European Commission

ERA PROGRESS REPORT 2018

Data gathering and information for the 2018 ERA monitoring – Technical Report

Written by PPMI and Science-Metrix
February 2019

Research and Innovation

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EUROPEAN COMMISSION

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

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European Commission
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Luxembourg: Publications Office of the European Union, 2019.

PDF ISBN 978-92-79-99760-0 doi:10.2777/103628 KI-01-19-101-EN-N

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EXECUTIVE SUMMARY

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 study is to assist the European Commission in implementing the 2018 ERA Monitoring Mechanism to assess the recent progress made towards achieving six ERA priorities.

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.

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 the analysis of indicators applied in the ERA Monitoring Mechanism, this report is the first to assess the implementation progress 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. Some of the main findings from this evidence-rich report are presented in brief below.

Priority 1 focuses on improving the effectiveness of national research systems, including through increased competition in the allocation of public funding for R&I through open calls for proposals and the use of peer-review panels composed of leading independent domestic and non-domestic experts. As the ERA process evolved, the 2015 ERA Roadmap has identified the 'strengthening of the evaluation of research and innovation policies and seeking complementarities between, and rationalisation of, instruments at EU and national levels' as the top action for Priority 1. The roadmap has also recommended that Member States should better align national and European policies and priorities, and optimise the use of public investments in R&I.

Study data confirmed that the competitive allocation of research funding through calls for proposals is now a common practice among ERA countries. However, the share of competitive funding varies across countries and is very uneven. There are also diverging opinions about ensuring the balance between competitive funding and block funding. While competitive funding is promoted by the Commission as a way to increase efficiency in research systems, many interviewees suggested that resource allocation should take into account differences in the research capacities and mandates of research performing organisations (RPOs), as well as planning of research activities. ERA countries have different traditions of funding research organisations and there is, in some countries, a resistance from RPOs to decrease block funding. This is particularly common in countries with less-developed national research systems.

The context around the implementation of Priority 1 remained heterogeneous, as ERA countries continued to be very different in terms of their support for and efficiency of their R&I activities. Even though there is substantial support for expenditures in R&I at the EU level, some countries have decreased their R&I spending since the previous ERA monitoring exercise, while others made no necessary or substantial increase. This is especially worrying in countries with less-developed national research systems as they are too reliant on EU structural funds to supplement domestic R&I budgets. A number of interviewees indicated that with the current EU funding period ending in 2020, some national research systems will face the challenge to ensure the same or higher amount of funding in the next funding period. Otherwise, some of the systems that fail to ensure the EU funding may risk decline in the quality of their research.

At the same time, EU Member States have been trying to make their national research and innovation systems more efficient and competitive through implementing national and regional smart specialisation strategies. Although the level of commitment and genuine planning was different in each country, this process allowed for better cooperation between different R&I actors, which in turn facilitated the development of a more comprehensive vision and encouraged more

sustainable and efficient investments in key strategic areas. Most of the smaller countries only developed national strategies, while most of the larger countries have a national strategy complemented by regional smart specialisation strategies. This practice encouraged the development of regions and better cooperation between regions to develop matching priorities.

Priority 2a focuses on transnational scientific collaboration to address current grand socioeconomic challenges. Key actions under Priority 2a included improving alignment between national funding rules and selection processes; advancing the definition of common research priorities; implementing joint research agendas, including joint or at least synchronised calls and the use of joint international peer reviews; and compatible national funding rules converging to common European standards.

The study found that although there was still an increase in international cooperation in the EU-28 over the recent period from 2014 to 2016, EU-28 Member States (France excluded) have seen a slowdown in growth on GBARD allocated to transnationally coordinated research since the previous monitoring exercise. While average annual growth stood at 7.2 % for the EU-28 between 2012 and 2014, it decreases to 3.9 % for the period 2014 to 2016.

Qualitative analysis showed that pooling of resources and research capacities to more effectively address common challenges remains the main perceived and actual added value of EU-level Public-to-Public Partnership (P2P) instruments, such as Joint Programming Initiatives (JPIs) and ERA-NETs. Active participation in JPIs, ERA-NETs and similar instruments was one of the most frequently emphasised strategic goals in the newest national ERA roadmaps for a number of ERA countries. In addition, evaluation, monitoring and impact assessment of the P2Ps in research is increasingly recognised as a catalyst for success of these instruments by ERA countries. In terms of the key areas for potential improvement, a lack of systemic coordination both among the different EU R&I partnerships and between these instruments and national research agendas and programmes, together with the lack of funding in some ERA countries, remain the main hindrances for successful coordination of national R&I policies and participation in P2P actions.

Priority 2b focuses on making optimal use of public investments in research infrastructures. The 2012 Communication 'A Reinforced European Research Area Partnership for Excellence and Growth' demanded that national commitments to the implementation of the European Strategy Forum on Research Infrastructures (ESFRI) Roadmap be ensured, maximum value for money from investment in research infrastructures be achieved, and barriers to the construction and operation of, and open access to research infrastructures across Europe be overcome.

As of 2018, there were 16 countries that had roadmaps in place with both ESFRI projects and funding needs identified. These countries were — ordered according to the year in which the national roadmap came into effect — Germany, Croatia, Estonia, Finland, Sweden, Denmark, Montenegro, Switzerland, France, Slovenia, Israel, Bulgaria, Greece, Italy, Romania and Hungary. Additionally, six countries had roadmaps identifying ESFRI projects but no funding requirements (Austria, Poland, Portugal, Czech Republic, Lithuania, and the Netherlands). Norway had a roadmap with funding requirements identified but no ESFRI projects identified. Ireland, the UK and Spain all had a roadmap in place but identified neither ESFRI projects nor the funding needs associated therewith. The remaining 18 countries had no national roadmap in place.

ESFRI Projects and Landmarks, on average, included more countries in 2018 than they did in 2016. Projects involved an average of 6.6 countries in 2016 and 9.1 in 2018. For Landmarks, that figure is 11.7 in 2018, up from 9.9 in 2016. In 2016, EU-28 Member States had an average participation of 21 % in developing projects and of 30 % in operational Landmarks. These EU-28 averages increased to 29 % (38 % increase from 2016) and 37 % (23 % increase from 2016), respectively, in 2018. The higher growth figure for developing projects compared to operational Landmarks is indicative of a continued expansion potential for ESFRI initiatives and services, as well as of increased inclusion among ERA countries.

In addition, quantitative analysis showed that countries that have a national roadmap policy in place are more likely to be participating in a greater share of ESFRI projects in the preparatory phase and operational landmarks. Qualitative analysis showed that there remains the need for more cooperation and synchronisation of national research infrastructures in terms of their inclusion into a harmonious pan-European landscape of research infrastructures. Instruments that could serve this purpose include the improvement of communication strategies and networking events, more outreach events and more dedicated funding/support to ESFRI and the European Research Infrastructure Consortium (ERIC) instrument.

Priority 3 aims to ensure an open labour market for researchers. ERA countries are expected to facilitate researchers' mobility by allowing non-nationals/non-residents to access national grants, and by making grants portable across borders. Furthermore, transparent, open and merit-based recruitment procedures must become a standard practice in all research performing organisations in ERA.

In terms of the number of researcher job postings from a given country that are advertised through the EURAXESS job portal per 1 000 researchers in the public sector, the EU-28 Member States appeared to be positioned in a downward trajectory with annual average declines of 5 % for the whole country group since 2014. This average annual decline reversed a previous course of positive growth over the 2012 to 2014 period. Results at the aggregate level contrasted sharply with a few very strong growth rates that stood out from the portrait of individual countries (i.e. Finland, Germany, Latvia, Turkey and Luxembourg), whereas decreases were driven by Bulgaria (61 % average annual decrease), Greece (45 % decrease) and Sweden (44 % decrease).

In terms of the share of doctoral candidates with citizenship of another EU Member State, the data for 2013-2016 show that the EU-28 average score has moderately increased since 2013, i.e. from 6.4 % to 7.1 % in 2016.

While the last ERA Progress Report, based on MORE survey results for 2012, found that 49 % of respondents in EU-28 Member States were satisfied with the hiring procedures in their institution, the present study found that this score has increased to 65 % based on the 2016 MORE survey. This means that a significantly higher number of researchers is now satisfied with the recruitment procedures used by RPOs.

Qualitative analysis confirmed that a large gap still exists between EU countries in terms of the open labour market and career development opportunities provided to researchers, measured by the availability of opportunities for learning, research funding opportunities, financial security, salaries and shares of fixed-term contracts. This heterogeneity reflects different higher education and research systems, as well as economic developments influencing public budgets for research and hence research funding and salaries of researchers. In addition, different employment status of researchers across different European countries and the resulting limited portability of social security and pension schemes across borders is one of the key barriers for international mobility of researchers.

Priority 4 focuses on gender equality and gender mainstreaming in research. The 2015 ERA Roadmap renewed the commitment of the Member States to foster gender equality in research. Moving forward, the top action priority is to translate the various national equality legislations 'into effective action to address gender imbalances in research institutions and decision-making bodies.' At the same time, the Roadmap sought to improve the integration of the gender dimension into research and development policies, programmes and projects.

Regarding gender balance in research positions, the aggregate score for EU-28 Member States remained mostly unchanged for the share of women in Grade A positions in the higher education sector and for the share of female PhD graduates since the last ERA monitoring exercise. The study results also showed that while gender parity was nearly reached by all ERA countries at the entry stage of an academic career, women remain largely under-represented in higher academic echelons (based on the Headline indicator). It should also be noted that there are some fluctuations in terms of gender parity depending on the field of study.

A number of gender equality plans and related policies were implemented across ERA countries to tackle unconscious/implicit gender biases, to include gender in research programmes and training and to promote programmes and resources for equal opportunities in career progression with various degrees of progress.

Despite some progress towards gender equality in research and innovation, gender inequity in research and academia is, however, still evident. Efforts towards increasing the enrolment and retention of women in science, implementation of work and life balance policies, reducing gender pay gap and removing obstacles to women's career progression are still needed in order to achieve gender parity.

Priority 5a invites to fully implement knowledge transfer policies at national level in order to maximise the exploitation of scientific results. Furthermore, RPOs and RFOs (research funding organisations) are expected to make knowledge transfer an integral part of their activities.

At the aggregate EU-28 level, for the year 2014, 15 % of firms were found to cooperate with either universities, government, public or private research institutes. The EU-28 share of enterprise collaboration with universities remained roughly stable from 2012 to 2014 while the EU-28 share of enterprises cooperating with government, public or private research institutes has experienced an average annual increase of 4 % in the same period (in this latter case, many Member States had missing data and were thus omitted in the aggregate).

EU Member States did not progress since 2013, the latest available year in the previous monitoring exercise. The average share of public research financed by the private sector stood at 7.1 % in 2013, whereas it stood at 7 % in 2015. Pronounced decreases since the last monitoring exercise were found in the least performing countries (Cluster 4) on this indicator.

Qualitative analysis revealed that a growing number of organisations across ERA countries are promoting knowledge transfer and uptake of scientific findings. For instance, in Estonia technology development centres and clusters which foster the cooperation of doctoral students with enterprises and businesses area being implemented. Spain has designed a large number of support schemes to foster R&D activities. Hungary has held and continues to hold cooperation between business and academia as a priority of STI policy which has resulted in a higher number of corporate research centres and R&D labs that work closely with academic partners.

Priority 5b focuses on ensuring open access to publications and data. Freedom of access to and use of existing scientific knowledge was recognised as input for the continuous reproduction of R&I activities, and enhanced possibilities to capture the economic benefits that can be associated with R&I.

Open access (OA) evolved and progressed rapidly over the last few years and it is possible to observe that the majority of ERA countries have adopted policies, and to some extent legal measures, for open access to publications and open data practices. However, even in countries where legal measures have been adopted, its enforcement varies greatly. The EU-28 share of 2016 publications that are available in any form of OA now stands at 49 %; with similar shares of gold and green OA papers. Nevertheless, there remains substantial variance in the ratio of gold to green OA across individual countries with some of them scoring much higher in gold OA while others do so in green OA.

Turning from OA to research publications towards OA to research data, the progress has been much slower and a great diversity of approaches across national contexts and disciplines can be found. Financial and technical challenges relating to the storage and usable formatting of data made available in OA resulted in low shares of papers for which datasets were made available online. Dataset distribution and circulation emerge as perhaps the next great challenge for OA policy.

Priority 6 indicates that effective international (third country) cooperation is necessary 'to address grand societal challenges, ease access to new emerging markets and increase the attractiveness of the ERA for talented minds and investors worldwide.' In the context of a highly globalised world, this enhanced approach to internationalisation seeks to underpin Europe's leadership in R&I, with the expectation that ERA partners can take maximum advantage of a diversity of bilateral and multilateral relations and exchanges involving R&I with third countries.

