector RPOs in your country/ your organisation in particular? Have there been any positive or negative developments in this field from 2016 to 2018?

[For EU level stakeholders] What are the most prevalent obstacles to open recruitment of researchers in public sector RPOs among Member states and Associated Countries? Could you identify any good practice examples of removing such obstacles during the period from 2016 to 2018?

Q15. Member States and Associated Countries are invited to provide structured doctoral training based on the Principles for Innovative Doctoral Training[29] and to strengthen initiatives on the professional development of researchers.

[For RFOs] To the best of your knowledge, to what extent organisations, providing PhD degrees in your country, base their doctoral training on the Principles for Innovative Doctoral Training? Could you briefly comment about the overall developments in this field in your country in recent years?

[For RPOs] Does your organisation provide PhD degrees? If yes, are these doctoral training programmes based on the Principles for Innovative Doctoral training? What specific actions has your organisation undertaken in recent years to renew/ improve its doctoral training programmes?

[28] The 'HR Strategy for Researchers' supports research institutions and funding organizations in the implementation of the Charter & Code in their policies and practices. More information can be found https://euraxess.ec.europa.eu/jobs/hrs4r.

[29] In 2011, the European Commission published The Seven Principles of Innovative Doctoral Training: i) Research excellence, ii) Attractive Institutional Environment, iii) Interdisciplinary Research Options, iv) Exposure to Industry and other relevant employment sectors, v) International networking, vi) Transferable skills training, vii) Quality Assurance. More can be found here https://euraxess.ec.europa.eu/belgium/jobs-funding/doctoral-training-principles.

[For EU stakeholders] Please provide a broader picture on the current situation/ trends in Member States and Associated countries regarding the application of the Principles for Innovative Doctoral Training in their doctoral training programmes? Could you identify any good practice examples?

Q16. ERA strategic documents invite Member States and Associated Countries to develop and implement structured programmes to increase mobility between industry and academia.

[For RPOs] Are there any national level mobility programmes/ schemes in your country aimed at fostering mobility between industry and academia? Have any new programmes been developed/ terminated during 2016-2018? Does your organisation implement any of these programmes?

[For RFOs] Does your organisation implement any mobility programme/ scheme aimed at fostering mobility between industry and academia? If yes, please describe them briefly. Are there any other national level mobility programmes/ schemes implemented by other RFOs/ RPOs in your country?

[For EU stakeholders] Please provide a brief overview of the overall situation on mobility between industry and academia in Member States and Associated countries. How has the situation changed in recent years? Could you identify any good practice examples at national level facilitating mobility between industry and academia?

ERA priority 4: Gender equality and gender mainstreaming in research	Translating EU-level strategies and national equality legislation into effective action to address gender imbalances in research institutions and decision-making bodies and integrating the gender dimension better into R&D policies, programmes and projects.

Q17. ERA strategic documents invite Member States and Associated countries to develop policies on Gender Equality in RPOs and regularly monitoring their effectiveness.

[For RPOs and RFOs] How would you describe the overall situation of gender equality in RPOs in your country and in your organisation specifically? Has the situation improved/ deteriorated in recent years? Please consider such aspects as legal and other barriers to the recruitment, retention and career progression of female researchers; gender imbalances in decision making processes.

[For EU stakeholders] Please provide a brief overview on gender equality in the research and development field among Member States and other Associated countries. What are the key regional/ country level differences/ trends? Please consider such aspects as legal and other barriers to the recruitment, retention and career progression of female researchers; gender imbalances in decision making processes.

[For RPOs and RFOs] Are there any national level policies aimed to ensure Gender Equality in RPOs? Is there a monitoring system in place to evaluate the effectiveness of these policies?

[For RPOs] What specific actions has your organisation undertaken in recent years to ensure gender equality in its daily functioning (e.g. developed gender equality plans, conducted impact assessments/ audits of procedures and practices to identify gender bias, etc.)?

[For EU stakeholders] Could you identify any good practice examples at national level aimed at enhancing Gender Equality in RPOs?