EU Member States have experienced steady increases in non-ERA co-publications since the last monitoring exercise. Average annual growth for EU-28 was found to be 4.4 % for the period spanning 2014 to 2016, an intensity similar to that observed over the longer term from 2007 to 2016 (4.2 %). Countries that increased their performance the most in recent years (short-term growth) include Latvia (31 points ahead of the EU-28 level in average yearly growth) and FYR Macedonia (23-point lead). International cooperation as measured by non-ERA co-publications appears to have been very much geographically concentrated. High-GDP countries and smaller western European countries had the strongest performances.

The study also found that the shares of non-EU doctoral students were increasing moderately, while some countries experienced strong surges in this indicator. For EU Member States as a whole, 14 % of doctoral students held non-EU nationalities. From 2013 to 2016, annual average growth within EU Member States has been measured at 3.8 %. Countries with noteworthy growth rates include

FYR Macedonia, whose annual average growth is 103 %, Lithuania (49 %) and Cyprus (41 %). Malta has seen its share of non-EU doctoral students decrease at an average annual rate of -15 %, but this case represented the only notable decrease (by more than -6 %) among ERA countries.

For the first time, this ERA Progress Report has also provided an assessment of **progress with implementation of the National Action Plans (NAPs)**. 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 the reasons for this was the establishment of 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; in our opinion, however, they have achieved less progress mainly due to the 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.

1 INTRODUCTION

According to the European Commission's 2012 Communication 'A Reinforced European Research Area Partnership for Excellence and Growth,' the European Research Area (ERA) is a

> unified research area open to the world based on the Internal Market, in which researchers, scientific knowledge and technology circulate freely and through which the Union and its Member States strengthen their scientific and technological bases, their competitiveness and their capacity to collectively address grand challenges.

The building of the ERA is an evolving process that recognises the heterogeneity of national research and innovation systems across Europe, as well as differences in the implementation of ERA priorities at three different but interrelated levels: **the European level** (actions are mainly coordinated by the European Commission with support and inputs from the European-level stakeholder organisations), **the national level** (where the Member States and Associated Countries play the key role), and **the organisational level** (where research funding organisations (RFOs) and research performing organisations (RPOs) and their umbrella organisations play the key role).

While significant progress has been achieved in setting up the conditions necessary for building the ERA, the previous monitoring reports have indicated certain gaps. The 2014 monitoring exercise highlighted the unevenness of progress made among the countries, pointing to the need for speeding up the pace of implementation of the ERA in particular in some groups of countries. For example, the 2014 monitoring exercise revealed that only half of the Member States had implemented measures to at least a medium degree, and that striking regional differences in implementation existed between western European countries and Central/Eastern European countries — the former faring better than the latter. Notably, the distinction between Member States and Associated Countries did not appear to be relevant. In the context of the 2014 ERA Progress Report, the key implementation priorities were refined to some extent in the ERA Roadmap adopted in 2015.

The 2016 ERA Progress Report confirmed that these differences among countries still existed in 2016. Although the report said that it is not the same group of countries leading the way within each specific priority, mainly western and Nordic European countries emerged as a leading group overall (in particular Belgium, the Netherlands, Sweden, the UK, Norway and Switzerland). The report also noted, however, that due to differences in the data between the 2014 and 2016 monitoring exercises, it was not possible to say with certainty whether the gap between the leaders and the rest is widening or narrowing. Finally, the 2016 report argued that an explicit definition of targets for each priority would help focus the efforts of ERA countries and may lead to greater convergence between national policies.

While such targets were not set, the key ERA players decided to use another mechanism to inspire the commitment of the Member States and the Associated Countries to building ERA – the National Action Plans (NAPs). In their respective NAPs, the Member States and the Associated Countries (that decided to draft them) laid out their plans on how they were going to contribute to building ERA at the national level. This report provides an assessment of the extent to which ERA countries followed up on their plans.

Otherwise, the report is structured according to ERA priorities and provides quantitative and qualitative information on how the Member States and the Associated Countries are progressing with each of them. ERA implementation priorities were defined in the 2012 Communication by the European Commission. In addition to the five ERA priorities, the reforms and actions necessary to implement them were defined, and the international dimension outside the ERA was identified as a cross-cutting theme. Subsequently, in the consultation with the European Research Area and Innovation Committee (ERAC), the ERA-Related Groups and most of the organisations that make up the ERA Stakeholder Platform, the international dimension was transformed into a sixth priority for the 2015 ERA Roadmap, as follows:

(1) more effective national research systems;

(2) optimal transnational cooperation and competition;

(3) an open labour market for researchers;

(4) gender equality and gender mainstreaming in research;

(5) optimal access to and circulation and transfer of scientific knowledge, including via digital ERA; and

(6) international dimension outside the ERA.

Moreover, Priorities 2 and 5 were split into two sub-priorities each. The following paragraphs will describe the evolution of the broad priorities from the 2012 Communication into the top action priorities of the 2015 ERA Roadmap.

1.1 ERA priorities and actions

Priority 1 – More effective national research systems: The 2012 ERA Communication recognised open competition as key to deriving maximum value from public investments in research and innovation (R&I). Member States were expected to increase competition in the allocation of public funding for R&I through open calls for proposals and the use of peer-review panels composed of leading independent domestic and non-domestic experts. Competition was intended to promote internationally competitive levels of research performance. In addition, institutional funding decisions were expected to build on performance assessments of organisations and teams and the quality of their outputs. As the ERA process evolved, the 2015 ERA Roadmap has identified the 'strengthening of the evaluation of research and innovation policies and seeking complementarities between, and rationalisation of, instruments at EU and national levels' as the top action for Priority 1. The Roadmap recommends that Member States better align national and European policies and priorities, and optimise the use of public investments in R&I. The role of the European Commission is to develop policy tools that facilitate partnerships and mutual learning.

Priority 2a – Jointly addressing grand challenges: The 2012 Communication acknowledged the need for the European Union to collectively address grand challenges, while maximising the limited public research funds available. The document proposed the use of Joint Programming Initiatives (JPIs) to exploit synergies between national and international programmes, and to better anchor cooperation with international partners. Key actions under Priority 2 included improving alignment between national funding rules and selection processes; advancing the definition of common research priorities; implementing joint research agendas, including joint or at least synchronised calls and the use of joint international peer reviews; and compatible national funding rules converging to common European standards. The 2015 ERA Roadmap underlined that the potential of Joint Programming is yet to be fully realised, hence the top action priority of 'improving alignment within and across the Joint Programming Process and the resulting initiatives (e.g. JPIs) and speeding up their implementation.' Horizon 2020 and Horizon Europe are expected to play a prominent role in this area. At the same time, ERA countries are invited to improve cross-border collaboration and promote the best use of resources at the scale required to tackle issues that demand large, concerted and sustained research efforts.

Priority 2b – Make optimal use of public investments in research infrastructures: The ERA process has identified a strong connection between excellent research and the availability of access to world-class facilities and research infrastructures (RIs). The 2012 Communication set the challenges of ensuring national commitments to the implementation of the European Strategy Forum on Research Infrastructures (ESFRI) Roadmap, achieving maximum value for money from investment in RIs, and overcoming barriers to the construction and operation of, as well as open access to RIs across Europe. A target was also introduced to complete or initiate construction of 60% of the ESFRI Roadmap priority RIs by 2015. Because of the magnitude of the required investment, the 2012 Communication called upon Member States to mobilise regional, national and European Union funds, and to open up to partnerships with third countries. The commitment towards the optimal use of public investments in high-quality, accessible research infrastructures was maintained in the 2015 ERA Roadmap. RIs are placed not only at the foundation of the knowledge triangle of research, education and innovation in Europe, but are expected to underpin the region's efforts 'to lead the global movement towards open, interconnected, data-driven and computer-intensive science,' and to tackle societal challenges. The top action priority remains to make 'optimal use of public investments in RI by setting national priorities compatible with the ESFRI priorities and criteria taking full account of long-term sustainability.'

Priority 3 – An open labour market for researchers: The key ERA documents clearly state that researcher mobility contributes to research excellence. However, the lack of transparent, open and merit-based recruitment still remains a factor that reduces the attractiveness of research careers and hinders mobility, gender equality and research performance. Member States are expected to facilitate mobility by allowing non-nationals/non-residents to access national grants, and by making grants portable across borders. The 2012 Communication endorsed the use of initiatives such as 'Money Follows Researcher' to remove barriers and enhance the portability of national grants while protecting the interests of all parties. Additional barriers identified included human resource policies that hinder career prospects for young researchers, as well as 'inadequate gender equality practices, social security obstacles and insufficient academia-business mobility.' The 2015 ERA Roadmap has renewed this commitment by stating: 'The goal is a truly open and excellence-driven ERA in which highly skilled and qualified people can move seamlessly across borders, sectors (e.g. academia and industry) and disciplines to where their talents can be best employed to advance the frontiers of knowledge and support innovation throughout Europe and beyond.'

Priority 4 – Gender equality and gender mainstreaming in research: The 2012 Communication highlighted that despite the presence of national and EU-level strategies on gender equality, several indicators demonstrated the persistent gaps in this area. The inability to tap into the talent of highly skilled women represents a major challenge for European research systems. For example, the share of women in leading public sector research positions in 2012 was below the Council's 2005 goal of 25 %, while there was limited integration of a gender dimension into the design, evaluation and implementation of research activities. The 2015 ERA Roadmap has renewed the commitment of the Member States to foster gender equality in research. Moving forward, the top action priority is to translate the various national equality legislations 'into effective action to address gender imbalances in research institutions and decision-making bodies.' At the same time, the Roadmap sought to improve the integration of the gender dimension into research and development (R&D) policies, programmes and projects.

Priority 5a – Fully implementing knowledge transfer policies at national level in order to maximise the exploitation of scientific results: The 2012 Communication invited the ERA stakeholders to foster knowledge creation, transfer, circulation and access in order to enhance the potential to extract economic benefits from R&I. These considerations were expected to inform and guide academia–industry interactions and linkages around research, as well as cooperation within ERA countries, and between ERA and non-ERA countries. The 2015 Roadmap has transformed this component of Priority 5 into a more strategic and explicit approach to the removal of legal, political and technical barriers to knowledge circulation and knowledge use. Sub-priority 5a stresses that the transfer, uptake and use of research results is a relevant input into increased growth and competitiveness, with benefits for diverse communities and organisations — public and private — involved in research. The top action priority is to fully implement national knowledge transfer policies in ways that maximise knowledge dissemination, uptake and use. Furthermore, RPOs and RFOs are expected to make knowledge transfer an integral part of their activities.

Priority 5b – Open access to publications and data in an open science context: The 2012 Communication endorsed initiatives that promote broad open access to and use of publicly funded scientific publications and data. Freedom of access to and use of existing scientific knowledge was recognised as input for the continuous reproduction of R&I activities, and enhanced possibilities to capture the economic benefits that can be associated with R&I. Particular emphasis was placed on promoting an enhanced digital ERA. However, the Communication also recognised the uneven state of advancement of ERA country policies in this area. The 2015 Roadmap reformulation of Priority 5 into Sub-priority 5b made more explicit the ERA's commitment to open access to the outputs of publicly funded research, whether scientific publications, through gold and/or green practices, or data.

Priority 6 – International cooperation: The 2012 Communication introduced international cooperation involving R&I with third countries as a 'vital, cross-cutting and integral part' of the ERA implementation process. The 2015 Roadmap has transformed this international dimension into an explicit ERA Priority 6. Thus, effective international cooperation is considered necessary 'to address grand societal challenges, ease access to new emerging markets and increase the attractiveness of the ERA for talented minds and investors worldwide.' In the context of a highly globalised world, this enhanced approach to internationalisation seeks to underpin Europe's leadership in R&I, with the expectation that ERA partners can take maximum advantage of a diversity of bilateral and multilateral relations and exchanges involving R&I with third countries.

1.2 Objective of the study

The ongoing ERA Monitoring Mechanism (i.e. the 2018 EMM) aims to document and assess recent progress in the ERA implementation process, while taking account of 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 (MS) and Associated Countries (AC), and RFOs/RPOs.

As such, the overarching objective of this study is to assist the European Commission in implementing the 2018 EMM to assess recent progress made by each of the three core types of actors in support of further evidence-based policy development towards achieving all ERA priorities. Building on the monitoring approach suggested by the ERA Progress Report 2016 (see ERA Monitoring Handbook prepared in 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 as described in Section 1.1 above. The analysis of ERA progress in this study covered a timespan of approximately 10 years (2007-2017). Data from all 28 EU Member States and 16 Associated Countries were used to examine progress at the European, regional, country and organisational levels. The set of 44 countries will be referred to as 'ERA countries' throughout this report. In addition to analysis of indicators foreseen in the EMM, this report provides an assessment of implementation progress on the basis of the National Action Plans adopted by ERA countries. For the first time this ERA Progress Report 2018 assesses whether

ERA countries deliver on promises made in their NAPs. The evidence base presented in this report is expected to support ongoing policy development and efforts towards the improved implementation of ERA.

2 METHODOLOGY

Four lines of evidence have been used in achieving this study's goal: desk research and document review (presented in Section 2.1), interviews (Section 2.2), the compilation of quantitative data (Section 2.3), and assessment of implementation progress on the basis of the National Action Plans (Section 0). Altogether, these tools enabled the collection, organisation, assessment, and synthetisation of qualitative and quantitative information at the European, regional, national and organisational levels. Note, however, that not all lines of evidence provided information for each of these levels and that the results for each level and methodological instrument are presented in an integrated fashion in this report. Whenever possible, we aimed to ground our conclusions in two or more lines of evidence.

2.1 Desk research and document review

Desk research and document review provided the framework for the present study, 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 at the level of research organisations.

Refer to Table 1 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 1 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 performed 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 the ERA Communication and the 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.

2.2 Interviews

In total, 73 telephone interviews were conducted between mid-July and August 2018. The interviews involved 64 representatives of RFOs and 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.

2.3 Compilation of quantitative data

Finally, extensive quantitative data were assembled by the study team to compute indicators selected to assess progress towards the ERA at the regional and country level. The European Research Area and Innovation Committee (ERAC) selected eight core high-level indicators (one per priority, or per sub-priority for priorities 2 and 5) that are regarded as being the most relevant in monitoring progress in achieving the ERA (ERAC Secretariat, 2015a). 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 2 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 aggregated for the first time 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.

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

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 3.5.5 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 were available in 2016 for 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. The share of 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 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 EU-28 aggregate scores for 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).

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. Refer to the 2018 ERA Monitoring Handbook for the details justifying the change of indicators[2].

[2] The 2018 ERA Monitoring Handbook provides full methodological details on the policy relevance, limitations and computation of each quantitative indicator.

Table 2 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 (EIS: SII)
Sub-priority 2a: Optimal transnational cooperation	Participation in Public-to-Public Partnerships per 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* and 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)	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 the 2018 ERA Monitoring Handbook.
* Due to data limitations, the indicators identified by an * replace the indicators originally identified by the ERAC. Refer to 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.

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 were 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 were 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 are 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 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 present report cannot meaningfully speak about how well one country or region is positioned in relation 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 [3], displayed in percentage point difference for the CAGR (displayed in this 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 [4]. 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 scores. Additionally, performance in the most recent year is also benchmarked relative to each ERA country. This benchmarking is conveyed through the

[3] Weighted averages are usually used to ensure representativeness of the whole (i.e. as if the EU-28 was a single country). Refer to the 2018 ERA Monitoring Handbook for details on how EU-28 scores were computed by indicator.

[4] 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).

clustering approach implemented throughout the report [5]. 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) average 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.

Recommendation 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, 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 EU 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), 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 researchers. 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 normalisation 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 normalisation 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 2018 ERA Monitoring Handbook). 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 normalisation unit instead of the public sector researchers. This

[5] The strongest performances are found in Cluster 1, which is more than one standard deviation above the ERA 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.

normalisation 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).

2.4 Assessment of implementation progress on the basis of the National Action Plans

An assessment of implementation progress of ERA policies on the basis of the National Action Plans (NAP) represents an additional task when compared to previous ERA Progress Reports. Such an assessment was carried out by taking into account both quantitative (where available) and qualitative (especially) elements provided by each country 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 mentioned above, the assessment of the NAPs does not look so much at the quantitative targets set by the NAPs, but rather provides a qualitative analysis of the level of implementation of NAPs across countries. It therefore analyses the level of implementation of the NAPs and describes 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 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 implementation progress of NAPs 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 the feasibility of technical assessment of progress against it. The resulting performance assessment frameworks were country-specific. Importantly, a reconstructed framework only represented the logic of intervention behind a 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 a 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 this 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 are 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 4); 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 categorical assessment indicated above was integrated across the countries thereby revealing which ERA priorities witnessed more substantial progress during the reference period under analysis (please refer to Section 4 for full analysis).

3 RESULTS BY INDIVIDUAL PRIORITY

In each subsection below, the information is organised according to the following pattern. General considerations and context around each ERA priority will provide introductory framing. Relevant quantitative information for monitoring progress in achieving the ERA is then presented. This information includes, for each priority, a set of three EMM indicators that were selected by the European Research Area and Innovation Committee (ERAC): one core high-level (or Headline) indicator with two accompanying metrics to capture, inasmuch as is possible, the inputs, outputs and outcomes/impacts of ERA policies/actions (selected at an ad hoc workshop of the ERAC in March 2016; see also ERAC Secretariat, 2015a). The Headline indicator for the relevant priority is presented first, and subsequently contextualised with the findings of its two accompanying EMM indicators. The quantitative findings of the Headline and complementary EMM indicators are elucidated throughout by qualitative information gathered through document reviews and interviews. Finally, any qualitative findings that are particularly salient to the priority in question, but not easily framed in connection to a specific quantitative indicator, are presented in a final dedicated subsection.

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[6] 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 [7] 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

[6] 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).

[7] In cases where data for EU-28 Member States were not available, the weighted average (see Footnote 3 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 the 2018 ERA Monitoring Handbook).

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.

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 5) 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 [8]. 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 [9]; 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 [10].

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 [11]), 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 this 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 (Table 16), 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 this 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 this report, as it shows

[8] 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 5.

[9] 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.

[10] 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.

[11] Refer to the 2018 ERA Monitoring Handbook for the extraction dates of the presented data.

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.

3.1 Priority 1 – More effective national research systems

3.1.1 Policy context

The goal of ERA Priority 1 is to better align national policies with ERA-wide policies and enhance the effectiveness of national research systems in ERA countries. The main emphasis is on the long-term commitment from governments and the Commission to invest in R&I systems and ensure an effective use of public R&I funds. As was indicated in the previous ERA Progress Report, the context around the implementation of this priority remains heterogeneous as ERA countries are different in terms of their support for and efficiency of their R&I activities. Even though there is a lot of support for expenditures in R&I at the EU level, some countries are decreasing their R&I spending while others made no necessary or substantial increase. This is especially worrying in countries with less-developed national research systems as they are too reliant on EU structural funds to supplement domestic R&I budgets. A number of interviewees indicated that with the current EU funding period ending soon, some national research systems could experience a deterioration.

Some countries have also seen a decline in private sector R&I investments. In this context, most ERA countries employ indirect support measures to strengthen the private R&D base (e.g. Ireland, the Netherlands, Slovakia, Belgium, Spain, Italy, Malta, Lithuania, France, Latvia, Croatia, Czech Republic, Poland, Slovenia, the UK). This is achieved through a variety of R&D tax incentives. ERA countries differ in their use of these support measures as they have different priorities and seek to stimulate different types of companies or R&D activities. Tax incentives are widely used and, in some cases, are very generous. Spain has one of the most generous schemes, which is based on three different elements: tax deduction for R&D&I activities, income reduction for transferring intangible assets and social security benefits for full-time R&D personnel (Fernández-zubieta et al., 2016). Another example is Slovakia where a special 125% tax deduction for private companies investing in R&I is offered (European Semester Country Report Slovakia 2017). Despite the generosity of these incentives, their usage and impact remain limited (European Semester Country Report Slovakia 2017; Fernández-zubieta et al.,2017). In the case of Slovakia, businesses claim that eligibility criteria are not always clear, and the scheme is not generous enough. Tax allowance for R&D expenditure in Latvia resulted in more companies reporting their innovative activities, which were previously accounted for in operational expenditure (European Semester Country Report Latvia 2016).

Additionally, several Member States are looking into the necessity to update their national R&I documents and reform their R&I bodies based on the results from their evaluation and monitoring activities. These activities allow countries to follow their progress and identify existing barriers in the implementation process. Qualitative data suggest that most countries have evaluation and monitoring systems in place. Their effectiveness varies, however. Countries with less-developed national research systems are usually more susceptible to experience issues due to a fragmentation of their national research systems where cooperation between different actors responsible for R&I is weak and the division of tasks is complex and unclear.

At the same time, EU Member States are trying to make their national research systems more efficient and competitive through implementing national and regional smart specialisation strategies. The level of commitment and genuine planning is different in each country. The qualitative data suggests, however, that this process allowed for better cooperation between different R&I actors, which in turn facilitated the development of a more comprehensive vision and encouraged more sustainable and efficient investments in key strategic areas. Smaller countries developed only national strategies, while in most of the larger countries a national strategy is complemented by regional strategies. This practice encourages the growth of regions and better cooperation efforts between regions on the basis of matching priorities. At the same time, the example of Spain shows that some regions replicated national objectives instead of identifying genuine regional priorities (Fernández-zubieta et al.,2017).

Given the importance of EU funds for countries with less-developed national research systems, their smart specialisation strategies are well aligned with European goals and priorities. Countries with more-developed national research systems also align their smart specialisation strategies with European goals and priorities, yet they are more flexible and independent in drafting their strategic

documents. Additionally, the implementation and monitoring of smart specialisation strategies has just recently started in some countries and results on the progress are currently limited in most Member States, as indicated in the R&I Observatory country reports. Some regions in Associated Countries are increasing their knowledge on the concept of smart specialisation. The implementation and monitoring of smart specialisation constitute an ongoing process and it requires dedicated bodies, methodologies, experts, and dialogue between stakeholders. Robust monitoring and evaluation mechanisms are required to ensure evidence-based developments and when necessary modifications to the strategy in order to achieve substantial progress.

Table 3 ERA countries with/without national strategy for R&I as of 2018

Country	Type of strategy
	Single overarching strategy
Austria	National R&I strategy (2011)
Bulgaria	National strategy for development of scientific research in the Republic of Bulgaria 2017-2030
Czech Republic	The National Research, Development and Innovation Policy of the Czech Republic 2016-2020
Denmark	The Innovation Strategy: Denmark A Nation of Solutions (2012-2020) (Updated in 2015)
Estonia	Knowledge Based Estonia 2014-2020 (2014)
Finland	The Government Programme sets the direction of research and innovation policy, with the guidance of the Research and Innovation Council (RIC). While the Strategic Government Programme 2015-2020 has been announced, with ministerial groups being responsible for achieving certain R&I objectives. Still pending is the designation of the RIC, the structure of which is under revision. The de facto R&I strategy remains the latest updated RIC research and innovation policy review. Reformative Finland: Research and Innovation Policy Review 2015-2020.
France	National research strategy – France Europe 2020 (2015)
Germany	High-Tech Strategy 2025
Greece	National Strategy for Research, Technological Development and Innovation (ESETAK) 2015-2021. Action plan to implement this strategy remains pending.
Iceland	Science and Technology Policy Council Action Plan 2017-2019
Ireland	Strategy for research and development, science and technology, 2016-2020
Italy	National Research Programme 2014-2020 (approved in 2016)
Malta	Multi-annual National R&I Strategy 2020 (2014)
Norway	Long-term plan for research and higher education 2015-2024 (2014)
Romania	National Strategy for Research, Development and Innovation 2014-2020
Slovakia	The national Smart Specialisation Strategy (RIS3 document) is the national R&I strategy for 2014-2020
Slovenia	Research and Innovation Strategy of Slovenia (RISS) 2011-2020 (2011)
Spain	Spanish Strategy for Science and Technology and Innovation, 2013-2020 (2013)
Sweden	The National Innovation Strategy and the Research Bill 2016
Turkey	National Science, Technology and Innovation Strategy (2011-2016) Tenth 5-Year Development plan (2014-2018)
United Kingdom	Our Plan for Growth: science and innovation (2014)
	Multiple strategies
Belgium	Major multi-annual plans for R&I include successive versions of the 'Marshall plan' complemented by 'Creative Wallonia' and 'Digital Wallonia' in Wallonia; regional innovation plan in Brussels; and 'VISIE 2050: a long-term strategy for Flanders' in Flanders. These main regional strategies reflect a broad political commitment to boost productivity and address societal challenges through research and innovation.
Cyprus	In 2014 the National Council for Research, Technology Development and Innovation (NCRTDI) delivered a report proposing the reform of the RTDI system, including a new strategy for Research, Innovation and Entrepreneurship. The main findings and recommendations of the study have also been identified in the Smart Specialisation