ERA priority 5(A): Fully implementing knowledge transfer policies in order to maximize the exploitation of scientific results	Fully implementing knowledge transfer policies in order to maximize the dissemination, uptake and exploitation of scientific results. RPOs and FROs should make knowledge transfer second nature by integrating it in their everyday work.

Q18. ERA strategic documents call Member States and Associated Countries to support their RPOs in establishing policies and procedures for the management of Intellectual Property[30].

[For RPOs] Does your organisation have a formal policy for Intellectual Property Management with clearly defined procedures? When was the policy developed? To the best of your knowledge, do other RPOs in our country also have policies for Intellectual property management? Does your local or national government provide support for RPOs to establish such policies? What kind of support?

[For EU stakeholders] To the best of your knowledge, do RPOs in Member States and Associated Countries have their own policies for the management of Intellectual Property? How prevalent are these policies? Could you identify any good practice examples?

Q19. Member States and Associated Countries are also invited to develop indicators to quantify the economic and social impact of knowledge transfer policies[31].

[For RPOs and RFOs] To the best of your knowledge, does your country have a monitoring system aimed to measure the economic and social impacts of knowledge transfer policies? When was such monitoring system developed?

[For EU stakeholders] How prevalent are monitoring systems aimed to measure the economic and social impacts of knowledge transfer policies among Member States and Associated Countries? Could you identify any good practice examples?

Q20. ERA strategic documents also call Member States and Associated Countries to promote networking, sharing of know-how and good practices between RPOs and the

[30] Intellectual property policy constitutes of the basic set of principles which RPOs should implement to effectively manage the intellectual property resulting from their own or collaborative activities in the field of research and development. More information can be found http://ec.europa.eu/invest-in-research/pdf/download_en/ip_recommendation.pdf.

[31] Knowledge transfer policy complement those relating to Intellectual Property policy by focusing more specifically on the active transfer and exploitation of such intellectual property, regardless of whether or not it is protected by IP rights. More information can be found http://ec.europa.eu/invest-in-research/pdf/download_en/ip_recommendation.pdf.

private sector (e.g. mobility schemes, collaborative research between public and private research performers)

[For RPOs] Does your organisation actively collaborate with private sector in sharing knowledge (e.g. carry out collaborative research projects)? Has such cooperation increased or decreased in recent years? Are there any local or national level policies aimed to encourage or facilitate collaboration between public and private research organisations?

[For RFOs] Does your organisation implement any specific measures aimed to foster the cooperation between public and private research performers? To the best of your knowledge, are there any other local or national level policies aimed to encourage or facilitate collaboration between public and private research organisations?

[For EU stakeholders] Please provide a brief overview of the overall situation on cooperation between RPOs and the private sector in Member States and Associated countries? How has the situation changed in recent years? What are the key regional/ country level trends/ differences? Could you identify any good practice examples at national level?

ERA priority 5(B): Promoting Open access to scientific publications	Open access to publications and data in an open science context

Q21. ERA strategic documents call research stakeholders to adopt and implement open access measures[32] for publications and data resulting from publicly funded research.

[For RFOs and RPOs] How prevalent are the open access measures among RPOs in your country? Are there any national level policies requiring to publish publicly funded research results in open access? What are the key challenges for open access?

[For EU stakeholders] How prevalent are the open access measures among Member States and Associated countries? What are the key regional/ country level differences? How has the situation improved/ deteriorated in recent years? Could you identify any good practice examples at national level?

[For RFOs] Does your organisation require from RPOs to publish results of publicly funded research projects in open access (e.g. Gold[33] or Green[34] Open access standards)?

[32] Open access (OA) can be defined as the practice of providing on-line access to scientific information that is free of charge to the user and that is re-usable. In the context of R&D, open access to 'scientific information' refers to two main categories: i) Peer-reviewed scientific publications (primarily research articles published in academic journals); ii) Scientific research data: data underlying publications and/or other data (such as curated but unpublished datasets or raw data). More information can be found: http://ec.europa.eu/research/openscience/index.cfm?pg=openaccess

EC Recommendation on access to and preservation of scientific information (2012) can be found here: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012H0417&rid=1

[33] Gold open access standard – publications (research results) are freely accessible to readers immediately and without restrictions.