Country	Type of strategy
	Strategy (S3CY) and its corresponding Action Plan 2015-2022. In 2015 the Research Promotion Foundation (RPF) published a draft new RTDI programme that will implement the S3CY. The Action Plan for Growth of the Presidency's Unit for Administrative Reform supports the RTDI system, particularly in areas linked to entrepreneurship.
Croatia	Several national strategies shape the development of the national innovation system. The Strategy for Education, Science and Technology6 (SECT) sits at the centre of this heterogeneous policy framework. Additional references include the Strategy for fostering innovation 2014-2020 and the Industrial Strategy (2014).
Hungary	National Research and Development and Innovation Strategy (2013-2020). In order to enhance R&D&I performance, the National Smart Specialisation Strategy (S3) and the Research Infrastructures Hungary were adopted. There is also the Széll Kálmán Plan 2.0 of 2012, which defines the mid-term and long-term aims of the government and is aligned to the EU-2020 documents.
Latvia	The main strategic frameworks in which the country operates are the Guidelines for National Industrial Policy 2014-20, the Guidelines for Science, Technology Development and Innovation (2014-20) and in particular the Smart Specialisation Strategy (RIS3, 2014-20)
Lithuania	Several strategies and programmes in the field of R&I, although the National Progress Strategy 'Lithuania 2030' is an overarching reference as it sets the strategic direction for the development of the country. It includes some general terms around R&I. Six other documents influence the direction of R&I: the National Progress Strategy 'Lithuania 2030;' the National Progress Programme for Lithuania for the period 2014-2020 (NPP); the Programme for Development of Studies and R&D for 2013-2020; the updated Concept of the Establishment and Development of Integrated Science, Studies and Business Centres (Valleys); the Lithuanian Innovation Development Programme for 2014-2020 and the Programme on the Implementation of the R&D&I Priority Areas and Their Priorities.
Moldova	National Innovation Strategy (2012-2020) and the R&D Strategy 2020
Montenegro	No research and innovation strategy on smart specialisation. However, the country has an Action Plan for implementation of the Strategy for Scientific Research Activities 2012-2016 Strategy of Innovation Activity (2016-2020)
Netherlands	In July 2018, the new SME action plan and digitalisation agenda and a new strategy entitled: 'Naar een missiegedreven innovatiebeleid met impact' prepared by the Ministry of Economic Affairs and Climate were sent to Parliament. The Ministry of Education has published the National Science Agenda and is preparing an update of the Science vision. Other important documents include: Research and Innovation Strategy for Smart Specialization (RIS3) Northern Netherlands (2014-2020) and NOW strategy 'Connecting Science and Society' for 2019-2022 (announced in 2018).
Poland	The strategic framework includes the Strategy for Innovativeness and Efficiency of the Economy as the overarching document (2013). This is supplemented by the Enterprise Development Programme (PRP) as implementing programme of SIEG (2014); National Smart Specialisations (KIS) (2014); National Research Programme (KPB) (2014); Polish Roadmap of Research Infrastructures (PMDIB) (2014); Operational Programme Smart Growth 2014-2020(POIR) (2014); Regional Operational Programmes (RPOs). Strategy for Innovation and Efficiency of the Economy – Dynamic Poland 2020 (2013-20)
Portugal	Since the late 1980s, the R&I strategies have built on European Union Support Frameworks (CSF), which shape the R&I policy measures toolkit and the required financial commitments. The CSF currently in place, Portugal 2020, covers the period 2014-2020 and includes four thematic areas and seven regional programmes.
Switzerland	Political foundations: Bill on the promotion of education, research and innovation for 2017-2020. Legal foundations: Federal Act on the Promotion of Research and Innovation (RIPA) (2012) and the corresponding implementing ordinance (V-FIFG). Higher Education Act 2011.
	No formalised overall strategy

Country	Type of strategy
Israel	The government follows an innovation policy of supporting some specific needs in some areas. For instance, the Innovation Authority, responsible for providing high-quality services to Israeli innovation system, has commenced operations in 2017.
Luxembourg	No formalised strategy officially and formally approved, although policies and strategies relating to R&I are included in the annual plan Luxembourg 2020
Ukraine	Law 'On Scientific, Scientific and Technical Activity' adopted in 2016 and Strategic directions of innovation activity in Ukraine were set for 2011-2021

Note: Data unavailable: AL and FO.
Source: Compiled by PPMI Group.

In line with the goal of Priority 1 to ensure an effective use of public research and innovation funds, and notwithstanding differences in actual implementation across ERA countries, the allocation of R&I funds continues to become more competitive and performance orientated. This trend was already visible in the previous ERA Progress Report but was confirmed again by interview data. The financial crisis has also encouraged some countries to review their funding practices and capabilities (Reale, 2017). As a result, many ERA countries have adopted performance-based funding policies with the goal to increase research productivity and to ensure the accountability of research performing organisations (Rand Europe and Deloitte, 2017). Different performance-based funding schemes were implemented across ERA countries. Formula-based non-bibliometric allocation model, which evaluates educational and research metrics is, for example, used in Austria and the Netherlands. Belgium, Croatia, Denmark, Finland, Poland, Portugal, Sweden and Norway adopted formula-based bibliometric allocation system, which can be based on research outputs such as publications, scientific awards, patents, and knowledge transfer outputs (Rand Europe and Deloitte, 2017). UK, Lithuania, Czech Republic, Estonia, France, Slovakia and Italy use a peer-review assessment-based allocation model, which is based on quantitative formula of research outputs through a peer-reviewed assessment (Rand Europe and Deloitte, 2017).

It is important to note that despite its wide use across countries, the methodologies and implementation of performance-based funding are heterogeneous due to the differences of national research systems, governance systems and administrative traditions (Jonkers and Zacharewicz, 2016). As a result, the share of organisational-level funding, which is allocated through performance-based funding, varies greatly in ERA countries. Interview data suggest that countries, where the percentage of performance-based funding is relatively high compared to block funding, experience some negative effects. This sentiment was more common in countries with less-developed national research systems where general funding levels are usually lower and research performing organisations have unequal competitive capabilities.

3.1.2 Headline indicator

The Headline indicator identified by the ERAC to assess progress on Priority 1 is the Adjusted Research Excellence Indicator (AREI) computed by the Directorate-General Joint Research Centre (JRC). Its main benefit as the Headline figure is that it covers four dimensions of high relevance to research effectiveness and covers all ERA countries, with the exception of the Faroe Islands (ERAC Secretariat, 2015a). It covers ERC grants per public R&D expenditures, which is a good proxy to appreciate the success of countries in securing ERA-wide project-based competitive funding. It also 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. These exchanges are themselves expected to foster more integrated and efficient R&I ecosystems. The Headline indicator also covers PCT patent applications per population (OECD, 2016), which is a good output indicator to capture the innovation of national R&I systems. Finally, it covers the share of the top 10 % most cited publications per total publications (CWTS), which is a good proxy of the excellence of a country's research impact. Even though this indicator covers a range of dimensions pertaining to research effectiveness, it cannot be regarded as providing comprehensive coverage of all relevant dimensions under Priority 1, given its very broad scope. Also, the component on most cited publications cannot be computed beyond 2015, because scientific publications need sufficient time to accumulate citations over an adequately long period. Typically, a citation window consisting of the publication year plus two years is used (i.e. up to 2015 in this study). For details on the methodology used in computing the adjusted REI, please refer to Vértesy (2018). Country-by-country results are outlined in Table 4[12] and are mapped in Figure 1.

[12] Refer to page 11 for a guide to reading the quantitative results tables.

Since the last ERA monitoring exercise, which included findings for 2013 and covered the 2010-2013 period, EU-28 Member States continued to progress in terms of this indicator, but at a slower pace with an annual average growth of 3.2 % from 2013 to 2016, compared to a long-term (2010-2016) annual growth of 4.9 %. Countries that increased their performance the most in recent years include Malta (17 %), Luxembourg (10 %), Norway (8 %) and Austria (8 %). Malta was in fact the only country to significantly reduce its gap with the EU-28, from a 24-point deficit in 2013 to a 17-point deficit in 2016.

Country ranking remained roughly unchanged compared to the latest available year in the 2016 report.[13] The most notable changes include Malta (gain of six positions, now in 22nd position), Moldova (gained five places, now 36th), Georgia (lost 5 places, now 31st), and Bulgaria (lost 5 places, now 35). Note that the analysis of rankings is based on the updated time series.

The strongest performer, leading by a wide margin in 2016, was Switzerland, with a score of 98, twice as large as the EU-28 average of 45. Switzerland was followed by Denmark, the Netherlands, Sweden, the UK, Israel and Luxembourg in Cluster 1, all of which had a score above 57. The countries lagging the most were Bosnia and Herzegovina, Montenegro, and Albania in Cluster 4. There were more countries below the unweighted ERA average (26 countries in Clusters 3 and 4) than above (17 countries in Clusters 1 and 2). This is attributable to the high scores of the leading countries, which pulled the average upwards.

The economic strength of ERA nations, as represented by their GDP, was concentrated within the groups made up of the most effective national research systems (i.e. those with scores above the ERA average). Three quarters of the GDP of the countries presented in Table 4 (excluding GDP data from Israel in Cluster 1, and Armenia, Georgia, Moldova, Tunisia and Ukraine in Cluster 3) are concentrated in Clusters 1 and 2. Given its large number of countries (23 or 18 for those with GDP figures), Cluster 3 includes mostly small economies, as does Cluster 4. Thus, apart from Italy, which sat just below the ERA average, those lagging behind in the effectiveness of their national research systems were smaller economies, many of which are located in Eastern Europe.

The inequalities across countries have moderately increased since the last monitoring exercise in *2016*. In fact, apart from Malta, the countries in the least performing groups (Clusters 3 and 4) have generally not lost or gained significant ground relative to the most performing groups (Clusters 1 and 2). There is virtually no correlation at country level between short-term (2013 to 2016) annual growth and performance in 2016, and the unweighted average of the countries' annual growth is very similar for the first three clusters (~4 %), which represent 40 out of the 43 countries. Three countries, Greece, Bosnia and Herzegovina, and Montenegro, experienced a moderate annual decline of about 2 % from 2013 onwards.

In the long term, from 2010 to 2016, the most performing countries (Clusters 1 and 2) increased their lead over the least performing countries (Clusters 3 and 4). The annual unweighted average growth for the countries in each cluster decreases from the top to the bottom cluster (CAGR of 6.2 % in Cluster 1, 4.9 % in Cluster 2, 3.1 % in Cluster 3 and 1.4 % in Cluster 4). In the long term, this pattern appears to be associated with a concomitant increase in the disparities in the effectiveness of the national research system of ERA countries as presented in Table 4. The Gini coefficient, a common metric used in economics to quantify inequalities in the wealth of various groups, has steadily increased from 0.302 in 2010 to 0.332 in 2016 (CAGR of 1.5%) for ERA scores on this indicator.[14]

[13] In comparing country rankings between the latest available year in the 2016 and current report, countries were excluded if a score could not be inmputed for both years (imputation was generally only done by taking the score from the preceding year and occasionally from the following; imputation was never done for gaps greater than one year between the actual and imputed years).

[14] In comparing Gini coefficient between two dates, countries were excluded if a score could not be imputed for both years (imputation was generally done by taking the score from the preceding year and occasionally from the following year; imputation was never done for gaps greater than one year between the actual and imputed years).