[34] Green open access standard – a publication (research results) is published in a traditional paid subscription journal (not Open Access). However, the same publication still remains accessible free of charge in an Open Access institutional repository (open publication database).

[For RPOs] Whether and to what extent does your organisation publish results of publicly funded research projects in open access (e.g. Gold or Green Open access standards)?

ERA priority 6: International Cooperation	Effective international cooperation with third countries to address grand societal challenges, ease access to new emerging markets and increase the attractiveness of the ERA for talented minds and investors worldwide.

Q22. ERA strategic documents foresee that Member States and Associated Countries should define national strategies for internationalisation to foster stronger cooperation with key third countries.

[For RPOs and RFOs] Are there any national level strategies aimed to enhance international cooperation with third countries? How would you describe the overall situation of cooperation with third countries in the research and development field? Would you say that the cooperation has improved or deteriorated in recent years? Does your organisation play any role in these cooperation activities?

[For EU level stakeholders] To the best of your knowledge, which countries has the most comprehensive national strategies to foster stronger cooperation with the third countries in the research and development field? What are the key regional/ country level differences?

8 ASSESSMENT OF PROGRESS OF IMPLEMENTATION ON THE BASIS OF THE NATIONAL ACTION PLANS

An assessment of progress of implementation of ERA policies on the basis of the National Action Plans (NAP) represents an additional task when compared to previous ERA Progress Report editions. Such an assessment was done by taking into account both quantitative (where available) and qualitative (especially) elements provided by each Member State in their respective National Action Plans. Importantly, the analysis of NAPs provided in this report has only assessed elements established directly by NAPs (such as objectives, baselines, targets, timelines and milestones), as any political assessment remains up to the Commission.

As said above, assessment of the NAPs does not look so much at the quantitative targets set by the NAPs but rather provide a qualitative assessment of the level of implementation of NAPs across Member States. It therefore analyses the level of implementation of the NAPs and describe challenges, strengths, bottlenecks, and any other issues/ topics linked to the implementation of the NAPs. This ERA Progress Report provides a synthetic analysis on implementation of NAPs in all ERA countries, while a more in-depth country-by-country analysis is provided in the ERA Country Profiles.

The relevant country NAPs were used as a basis (analytical framework) for this task. It should be noted that the objective of this task was not to assess the "ERA or Commission compliance" of the NAPs, but rather how countries are implementing what was announced in their own NAPs.

Our analysis proceeded in the following steps:

1. Detailed analysis of individual NAPs to identify tangible policy objectives, baselines and timelines (which together were called the progress assessment framework), according to which we were able to assess the progress of NAPs' implementation for each country.

2. Thorough cross-examination of all quantitative and qualitative data extracted from various sources (desk research, interviews, quantitative analysis) with the elements of reconstructed progress assessment frameworks: tangible policy objectives, baselines and timelines identified in the first step;

3. Reporting the results of the assessment.

The key criteria for inclusion of any element into a reconstructed NAP performance framework was be the feasibility of technical assessment of progress against it. The resulting performance assessment frameworks we country-specific. Importantly, a reconstructed framework only represented the logic of intervention behind NAP (or its components, priorities) without evaluating whether it is adequate, comprehensive, appropriate to the role of a country in ERA, and so on. All elements (targets, milestones, objectives, announced actions) that could be assessed/ monitored on qualitative level were included in the exercise. We also found elements that could not be monitored in the selected NAPs, which are discussed in the dedicated section of the ERA Progress Report.

Thorough cross-examination of all quantitative and qualitative data extracted from various sources (desk research, interviews, compilation of quantitative indicators) with the elements of reconstructed progress assessment frameworks of the NAP's identified all areas where technical assessment of progress was feasible. This was a bidirectional analysis. The already collected information was screened for indications of data which would be relevant to assess the progress against the identified elements of a reconstructed NAP performance framework. On the other hand, the collected data informed certain aspects and improvement of a reconstructed NAP performance framework, e.g., where the original NAP uses an indicator but does not define its baseline or target, but the collected data indicates that these have been defined in the subsequent, more recent policy documents. Such analysis has informed the technical assessment on progress of NAP implementation. Above all the assessment was driven by availability of information, with clear indications where information was not sufficient to make a technical assessment. In all cases we have clearly differentiated between lack of data and lack of progress. Also, any qualifications and/ or limitations to reliability of data and hence assessment were always clearly indicated.