Table 4 Adjusted Research Excellence Indicator (2010-2016)

Country	Weight in GDP	Score (2016)	CAGR			Trendline
			Short-term (2013-16)	Lead/Gap to EU-28 CAGR	Long-term (2010-16)	
EU-28		**45.0**	**3.2%**	**N/A**	**4.9%**	
Cluster 1	27.0%	72.4	3.8%	0.6	6.2%	
Cluster 2	48.6%	47.6	4.2%	1.0	4.9%	
Cluster 3	24.3%	21.1	4.0%	0.8	3.1%	
Cluster 4	0.2%	12.6	0.3%	-2.9	1.4%	
Cluster 1						
CH	3.6%	97.5	-0.5%	-3.7	3.3%	
DK	1.7%	78.6	7.1%	3.9	8.0%	
NL	4.2%	74.5	4.6%	1.4	6.7%	
SE	2.8%	70.3	4.8%	1.6	5.1%	
UK	14.4%	68.7	1.0%	-2.2	4.6%	
IL	:	59.9	0.2%	-3.0	2.8%	
LU	0.3%	57.5	9.7%	6.5	12.9%	
Cluster 2						
BE	2.5%	55.8	3.0%	-0.2	6.7%	
FI	1.3%	54.9	2.9%	-0.3	4.6%	
AT	2.1%	54.9	8.1%	4.9	5.8%	
IE	1.6%	52.9	7.0%	3.8	8.7%	
DE	18.8%	50.3	2.6%	-0.6	4.7%	
NO	2.0%	50.2	8.2%	5.0	2.2%	
FR	13.3%	46.6	3.3%	0.1	4.8%	
IS	0.1%	37.9	0.0%	-3.2	1.7%	
CY	0.1%	37.1	3.2%	0.0	5.1%	
ES	6.7%	35.1	3.5%	0.3	4.7%	
Cluster 3						
IT	10.0%	34.4	3.6%	0.4	4.4%	
HU	0.7%	31.4	3.6%	0.4	4.6%	
EE	0.1%	30.4	4.6%	1.4	5.0%	
PT	1.1%	30.1	6.0%	2.8	5.1%	
MT	0.1%	27.8	17.3%	14.1	12.7%	
SI	0.2%	25.9	-0.1%	-3.3	0.0%	
EL	1.0%	25.2	-1.9%	-5.1	1.2%	
CZ	1.1%	23.2	3.2%	0.0	1.8%	
AM	:	20.7	4.7%	1.5	5.6%	
LV	0.1%	19.6	3.3%	0.1	3.5%	
SK	0.5%	19.5	5.6%	2.4	3.2%	
HR	0.3%	19.1	7.1%	3.9	4.7%	
PL	2.5%	18.7	4.2%	1.0	3.2%	
GE	:	18.2	0.5%	-2.7	5.1%	
RO	1.0%	16.8	3.5%	0.3	2.7%	
TR	4.7%	16.7	-0.2%	-3.4	-0.5%	
LT	0.2%	16.7	4.4%	1.2	0.5%	
BG	0.3%	16.6	-0.1%	-3.3	-0.1%	
MD	:	15.4	7.0%	3.8	3.5%	
RS	0.2%	15.2	2.6%	-0.6	1.3%	
TN	:	15.0	3.6%	0.4	1.5%	
MK	0.1%	14.3	1.1%	-2.1	3.5%	
UA	:	14.3	5.9%	2.7	2.2%	
Cluster 4						
BA	0.1%	13.2	-1.9%	-5.1	2.0%	
ME	0.0%	12.8	-2.3%	-5.5	-0.7%	
AL	0.1%	11.9	5.1%	1.9	3.0%	

Note: The adjusted REI is 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); ERC grants per public R&D expenditures (DG-RTD, Eurostat, OECD) and participation in Marie Skłodowska-Curie fellowships (DG-EAC).
Data unavailable: FO
(:) = missing data

Source: Calculations by European Commission, DG Joint Research Centre, Competence Centre on Composite Indicators and Scoreboards. For details on the methodology, please refer to Vértesy (2018 forthcoming).

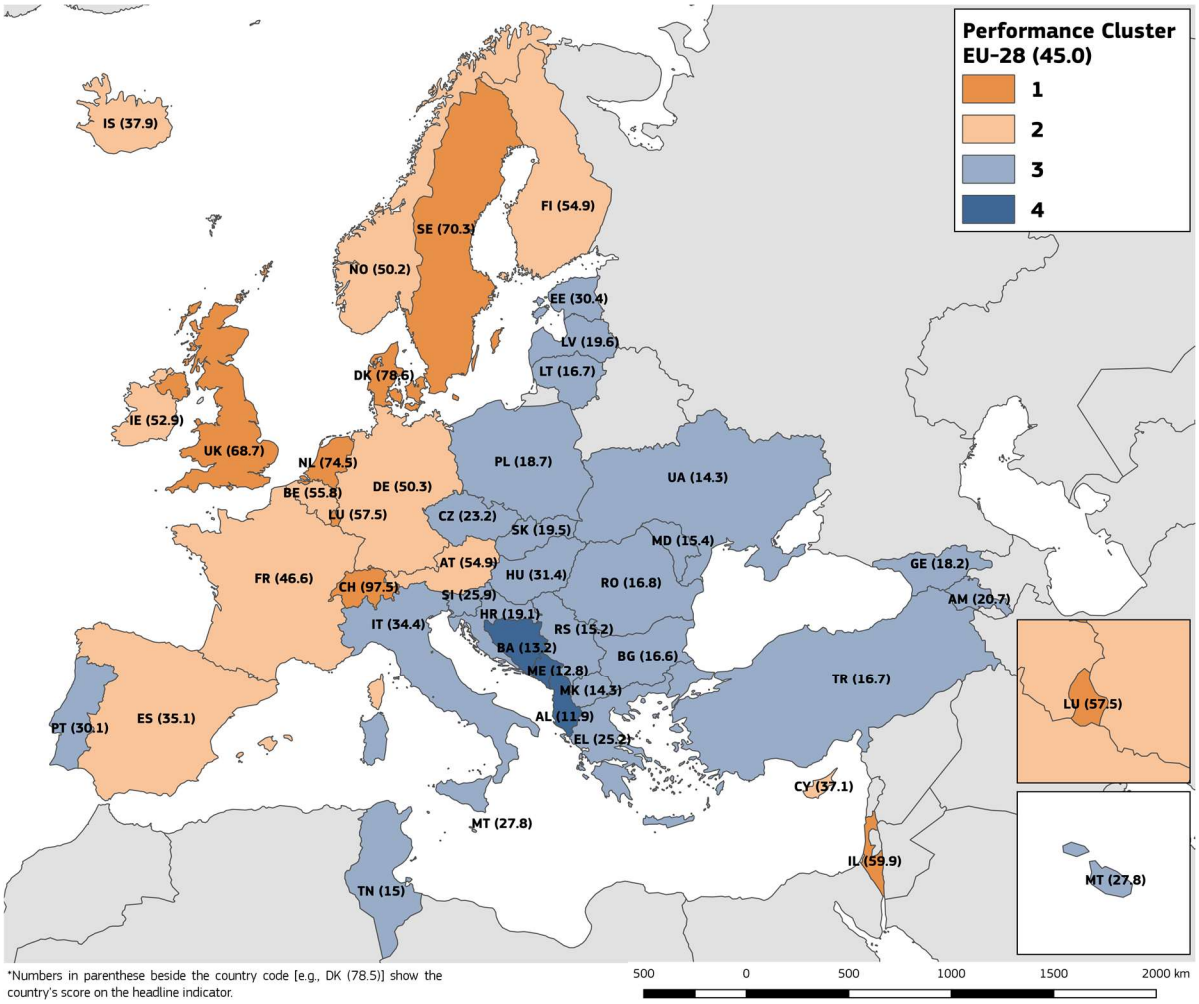

Figure 1 Map of Adjusted Research Excellence Indicator (2016)

Note: As per Table 4.

Source: Calculations by European Commission, DG-Joint Research Centre, Competence Centre on Composite Indicators and Scoreboards; for details on the methodology, please refer to Vértesy (2018 forthcoming).

3.1.3 Complementary EMM indicators

GBARD as a percentage of GDP

Public funding for R&D is the main 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 relative performance of countries as measured by the adjusted Research Excellence Indicator (i.e. the previous Headline indicator). Research Performance Based Funding (RPBF) systems promote the support of more effective national R&I systems under ERA Priority 1. As these systems become more prevalent across Europe, it would make sense to use an indicator capturing the extent to which government budget allocations for research and development (GBARD)[15, 16] are awarded on a competitive basis, through project-based and/or institutional funding.

[15] Previously labelled 'Government budget appropriations or outlays for research and development (GBAORD)' until the 2015 edition of the Frascati Manual. The Eurostat data used in producing the indicators presented in this report are still labelled using 'GBAORD' in Eurostat's database.

[16] As per Eurostat metadata (http://ec.europa.eu/eurostat/cache/metadata/en/gba_esms.htm), 'GBAORD data are measuring government support to research and development (R&D) activities, or, in other words, how much priority Governments place on the public funding of R&D … GBAORD data are broken down by: Socio-economic objectives (SEOs) in accordance to the Nomenclature for the analysis and comparison of scientific programmes and budgets (NABS, 2007) - (See annex at the bottom of the page)' and 'Funding mode into: project funding and institutional funding (non-mandatory data). Part of GBAORD, which is allocated to transnational cooperation in R&D, is further broken down into three specific categories: transnational public R&D performers; Europe-wide transnational public R&D programmes and bilateral or multilateral public R&D programmes established between Member State governments or with EFTA and candidate countries.'

Unfortunately, data measuring such aspects of national R&I systems are relatively scarce. For example, only some Member States and Associated Countries have available data for the share of GBARD allocated as project-based funding, with many gaps in their respective time series. An alternative would be to look at the actual performance and growth of countries in terms of the total government budget allocated to R&D, while accounting for the relative size of the countries' economies in any cross-country comparative analysis. Just such an indicator — that is, government budget allocations for GBARD as a percentage of GDP — was selected by the ERAC as the first complementary EMM indicator for Priority 1[17]. Note that normalisation by GDP can lead to some volatility in the scores of countries over time, since their GDP scores are intimately linked to external economic factors (e.g. the financial crisis of 2008) and can respond very differently to such factors. Results are presented in Table 5.

The *ERA Progress Report 2016* found very slight decreases at the aggregate level on this indicator over the period from 2008 to 2014. When adding data for 2015, 2016 and 2017, the findings obtained show these reductions to have accentuated in the recent period. Annual decreases at the EU-28 level were in the order of 1.7 % from 2014 to 2017, with a similar figure for the long-term trend when started just after the 2008 economic crisis (i.e. 2009 to 2017) instead of in 2008 as in the 2016 report. In recent years, GBARD per GDP decreased by more than 10 % annually in Ireland. It also decreased by roughly 5 % annually for a few countries distributed across all performance clusters; i.e. Finland in Cluster 1, Estonia in Cluster 2, Poland in Cluster 3 as well as Bosnia Herzegovina, Malta and Bulgaria in Cluster 4. Of the EU's strongest economies, the UK, Spain, and France have also had their investment levels trend downwards in recent years, with gaps of 2.4, 1.4 and 0.6 percentage points, respectively, to the EU-28's reference annual growth.

Country positions have been quite stable since the 2016 report. Nonetheless, the top country in the present report, Norway, advanced from its previous 5th place (based on the updated time series). Czech Republic also advanced by 4 places from 14th in 2014 to 10th in 2017. The strongest declines in the ranking were observed for Estonia moving from 9th to 14th and for Ireland moving from 24th to 28th.

The leading group of countries on this indicator consisted of Norway, Switzerland (although based on 2015 data), Denmark, Germany, Finland, Sweden and Austria. These countries contributed close to or more than 0.8 % of their GDP to GBARD in 2017. Those that relatively contributed the least (Latvia, Bulgaria, Malta, Romania, Bosnia and Herzegovina, and FYR Macedonia) allocated about 0.2 % or less of their GDP to GBARD. Although there are fewer countries above (16 in Cluster 1 and 2) than below (19 in Cluster 3 and 4) the ERA average, the ERA average (0.50 %) was located near the centre of the range of observed values across all groups (0 % to 1.01 %), thereby suggesting that country inequalities are small.

The most performing groups of countries on GBARD as a share of GDP (Clusters 1 and 2) concentrated close to two thirds of ERA's economy (61.6 %). Apart from the UK and Italy, these two groups include the largest economies (Germany, France, and Spain), most of the mid-size economies (i.e. the Netherlands, Switzerland, Sweden) and a number of smaller economies. Scores under the ERA average were, for the most part, associated with small economies that individually contributed less than 1 % to the ERA's GDP. Still, at the top of Cluster 3, i.e. the group just below the ERA average, are Italy and the UK which significantly increase the share of ERA's GDP located below the ERA average (38.4 %).

Overall, inequalities appeared to be rather small between ERA countries on this indicator, although growth profiles do seem to indicate that inclusion may decrease rather than increase. Indeed, the average short-term growth was slightly stronger in Cluster 1 and 2 than it was in Cluster 3 and 4. The Gini coefficient (a measure of country inequalities) also increased slightly from 0.223 in 2009 to 0.255 in 2017, with this latter score remaining low. Despite decreases at the aggregate level, growth can be observed for countries across all clusters with the most notable changes observed for Latvia in Cluster 4 (scoring 13 percentage points above the EU-28 average trend), Norway in Cluster 1 (7 points above), and Iceland in Cluster 2 (7 points above).