The assessment on progress was analysed and presented using the following categories:

- *Data not available/ sufficient to assess the progress or objectives of the NAP are too vague to be assessed* (n/a);
- *Very small change/ mixed progress* (+/-);
- *Presence of (some) progress* (+);
- *Substantial progress* (++)**.**

Results of the assessment of the implementation progress of NAPs are presented:

- In this main Technical Report, which provides an assessment of the general situation with the implementation of NAPs (see Section **Error! Reference source not found.**); and
- In the Country Profiles that describe the progress of NAPs implementation per ERA country. Here we provide a more in-depth analysis of the strengths, challenges and other specificities per each country.

While progress assessment frameworks are specific to a given country, the above indicated categorical assessment was integrated across the countries thereby revealing which ERA priorities witnessed more substantial progress during the reference period under analysis.

ANNEX 1: LIST OF KEY TERMS

European Research Area (ERA)

Includes the 28 Member States of the European Union (EU-28) and 16 Associated Countries:

- Austria (AT)
- Belgium (BE)
- Bulgaria (BG)
- Croatia (HR)
- Cyprus (CY)
- Czech Republic (CZ)
- Denmark (DK)
- Estonia (EE)
- Finland (FI)
- France (FR)
- Germany (DE)
- Greece (EL)
- Hungary (HU)
- Ireland (IE)
- Italy (IT)
- Latvia (LV)
- Lithuania (LT)
- Luxembourg (LU)
- Malta (MT)
- Netherlands (NL)
- Poland (PL)
- Portugal (PT)
- Romania (RO)
- Slovakia (SK)
- Slovenia (SI)
- Spain (ES)
- Sweden (SE)
- United Kingdom (UK)
- Albania (AL)
- Armenia (AM)
- Bosnia and Herzegovina (BA)
- Faroe Islands (FO)
- former Yugoslav Republic of Macedonia (MK)
- Georgia (GE)
- Iceland (IS)
- Israel (IL)
- Moldova (MD)
- Montenegro (ME)
- Norway (NO)
- Serbia (RS)
- Switzerland (CH)
- Turkey (TR)
- Tunisia (TN)
- Ukraine (UA)

Full counting of publications

Each publication is counted once for each entity (e.g. country, institution, author) appearing in the publication's author affiliations. For example, if a publication is authored by one author from the US, two authors from the UK and one author from France, it would be counted once for each country even though the UK appears twice in the author affiliations.

Fractional counting of publications

Typically, publications are counted using full counting, whereby each publication is counted only once in each institution/country/world region regardless of the number of authors from that institution/country/world region. This means that a publication between a French, a German and a Canadian researcher would count once for France, once for Germany, and once for the EU-28 as an ERA publication. In some cases where the number of publications is normalised by another metric such as the number of researchers, full counting creates an asymmetry between the numerator and denominator when aggregating the data at the regional level (i.e. EU-28). In the above example, the publication by France and Germany would not add up together at the EU-28 level using full counting (it would be counted only once), while the number of French and German researchers would add up in the denominator. Summing the publications across countries would not work either since the sum across EU-28 countries would add up to more publications than there are in practice; in the above example, there would be two publication counts for the EU-28, although there is only one publication. To circumvent this issue, fractional counting of publications has been used where appropriate.

The fractional counting of publications prevents a single paper from being counted multiple times; the sum of fractions across all papers and countries will add up to the number of world papers in the reference database. A fraction of each publication is equally distributed among all author addresses, which can then be codified by author, institution or country depending on the aggregation level at which the data are produced. For example, if a publication is authored by one author from the US, two authors from the UK and one author from France, this publication would be counted 0.25 times for the US, 0.5 times for the UK and 0.25 times for France. At the EU-28

level, the fraction of the publication that would be counted would amount to 0.75 (the sum of fractions across Member States).

Fractional counting of co-publications

Typically, co-publications are counted using full counting, whereby each co-publication is counted only once in each institution/country/world region regardless of the number of authors from that institution/country/world region. This means that a co-publication between a French, a German and a Canadian researcher would count once for France, once for Germany, and once for the EU-28 as a co-publication between two ERA countries (i.e. an ERA co-publication), although the sum across EU-28 countries would amount to two ERA co-publications (i.e. the sum of France and Germany). Because such an asymmetry is not present for researchers — i.e. the sum of researchers across Member States is equal to the total number of EU-28 researchers — the number of co-publications with ERA partners per FTE researcher will be underestimated for the EU-28 as a whole relative to individual Member States when using full counting. Also note that counting co-publications involving at least two ERA countries by considering the whole EU-28 as one large country is conceptually problematic since the EU-28 is not a country but a region embedding multiple ERA countries. Thus, co-publications involving at least two ERA countries have been counted using fractional counting so that the sum of co-publication fractions across countries equals the total number of publications at the world level, making it possible to sum the number of ERA co-publications and researchers in a symmetrical fashion at any aggregation level.

For a co-publication between a French, a German and a Canadian researcher, there are six bilateral links to be taken into account (i.e. DE–FR, DE–CA, FR–DE, FR–CA, CA–DE and CA–FR) since the co-publication must be counted in the perspective of each country (i.e. each link must have its reciprocal link taken into account). Each link is attributed an equal fraction of the publication; in this case the fraction for each link equals 1/6. Of those links, two correspond to a co-publication between two ERA countries (i.e. DE–FR, FR–DE) such that one third (or 2/6) of this publication would count as an ERA co-publication when aggregating at the ERA level (i.e. pooled ERA countries). Since both Germany and France are Member States, the number of co-publications for the EU-28 would also amount to a fraction of one third. For individual countries, only half of the links including them must be counted; only the links corresponding to their perspective (i.e. the ones where a country appears first, although the ones where a country appears last would also work) should be counted. Thus, for Germany and France, one sixth of this publication would count as an ERA co-publication.

ANNEX 2: INDEX LIST OF INDICATORS

Priority 1 – More effective national research systems

Headline indicator

— Adjusted Research Excellence Indicator

EMM indicators

— GBARD as a percentage of GDP

— European Innovation Scoreboard Summary Innovation Index

Priority 2a – Transnational cooperation

Headline indicator

— GBARD (EUR) allocated to Europe-wide transnational, as well as bilateral or multilateral, public R&D programmes per FTE researcher in the public sector

EMM indicators

— Member State participation (EUR) in Public-to-Public collaborations per FTE researcher in the public sector

— International co-publications with ERA partners per 1 000 FTE researchers in the public sector

Priority 2b – European Strategy Forum for Research Infrastructures (ESFRI)

Headline indicator

— Availability of national roadmaps with identified ESFRI projects and corresponding investment needs

EMM indicators

— Share of developing ESFRI Projects in which a Member State/Associate Country is a partner

— Share of developing operational ESFRI Landmarks in which a Member State/Associate Country is a partner

— Share of developing ESFRI Projects and operational ESFRI Landmarks in which a Member State/Associate Country is a partner

Priority 3 – Open labour market for researchers

Headline indicator

— Number of researcher postings advertised through the EURAXESS job portal, per 1 000 researchers in the public sector

EMM indicators

— Share of doctoral candidates with a citizenship of another EU Member State

— Share of researchers expressing satisfaction that the hiring procedures in their institution are Open, Transparent and Merit-Based

Priority 4 – Gender equality and gender mainstreaming in research

Headline indicator

— Share of women in Grade A positions in the Higher Education Sector

EMM indicators

— Gender dimension in research content

— Share of female PhD graduatesP1 – EMM indicator – European Innovation Scoreboard

Priority 5a – Optimal circulation, access to and transfer of scientific knowledge

Headline indicator

— Share of product and/or process innovative firms cooperating with universities, government, public or private research institutes