Long-term growth figures on this indicator show decreasing commitment to R&D for the EU-28 with a -2.0 % annual decline for the period 2009-2017. This report's results thus show that following the 2008 economic crisis, the share of GDP allocated to GBARD never recovered from its highest point of the 13 years from 2005 to 2017 which was observed in 2009 at 0.74 %. Long-term growths also do not support prospects for increased inclusion between ERA countries, with the two groups of countries below the unweighted ERA average (Cluster 3 and 4) having an average annual decrease

[17] Note that GBARD is not capturing indirect government funding for R&D (such as R&D tax incentives), which is increasingly used by a number of ERA countries (e.g., the Netherlands, Ireland) (OECD, 2015).

of -2.8 % whereas the two most performing country groups (Cluster 1 and 2) had an average annual decrease of -0.5 %. Iceland's long-term trend was not calculated due to a change in definition during the assessment period for this indicator; this caused a notable decline in its score in 2014.

The financial crisis of 2008 resulted in a number of ERA countries reducing their budget allocation to R&D, with their GBARD shrinking to a greater extent than their GDP. Some challenges clearly remain in order to fully recover from the decline in R&D funding and subsequently ensure its stability. The countries that have experienced the most severe decline in GBARD as a percentage of GDP include some of the most precarious R&I systems within the ERA. Thus, the growth dynamics of their R&I systems and their capacity to make progress in implementing the ERA might depend more strongly on their ability to get continued access to EU structural funds. However, some countries that experienced a decline in GBARD have made use of indirect fiscal measures (e.g. R&D tax incentives, not captured by GBARD) to compensate for the loss in direct funding (European Commission, & Directorate-General for Research and Innovation, 2016b, p. 143). It is thus difficult, on the basis of this indicator alone, to confirm whether there has been an overall contraction in public R&D funding across countries and to measure the extent of this contraction if confirmed.

Table 5 GBARD as percentage of GDP (2009-2016)

Country	Weight in GDP	Score (2017)	CAGR			Trendline
			Short-term (2014-17)	Lead/Gap to EU-28 CAGR	Long-term (2009-17)	
EU-28		**0.63%**	-1.7%	**N/A**	**-2.0%**	
Cluster 1	32.6%	0.87%	-0.8%	0.9	0.1%	
Cluster 2	29.0%	0.64%	-0.7%	0.9	-1.6%	
Cluster 3	36.7%	0.37%	-2.6%	-0.9	-3.3%	
Cluster 4	1.8%	0.14%	-2.0%	-0.4	-1.6%	
Cluster 1						
NO	2.1%	1.01%	5.5%	7.2	2.1%	
CH	3.5%	*0.90%*	:	:	*3.3%*	
DK	1.7%	0.89%	-3.8%	-2.1	-1.2%	
DE	19.1%	0.89%	0.6%	2.3	0.0%	
FI	1.3%	0.84%	-4.7%	-3.1	-2.9%	
SE	2.8%	0.80%	-1.3%	0.3	-0.9%	
AT	2.2%	0.77%	-1.0%	0.7	0.4%	
Cluster 2						
HR	0.3%	0.72%	0.8%	2.5	0.6%	
NL	4.3%	0.69%	-1.5%	0.1	-1.4%	
BE	2.6%	0.65%	-1.4%	0.3	-0.1%	
CZ	1.1%	0.65%	0.8%	2.4	1.3%	
FR	13.3%	0.64%	-2.3%	-0.6	-4.2%	
LU	0.3%	0.64%	0.0%	1.7	2.2%	
IS	0.1%	0.61%	5.1%	6.7	:	
EE	0.1%	0.61%	-5.0%	-3.3	-1.4%	
ES	6.8%	0.51%	-3.0%	-1.4	-5.6%	
Cluster 3						
IT	10.0%	0.50%	-1.5%	0.1	-2.8%	
UK	13.6%	0.49%	-4.0%	-2.4	-2.7%	
EL	1.0%	0.47%	2.5%	4.2	3.5%	
RS	0.2%	0.40%	-1.1%	0.5	:	
SI	0.3%	0.40%	-2.2%	-0.6	-6.3%	
PT	1.1%	0.37%	0.2%	1.9	-4.4%	
PL	2.7%	0.36%	-5.6%	-4.0	1.1%	
SK	0.5%	0.35%	-2.7%	-1.0	-0.3%	
TR	4.4%	0.34%	1.5%	3.2	-1.6%	
LT	0.2%	0.31%	-3.1%	-1.4	-6.1%	
CY	0.1%	0.31%	-3.8%	-2.2	-4.5%	
IE	1.7%	0.26%	-11.1%	-9.5	-8.3%	
HU	0.7%	0.26%	-2.8%	-1.1	-6.9%	
Cluster 4						
LV	0.2%	0.22%	11.1%	12.8	1.1%	
BG	0.3%	0.21%	-4.9%	-3.2	-4.9%	
MT	0.1%	0.19%	-5.5%	-3.8	2.7%	
RO	1.1%	0.19%	-4.1%	-2.4	-5.3%	
BA	0.1%	*0.04%*	*-6.8%*	-5.1	:	
MK	0.1%	*0.01%*	:	:	:	

Note: Break in time series: EE (2016); PL (2012); RO (2013); IS (2014)
Definition differs: AT (2009-2015)
Estimated: EE (2009-2015); UK (2017)
Provisional: 2017 (EU28, AT, HR, CZ, DK, EE, DE, HU, IT, LV, LT, MT, NL, PT, RO, SK, SI, IS, NO, RS); 2016-2017 (CY, FR, ES); EL (2011-2017)
Exception to reference year: BA (2016); MK (2014); CH (2015); Exception to long-term reference period: CH (2010-2015); Exception to short-term reference period: BA (2014-2016)
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).

European Innovation Scoreboard Summary Innovation Index

The Summary Innovation Index (SII) is the second EMM indicator for Priority 1 drawn from the European Innovation Scoreboard ([18]). It is a composite indicator integrating a multitude of factors distributed across 10 dimensions, which cover 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) (Hollander and Es-Sadki, 2018). 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 and impacts. In fact, the very broad set of indicators (27 in total) means that the SII covers a broader set of issues than those specific to Priority 1; 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). Full results for the SII are detailed in Table 6.

Between 2015 and 2017, the EU-28 Member States achieved, on average, moderate average annual increases of almost 2 % in their SIIs. This was a gain over the previous growth level recorded in the latest years (from 2013 to 2015) of the previous ERA monitoring exercise, which was in turn 1 % (based on the 2018-time series due to retrospective changes in the SII). Lithuania, Norway and Spain made the major contributions to this growth, posting average annual increases that placed them 5 or 6 points ahead of EU-28 average. Decreases were also to be observed on this indicator, with Estonia 6 points behind the EU-28 annual average over the 2015 to 2017 interval.

Country rankings in 2017 were very similar to those in 2015 (latest year in the 2016 report; analysis based on the 2018 time series due to retrospective changes in the SII). Iceland (from 7th to 12th position), Ireland (from 14th to 10th position), Spain (24th to 20th), Estonia (17th to 21th) and Lithuania (28th to 24th) were the only countries that shifted by more than three positions.

The leading countries based on their SII scores were Switzerland, Sweden, Denmark, Finland and the Netherlands, all of which are mid-size economies. They obtained a score of 0.65 or more, whereas the EU-28 average stood at 0.50. At the other end of the spectrum, the lowest results were obtained by Poland, Hungary, Bulgaria, FYR Macedonia, Romania and Ukraine (Cluster 4). The group of second least performing countries (Cluster 3) was large for this indicator, as it included 14 countries. It has grown larger since the last report, notably by pulling three countries from the group of least performing countries (Cluster 4).

Western European countries and large or medium economies tended to have the higher scores for this indicator. ERA's GDP was concentrated among the most performing countries (68.9 % among Clusters 1 and 2), although two of ERA's largest economies, Italy and Spain, scored below the unweighted ERA average and were placed in the second group from the bottom (Cluster 3). The smaller ERA economies tended to perform below the unweighted ERA average for this indicator.

Inequalities between ERA countries were not pronounced on this indicator, and recent country performances did not appear to reduce remaining inequalities further. The Gini coefficient changed little during the 2010-2017 period and was measured at 0.212 in 2017. Short-term increases and decreases were evenly distributed above and below the unweighted ERA average, and levels of inclusion therefore remained stable.

Long-term figures in average annual growth rates at the EU-28 level were similar for the current report and its predecessor (0.8 % for 2010 to 2017 and 0.7 % for 2008 to 2015). Long-term increases and decreases were also evenly distributed above and below the unweighted ERA average, indicating that inequality levels are likely to remain constant. Serbia's long-term annual average growth contrasted with short-term decreases (3 % and -3 % respectively), while the inverse was found for Romania (-5 % and 4 % respectively).

[18] Previously known as the Innovation Union Scoreboard.

Table 6 European Innovation Scoreboard Summary Innovation Index (2010-2017)

Country	Weight in GDP	Score (2017)	CAGR			
			Short-term (2015-17)	Lead/Gap to EU-28 CAGR	Long-term (2010-17)	Trendline
EU-28		**0.504**	**1.9%**	**N/A**	**0.8%**	
Cluster 1	13.6%	0.697	1.1%	-0.8	0.7%	
Cluster 2	55.3%	0.571	1.9%	0.3	0.8%	
Cluster 3	26.7%	0.359	0.9%	-1.0	1.3%	
Cluster 4	4.5%	0.213	2.4%	0.4	-0.3%	
Cluster 1						
CH	3.5%	0.808	1.6%	-0.3	0.9%	
SE	2.8%	0.710	1.2%	-0.7	0.5%	
DK	1.7%	0.668	-1.2%	-3.1	0.1%	
FI	1.3%	0.649	1.3%	-0.6	0.3%	
NL	4.3%	0.648	2.6%	0.7	1.8%	
Cluster 2						
UK	13.6%	0.613	3.9%	2.0	1.7%	
LU	0.3%	0.611	-1.2%	-3.1	0.8%	
DE	19.1%	0.603	0.5%	-1.5	-0.1%	
BE	2.6%	0.593	2.5%	0.6	0.8%	
IE	1.7%	0.585	5.1%	3.2	1.0%	
AT	2.2%	0.579	2.0%	0.1	1.1%	
IS	0.1%	0.576	-2.1%	-4.1	-0.1%	
NO	2.1%	0.571	8.1%	6.2	2.6%	
FR	13.4%	0.551	1.7%	-0.2	1.3%	
IL	:	0.541	-0.4%	-2.3	-0.6%	
SI	0.3%	0.465	0.3%	-1.7	0.2%	
Cluster 3						
CZ	1.1%	0.415	0.9%	-1.0	-0.5%	
PT	1.1%	0.406	1.2%	-0.7	-0.2%	
MT	0.1%	0.403	-0.2%	-2.2	2.9%	
ES	6.8%	0.400	7.4%	5.4	1.4%	
EE	0.1%	0.397	-4.2%	-6.1	-0.5%	
CY	0.1%	0.386	-0.9%	-2.9	-1.5%	
IT	10.0%	0.371	-0.4%	-2.4	0.4%	
LT	0.2%	0.359	8.2%	6.3	4.5%	
RS	0.2%	0.335	-3.0%	-4.9	3.0%	
HU	0.7%	0.332	2.1%	0.1	0.0%	
EL	1.0%	0.328	3.0%	1.1	-0.2%	
SK	0.5%	0.323	-0.6%	-2.5	1.1%	
TR	4.4%	0.286	1.2%	-0.7	4.2%	
LV	0.2%	0.285	-1.6%	-3.5	3.1%	
Cluster 4						
PL	2.7%	0.270	4.7%	2.8	0.8%	
HR	0.3%	0.258	0.2%	-1.7	-0.5%	
BG	0.3%	0.229	2.7%	0.7	-0.4%	
MK	0.1%	0.222	4.2%	2.3	4.4%	
RO	1.1%	0.157	4.1%	2.1	-4.9%	
UA	:	0.140	-1.7%	-3.6	-0.9%	

Note: Data unavailable: AL, AM, BA, FO, GE, MD, ME, TN
(:) = missing data

Source: Hollanders, H. and Es-Sadki, N. (2018) European Innovation Scoreboard. Report prepared for the European Commission. https://ec.europa.eu/docsroom/documents/30281/attachments/1/translations/en/renditions/native.

Comparing Headline to complementary EMM indicators

Comparing AREI and GBARD/GDP scores for ERA countries, a moderately strong and positive correlation was obtained (Pearson *r* of 0.71). Such a result highlights the importance of public funding for R&D in strengthening the R&I systems of countries. Correlation between the AREI and the SII was stronger, very strong in fact (Pearson *r* of 0.93). This is not particularly surprising since two of the indicators embedded in the AREI (i.e. share of top 10 % most highly cited publications per total

publications and PCT patent applications per population) are also covered by the SII. Looking across indicators for Priority 1, the performance on the Headline and the two complementary EMM indicators are positively and well correlated, which is to say that the strong performers are generally the same across each of these indicators. It might be tempting to conclude, based on these findings, that the use of a single indicator, in the form of the Headline indicator, is sufficient to synthesise performance across the ERA system under Priority 1. However, one should note that important variations remain at a country-by-country level across the various dimensions captured by the Headline and EMM indicators. These differences should not be overlooked as they most likely convey crucial information for understanding the functioning and explaining the relative performance of individual R&I systems. With respect to growth (both short term and long term), one finds a much more varied picture: a country that was growing strongly in one area was not necessarily showing a similar trend elsewhere. Correlations between growth scores across the three indicators were very weak or non-existent.