EMM indicators

— Share of public research financed by the private sector

— Number of public-private co-publications per million population

Priority 5b – Optimal circulation, access to and transfer of scientific knowledge

Headline indicator

— Share of publications available in open access

EMM indicator

— RFOs (i.e. members of Science Europe or other important sources of national funding) providing funds to cover costs of OA publishing

— Share of RFOs' (i.e. members of Science Europe or other important sources of national funding) publications that are available in OA

— Share of life sciences papers to which a country contributed and that have at least one open dataset in Figshare

Priority 6 – International cooperation

Headline indicator

—Co-publications with non-ERA partners per 1 000 researchers in the public sector

EMM indicators

— Non-EU doctorate students as a share of all doctorate students

— Exports of medium and high technology products as a share of total product exports

— Knowledge intensive services exports as percentage of total services exports

REFERENCES

Archambault É., Caruso J., and Beauchesne O. (2011). Towards a Multilingual, Comprehensive and Open Scientific Journal Ontology, in Noyons, B., Ngulube, P. and Leta, J. *Proceedings of the 13th International Conference of the International Society for Scientometrics and Informetrics (ISSI)*, Durban, South Africa, pp 66-77.

Archambault, É., Côté, G., Struck, B., and Voorons, M. (2016). *Research Impact of Paywalled versus Open Access Papers*. http://www.1science.com/oanumbr.html.

DG Education and Culture (2011), *Supporting growth and jobs—An agenda for the modernization of Europe's higher education systems* [pdf], Publications Office of the European Union, Luxembourg, available at http://ec.europa.eu/education/library/policy/modernisation_en.pdf.

DG Internal Market, Industry, Entrepreneurship and SMEs (2018), *European Innovation Scoreboard 2018* [pdf], Publications Office of the European Union, Luxembourg, available at https://ec.europa.eu/docsroom/documents/30281

DG Research and Innovation (2014), *European Research Area—Progress Report 2014* [pdf], Publications Office of the European Union, Luxembourg, available at http://ec.europa.eu/research/era/pdf/era_progress_report2014/era_progress-report_150521.pdf.

DG Research and Innovation (2015), *European Research Area—Facts and Figures 2014* [pdf], Publications Office of the European Union, Luxembourg, available at http://ec.europa.eu/research/era/pdf/era_progress_report2014/era_facts&figures_2014.pdf.

DG Research and Innovation (2016a), *She Figures Handbook 2015* [pdf], Publications Office of the European Union, Luxembourg, available at http://ec.europa.eu/research/swafs/pdf/pub_gender_equality/she_figures_2015_Handbook_final.pdf.

DG Research and Innovation (2016b), *She Figures 2015* [pdf], Publications Office of the European Union, Luxembourg, available at https://ec.europa.eu/research/swafs/pdf/pub_gender_equality/she_figures_2015-final.pdf.

DG Research and Innovation (2017), *Indicators report Europe – Annex to MORE3 study: Support data collection and analysis concerning mobility patterns and career paths of researchers*, Publications Office of the European Union, Luxembourg, available at https://cdn3.euraxess.org/sites/default/files/policy_library/indicators_report_1.pdf

EGGE (European Commission's Expert Group on Gender and Employment) (2009), *Gender segregation in the labour market: Root causes, implications and policy responses in the EU* [pdf], Publications Office of the European Union, Luxembourg, available at http://ec.europa.eu/social/main.jsp?catId=738&langId=en&pubId=364&furtherPubs=yes.

ERAC Secretariat. (2015a). ERAC Opinion on the ERA Roadmap - Core high level indicators for monitoring progress. ERAC 1213/15. European Union. Retrieved from https://era.gv.at/object/document/2343

ERAC Secretariat. (2015b). ERAC Opinion on the European Research Area Roadmap 2015-2020.