3.1.4 Additional policy highlights

Funding allocation and international peer review: Interview data confirmed that the competitive allocation of research funding through calls for proposals is a common practice among ERA countries. However, the share of competitive funding varies across countries and is very uneven. Countries with the largest share of project funding out of total national public funding are Estonia, the UK, Ireland, Poland, Czech Republic and Belgium (Reale, 2017). Contrary to the findings in the previous ERA Progress Report, interviewees emphasised that the inclusion of international experts in review panels continues to grow and is becoming a common practice. A number of countries have a long tradition of this practice where no major changes happened in recent years (including but not restricted to Austria, Denmark, Finland, Germany, the Netherlands, Norway, Portugal, Sweden and Switzerland). At the same time countries that have recently introduced this practice confirmed that the use of international expert review panels is becoming an integral part of their competitive funding allocation. Despite that, the inclusion of external reviewers can still prove to be challenging when they lack the required language competencies, or when submission systems need to be adapted to support English language submissions. However, several RFO representatives noted that applicants are expected or encouraged to submit their proposals in English to overcome the language barrier.

There is a diverging approach to ensuring the balance of competitive funding and block funding. While competitive funding is promoted by the Commission as a way to increase efficiency in research systems, resource allocation should be consistent with differences in the research capacities and mandates of research performing organisations, as well as planning of research activities. ERA countries have different traditions of funding research organisations, and in some countries, there is a resistance from RPOs to decrease block funding. This is particularly common in countries with less-developed national research systems. Some RPOs in these countries have less competitive advantage and do not manage to attain funding from competitive processes. This often means that it negatively influences their ability to attract best talent and develop and maintain research infrastructures. Therefore, different national research systems should look for an appropriate balance between competitive and block funding.

Improving the quality and relevance of research systems: Some ERA countries (e.g. Poland, Lithuania, Austria, Latvia, Norway) initiated higher education reforms in recent years to improve the quality and relevance of public research and education. In some countries reforms were concentrated on merging institutions, while in others (e.g. Austria) the effort was concentrated on improving financing of the higher education system. Interview data and literature indicated that there are concerns in some countries about the fragmentation of public education and research. This means that already limited funding is spread too thinly among a large number of existing institutions, which creates negative competition and undermines cooperative activities that could bring about positive results. The last ERA Progress Report already identified the trend of reducing a number of RPOs. This process is ongoing and several countries across Europe have either reduced a number of RPOs or are in the process of doing so. It is expected that these changes might encourage cooperation between RPOs but also increase their competitiveness to attract more competitive funding on the national level and internationally.

The quality and effectiveness of R&I systems also depends on efficient working links between their key actors. Some countries have merged a number of existing organisations or established new bodies that support R&I (e.g. Finland, Belgium, the UK, Latvia, France, Croatia, Hungary). For example, Belgian regions of Wallonia and Flanders merged the agencies responsible for R&I support in their regions. A large number of structures that support research and innovation challenge the overall consistency and coordination of the R&I policy. Very frequently the division of responsibilities and activities becomes unclear. In this case mergers are expected to streamline and simplify research and innovation support. A different approach was taken by the UK where the UK Research and Innovation (UKRI) organisation was established to improve the complementarity of different government supportive measures. This is expected to ensure an efficient approach to administrative functions and provide comprehensive support services.

Main findings

1. Despite improvements in recent years, alignment across multiple R&I national strategic documents can still be enhanced to provide a clearer direction and ensure that multiple bodies governing the national R&I ecosystems are efficiently integrated.
2. Monitoring and evaluation of the implementation of national R&I priorities and funding is central to improving efficiency and effectiveness of national research systems. This allows fragmentation to be reduced and areas for improvement to be identified. Most ERA countries recognise the importance of this practice. Yet, further development of monitoring and evaluation systems as well as genuine consideration of the results would contribute to making national research systems more effective.
3. The R&I system must be supported through sufficient and consistent funding in order to prevent deterioration of national systems and avoid the growth of performance gaps between ERA countries. Since the 2008 economic crisis, the GBARD as a share of GDP has been decreasing for most ERA countries. Only a few ERA countries showed strong growth across all performance clusters and these growth patterns were not sufficient to reduce inequalities between countries which increased slightly since 2009. Even though countries with less-developed research systems to some extent fill the gap in their funding allocations with EU structural funds, the upcoming new funding period can introduce uncertainties. Having said that, countries with more-developed research systems have to provide careful justifications if and when they introduce funding cuts. The lack of justification for funding cuts and limited cooperation with R&I stakeholders could have a negative effect on their R&I systems.
4. The linkages between key R&I national actors have to be further improved to ensure the quality and effectiveness of R&I systems. It is important that the main stakeholders are included in the policy dialogues and that there is a forum for them to share best practices and provide insights on the shortcomings of the system. At the same time, it is important that R&I support structures are consistent and effectively coordinated to avoid duplications in their responsibilities and activities.

3.2 Priority 2 – Optimal transnational cooperation and competition

3.2.1 Policy context

Transnational cooperation and coordination of research activities between ERA countries has a number of goals, including solving grand challenges that cannot be addressed by separate efforts of countries, improving excellence and quality of scientific outputs, improving access to knowledge, expertise and research infrastructures, developing common rules, procedures and standards and others. Initial European efforts at improving coordination focused mainly on 'specific' fields and through the activities of supranational intergovernmental organisations such as ESA (European Space Agency), CERN (European Organization for Nuclear Research), EURATOM, ESO (European southern Observatory), and EMBL (European Bioinformatics Institute). In the 1970s the first intergovernmental funding schemes (such as COST and EUREKA) appeared and were targeted at cooperative research, networking and transnational collaborations involving European and non-European research organisations (Reale et al., 2013). Finally, today a considerable part of European R&I policy focuses on the development of cooperation between national agencies in specific fields, and the reallocation of public research funding from national agencies to pan-European funding. The main instrument in this area are the so called Public-to-Public Partnerships (P2Ps) initiatives, which have proliferated substantially over the last decade with the emergence of a number of different European initiatives, based on Joint Programming Initiatives — (JPIs), Art 185 of the TFEU, ERA-NET Cofund actions, European Joint Programme (EJP) Cofund actions. Whereas each of these instruments has a different rationale behind and different implementation modalities, their goal is to enhance the coordination of national and EU R&I policies to more effectively address common societal challenges.

For instance, **JPIs** launched by the European Commission in 2008 aim at enabling transnational research and innovation by exploiting synergies between national and international programmes, and strategically aligning different sources of national and other funds at European level. The process of joint programming involves ERA countries – on a variable geometry and voluntary basis – agreeing on common visions and Strategic Research Agendas (SRA) to address major societal challenges. In 2018, 10 JPIs launched were launched, each of them focusing on a different thematic area:

- Alzheimer and other Neurodegenerative Diseases (JPND);
- Agriculture, Food Security and Climate Change (FACCE);
- A Healthy Diet for a Healthy Life;
- Cultural Heritage and Global Change: A New Challenge for Europe;
- Urban Europe – Global Urban Challenges, Joint European Solutions;
- Connecting Climate Knowledge for Europe;
- More Years, Better Lives – The Potential and Challenges of Demographic Change;
- Antimicrobial Resistance – The Microbial Challenge – An Emerging Threat to Human Health;
- Water Challenges for a Changing World;
- Healthy and Productive Seas and Oceans.

The **ERA-NET Cofund** mechanism (funded under the Horizon 2020 programme) is an instrument by which the EU provides additional funding, over and above the contributions of the individual countries involved, to increase the incentive for joint calls. ERA-NET Cofund involves single transnational calls with EU co-founding, where the typical beneficiaries are RFOs and in some cases RPOs. According to the analysis of ERA-NET Cofund actions under Horizon 2020, the Horizon 2020 Work Programme 2014/2015 included calls for proposals for ERA-NET Cofund actions, resulting in a total of 27 proposals being selected for funding by the European Commission. In addition, over 30 topics are included in the 2016/2017 Horizon 2020 Work Programmes. The 27 networks from 201/ 15 brought together a total of EUR 728.5 million, including contributions from EU Member States (57.8 %), associated countries (6.9 %), third countries (5.1 %) and the European Commission (30.2 %) (Gøtke et al. 2016).

The European Joint Programme (EJP) Cofund actions under Horizon 2020 is also a co-fund action designed to support coordinated national research and innovation programmes. The EJP Cofund aims at attracting and pooling a critical mass of national resources on the objectives and challenges of Horizon 2020 and at achieving significant economies of scales by adding related Horizon 2020 resources to a joint effort. In contrast to ERA-NET actions, the focus of EJPs are direct research and innovation activities of the participating programmes, normally governmental research organisations participating on the basis of their institutional funding. Another major difference among the two schemes is the funding rate: 33 % for the ERA-NET Cofund and up to 70 % for the EJP.

Finally, in contrast to Cofund actions, **Article 185 of the Treaty on the Functioning of the European Union (TFEU)** initiatives are driven by the participating Member States without having to follow a standard model of cooperation. The article foresees the participation of the EU in the joint implementation of (parts of) research and development of national programmes. Participating

Member States commit to integrating their research through a jointly defined programme that is validated by the Commission. The Commission provides financial support which can ensure financial stability in the longer term (contractual relationship for a duration of around 10 years with 25-50 % co-funding by the European Commission).

3.2.2 Headline indicator 2a – Transnational cooperation

As the Headline indicator for Sub-priority 2a, ERAC selected GBARD allocated to transnationally coordinated research (Europe-wide, transnational public R&D programmes and bilateral or multilateral public R&D programmes) expressed in euros per FTE researcher in the public sector. Although this indicator does not inform on the alignment of transnationally allocated research funding with the tackling of European grand challenges, it remains a good proxy to assess the extent to which governments take part in and increase their efforts towards joint programming in R&D. It should also be noted that although it is an input indicator, it can also be viewed as an output indicator since the emphasis placed on transnationally allocated funding can be regarded as a result of policy interventions at the national level. Note that this indicator can be affected by a country-size bias (in favour of small countries) and that it might 'understate the "true" figure as many research programmes may have a transnational dimension even though the funding was not explicitly allocated with such a condition attached' (ERAC Secretariat, 2015a). Country-by-country results are fully outlined in Table 7 and mapped in Figure 2.

EU-28 Member States (France excluded) have seen a slowdown in short-term growth on GBARD allocated to transnationally coordinated research since the *ERA Progress Report 2016*. While average annual growth for the EU-28 had reached 7.2 % in 2012–2014 (based on the updated time series), this figure was reduced to 3.9 % for the period extending from 2014 to 2016. Several countries contributed to these decreases in scores, including Croatia (which displays a 27-point gap in growth to the EU-28 annual average), Greece (25-point gap), Bulgaria (23-point gap) and Ireland (21-point gap). For the longer period of 2012 to 2016, EU-28 annual average growth was at 5.6 %.

Since the latest available year in the last report (2014), there has been moderate movement in terms of country ranking. Based on the updated time series, Slovenia and Hungary gained the most positions, four each, respectively moving from 20th to 16th and from 26th to 22nd. Two countries lost six positions: Croatia (from 15th to 21st) and Greece (from 18th to 24th). The rankings exclude Switzerland, Iceland, and Serbia for which scores could not be imputed for both 2014 and 2016.

The table reports a very strong performance for Switzerland, which had a score three times larger than the immediate follower, Belgium, and eight times larger than the EU-28 average. In fact, because the score for Switzerland is more than four standard deviations away from the average across available countries, it was not used to determine the clusters' boundaries; even though its score reflects an actual figure, it was considered as an outlier because of the specificity of the H2020 contribution mechanisms that were in place for Switzerland as well as for other Associated Countries (see Science-Metrix, 2017: p. 34). It is worth mentioning that Switzerland's score is based on data from 2012 because more recent data are not available. Following Switzerland, the strongest performing countries were Belgium, Italy, Iceland, Austria and Sweden, while the lowest scores were observed for Serbia and Bulgaria. The disparity between performers above the unweighted ERA average and performers below was quite pronounced, even though they both included a similar number of countries. The two groups with most performing countries (Cluster 1 and 2) included slightly less than half of all available countries (13 out of 31 countries).