ERA-Learn (2015), *1st Annual report on Public-Public partnerships* [pdf], available at https://www.era-learn.eu/documents/era-learn-publications/d3-3-era-learn-2020-annual-report-on-p2p-partnershipsno-1-2015.pdf

ERA-Learn (2017), *3rd Annual report on Public-Public partnerships* [pdf], available at https://www.era-learn.eu/documents/era-learn-publications/era-learn-ar2017-web.pdf

ESFRI (European Strategy Forum on Research Infrastructures) (2016), *Strategy Report on Research Infrastructures* [pdf], Science and Technology Facilities Council, available at http://www.esfri.eu/sites/default/files/20160308_ROADMAP_single_page_LIGHT.pdf.

European Commission (2012), *Communication from the Commission to the European parliament, the council, the European economic and social committee and the committee of the regions: A reinforced European Research Area partnership for excellence and growth* [pdf], Brussels, available at http://ec.europa.eu/euraxess/pdf/research_policies/era-communication_en.pdf.

Federer L.M., et al. (2018) *Data Sharing in PLOS ONE: An Analysis of Data Availability Statements*, PLOS ONE, https://doi.org/10.1371/journal.pone.0194768.

ICF International (2015), *Assessment of progress in achieving ERA in Member States and Associated Countries—Final Report to DG Research and Innovation*, Job Number 30260436.

IDEA Consult (2013), *Support for continued data collection and analysis concerning mobility patterns and career paths of researchers, Guidelines for the data analysis of the EU HEI survey data*, Brussels, available at http://ec.europa.eu/euraxess/pdf/research_policies/more2/Final%20report.pdf

IDEA Consult & WIPO (2017), *Support data collection and analysis concerning mobility patterns and career paths of researchers Guidelines for the data analysis of the EU HE survey data*, Brussels, unpublished at this time.

Rotolo D., Grassano N., Hutton J., Lang F., and Hopkins M. M. (2016) *Funding Data from Publication Acknowledgements: Coverage, Uses and Limitations*, Journal of the Association for Information Science and Technology, http://dx.doi.org/10.1002/asi.23737

Science-Metrix (2016), *Inception Report—Data gathering and information for the 2016 ERA monitoring*, Prepared for the European Commission, Contract 30-CE-0755994/00-15.

Science-Metrix (2017), *ERA Progress Report 2016: Technical Report* (No. EUR 28430 EN). Luxembourg: Publications Office of the European Union. Retrieved from http://ec.europa.eu/research/era/pdf/era_progress_report2016/era_progress_report_2016_technical_report.pdf.

Science-Metrix (2018), *Analytical Support for Bibliometrics Indicators— Open access availability of scientific publications*, Prepared for National Science Foundation's (NSF) National Center for Science and Engineering Statistics (NCSES), Contract NSFDACS1063289.

Vértesy, D. (2018) *The Adjusted Research Excellence Index: July 2018 update, Methodology Report*. European Commission, Joint Research Centre, I.1 / CC-COIN, unpublished.

How to obtain EU publications

Free publications:

- one copy:
  via EU Bookshop (http://bookshop.europa.eu);
- more than one copy or posters/maps:
  from the European Union's representations (http://ec.europa.eu/represent_en.htm);
  from the delegations in non-EU countries (http://eeas.europa.eu/delegations/index_en.htm);
  by contacting the Europe Direct service (http://europa.eu/europedirect/index_en.htm) or
  calling 00 800 6 7 8 9 10 11 (freephone number from anywhere in the EU) (*).

  (*) The information given is free, as are most calls (though some operators, phone boxes or hotels may charge you).

Priced publications:

- via EU Bookshop (http://bookshop.europa.eu)

KI-01-19-102-EN-N

The ERA Monitoring Handbook (2018) provides methodological guidance on the calculation of indicators, on the documents review and on the interviews that were conducted for the ERA Monitoring 2018 publication.

Organised by data source, information provided on each indicator includes a brief definition, rationale, computation method and any comments or critical issues for the reader to note. The handbook also includes a section on the verification and validation of data that outlines coherence checks and additional data considerations to be taken into consideration in the computation and interpretation of indicators. Finally, the annexes outline important information regarding international classification standards to which data for several of the indicators are tied, as well as key terminology and definitions.

Publications Office

ISBN 978-92-79-99761-7
doi:10.2777/764148