Economic strength is quite concentrated in the most performing country groups; Clusters 1 and 2 together accounted for 67 % of GDP. One notable exception is the UK, a large economy that sits right below the unweighted ERA average (Cluster 3). Note the absence of data for France.

Inequalities between countries appeared to be high but decreasing on this indicator. The Gini coefficient, a common metric used in economics to quantify inequalities in the wealth of various groups, has substantially decreased in recent years. It was measured at 0.560 in 2010 but has dropped to 0.453 in 2016. Over the short term, nine countries in the least performing country groups (Clusters 3 and 4) improved their score by more than 10 % annually. In the cases of Hungary and Slovakia, scores have increased by more than 100 % annually on average, which may have contributed to reducing inequalities. The strong average annual growth obtained in the aggregate by countries in Cluster 3 also point towards reductions in inequality. The decrease observed for Cluster 4 may go against this pattern slightly, although effects will be limited given that the Cluster is made up of only two countries.

Long-term average annual growth rates for country performance groups indicate good potential for greater inclusion, with Cluster 3 — the group with the most countries but still below the ERA unweighted average — obtaining a score much above the others (14 %). Additionally, it is noted that Bulgaria's, Croatia's and Lithuania's strong short-term drops were based on record scores attained

by those countries in 2014; their long-term trend is positive in comparison. Ireland's number of public sector researchers, the denominator of this indicator, has increased substantially since 2013, and a change in definitions used to collect this data appears as a likely explanation for the country's drop on this indicator.

Table 7 GBARD (EUR) allocated to Europe-wide transnational, as well as bilateral or multilateral, public R&D programmes per FTE researcher in the public sector (2007–2016)

Country	Weight in GDP	Score (2016)	CAGR			
			Short-term (2014-16)	Lead/Gap to EU-28 CAGR	Long-term (2012-16)	Trendline (2007-2016)
EU-28 (w/o FR)		**3 739**	**3.9%**	**N/A**	**5.6%**	
Cluster 1	25.9%	11 153	-0.6%	-4.5	2.6%	
Cluster 2	40.9%	3 713	3.0%	-0.9	4.1%	
Cluster 3	32.6%	1 197	19.5%	15.6	13.7%	
Cluster 4	0.6%	82	-19.5%	-23.4	3.2%	
Cluster 1						
CH	4.4%	*29 694*	:	:	:	
BE	3.1%	8 756	-4.5%	-8.4	-0.5%	
IT	12.4%	8 594	0.8%	-3.1	9.3%	
IS	0.1%	*6 909*	:	:	:	
AT	2.6%	6 674	-0.6%	-4.5	2.1%	
SE	3.4%	6 290	1.8%	-2.1	-0.4%	
Cluster 2						
DE	23.1%	5 198	6.3%	2.4	1.9%	
NO	2.5%	4 192	-2.5%	-6.5	-4.3%	
FI	1.6%	3 949	2.0%	-1.9	4.0%	
NL	5.2%	3 880	-1.2%	-5.1	9.7%	
LU	0.4%	3 155	9.6%	5.7	9.0%	
ES	8.2%	2 842	9.2%	5.3	12.7%	
CY	0.1%	2 774	-2.6%	-6.5	-4.1%	
Cluster 3						
UK	17.7%	2 741	5.1%	1.2	7.7%	
DK	2.0%	2 501	-7.1%	-11.0	-0.1%	
RO	1.2%	1 840	24.3%	20.4	15.6%	
CZ	1.3%	1 547	12.7%	8.8	1.7%	
SI	0.3%	1 430	22.3%	18.4	-1.5%	
IE	2.0%	1 330	-16.6%	-20.5	-14.0%	
EE	0.2%	1 293	17.4%	13.5	6.7%	
PT	1.4%	1 131	21.0%	17.1	11.8%	
PL	3.1%	*1 086*	68.8%	64.9	*94.0%*	
HR	0.3%	939	-22.6%	-26.5	3.9%	
HU	0.8%	875	112.3%	108.4	18.0%	
LV	0.2%	856	-8.8%	-12.7	11.0%	
EL	1.3%	676	-21.5%	-25.4	-17.2%	
MT	0.1%	380	33.2%	29.3	4.7%	
LT	0.3%	272	-5.4%	-9.3	24.7%	
SK	0.6%	263	125.8%	121.9	51.6%	
Cluster 4						
RS	0.3%	*101*	:	:	:	
BG	0.4%	63	-19.5%	-23.4	3.2%	

Note: The long-term CAGR is computed on the 2012-16 period (due to data restriction for EU-28) but the trendline shows data for the period 2007-2016. Break in time series: EU-28 (2012-2014, 2016); HR (2016); 2007 (DK, NO); 2011 (FI, EL, RO, SI); DE (2014, 2016); 2012 (BE, LV, NL); PT (2008, 2013); SE (2007, 2011, 2013); IS (2011, 2013). Definition differs: EU-28 (2012-2016); HR (2012-2015); FI (2011-2015); DE (2015, 2016); NL (2007-2015); SK (2007-2014); SE (2007); NO (2007-2009); CH (2008, 2010-2015). Estimated: EU-28 (2012-2016); AT (2008, 2010, 2012, 2014); HR (2013); DK (2014, 2016); EL (2007); IE (2007, 2011, 2013); IT (2012-2015); LU (2007); NL (2007-2016); SK (2007); UK (2007, 2008, 2010-2014); CH (2007-2009); 2007-2015 (BE, SE). Provisional: 2016 (AT, CY, CZ, IT, LU, MT, NL, PT, SI, SE, UK); 2015-2016 (EU-28, DK). Potential outlier: CY (2008); EE (2009); 2016 (HU, PT, SK). Eurostat country flags have been retained in the EU-28 aggregate. Imputed data in EU-28 aggregate for: PL (2016). Exception to reference year: PL (2015); IS (2013); RS (2014); CH (2012). Exception to long-term reference period: PL (2012-2015). Exception to short-term reference period: PL (2013-2015). Data unavailable: FR, AL, AM, BA, FO, MK, GE, IL, MD, ME, TR, TN, UA. (:) = missing data.
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. However, the time series do not appear to be affected. CH is more than four standard deviations away from the mean and was therefore not used in establishing the clusters' boundaries.

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

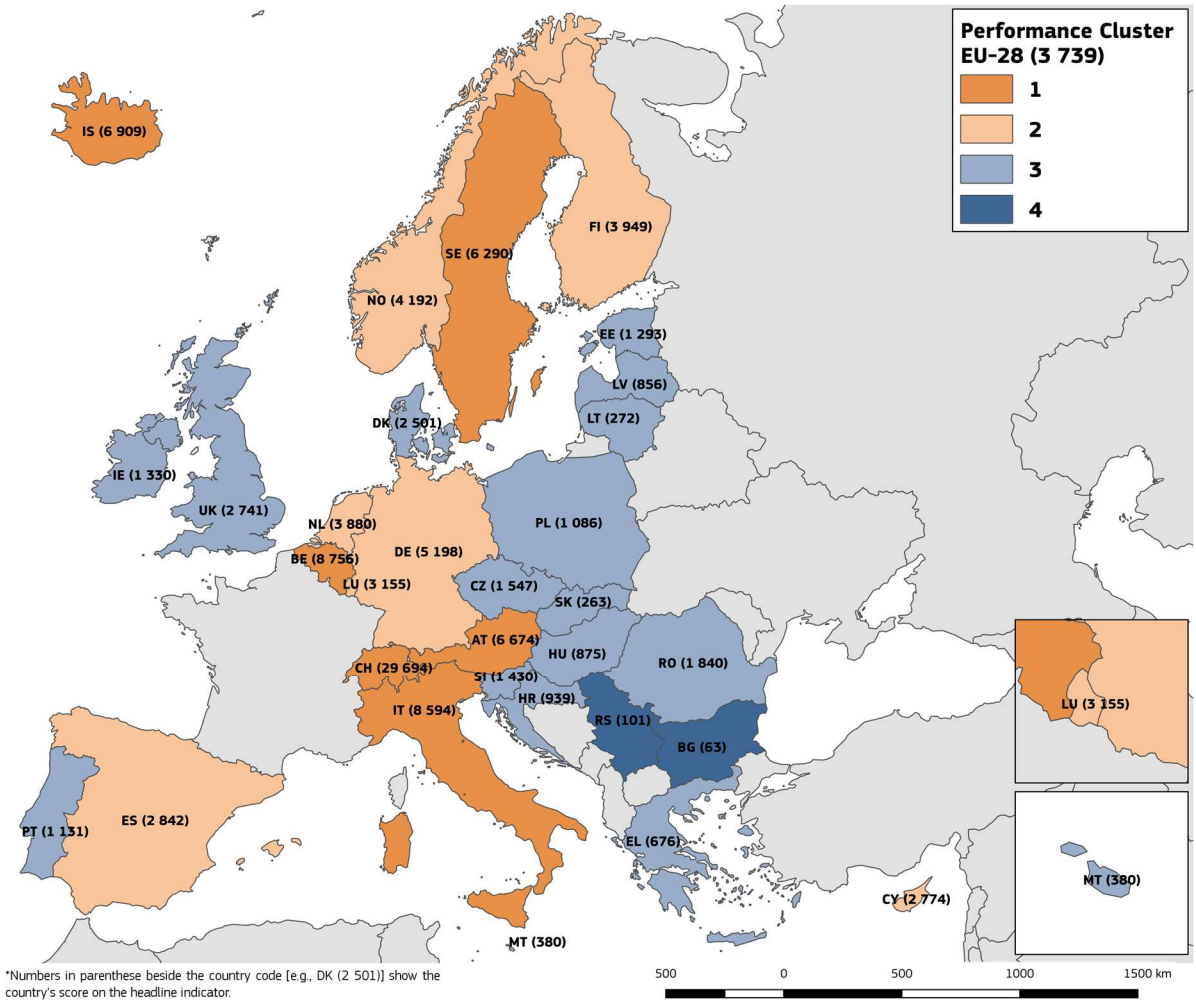

Figure 2 Map of GBARD (EUR) allocated to Europe-wide transnational, as well as bilateral or multilateral, public R&D programmes per FTE researcher in the public sector (2016).

Note: As per Table 7.
Source: Computed by Science-Metrix using Eurostat data (online data codes: gba_tncoor and gba_nabsfin07).

3.2.3 Complementary EMM indicators 2a

Member State participation in Public-to-Public Partnerships

Given the lack of data for many countries and years in the Headline indicator, the complementary indicators are perhaps more reliable to assess uniformity (or lack thereof) within the ERA. The first complementary indicator for Sub-priority 2a is the investment in Public-to-Public Partnerships, including ERA-NETs, Joint Programming Initiatives (JPIs) and Article 185 initiatives. To account for country size differences, national investments have been normalised by the number of FTE researchers. This indicator provides information along the same lines as the previous Headline indicator. Assuming that ERA-NETs and JPIs are specifically designed to address European grand challenges, this indicator might provide a better indication, compared to the Headline indicator, of the alignment between transnationally allocated research funding and the tackling of European grand challenges. However, data are only available for the 28 Member States and for five years (2012-2016); Associated Countries are not covered. Like the previous Headline indicator, this indicator can be affected by a country-size bias. Researchers from larger countries may be more likely to find domestic partners and thus have less incentive to develop transnational cooperation than researchers from smaller countries. Full results for this indicator are found in Table 8. Changes in definitions between the current and the last edition of the report make comparisons in findings unreliable, and they will not be made for this indicator. Indeed, since the *ERA Progress Report 2016*, the amount and quality of information for joint calls has been greatly improved, both for current and past data (personal communication with Optimat). Therefore, there can be notable differences in the present report when compared to the previous *ERA Progress Report*.

Wide changes in levels of participation in Public-to-Public partnerships are accentuated by limitations in the data set. At the EU-28 level, an average of EUR 558 per FTE researcher was invested in these partnerships in 2016. The average annual growth score of 0.7 % over the period from 2014 to 2016

resulted from the balancing out of a large number of pronounced increases and decreases in growth rates at the individual country level. Scores collected on this indicator dispersed along a very broad range of values. Cyprus is the clear leader with a score of EUR 5 316, more than twice as much as Latvia in 2nd position and almost 10 times the EU-28 average. Along with Cyprus and Latvia, Sweden, Austria, Malta and Finland were the top-performing countries. Bulgaria had the smallest investment relative to its number of researchers, with EUR 62. There is a clear cut-off between the above ERA average countries, which all scored above EUR 900, and the below ERA average countries, which all scored below EUR 600. The country groups below the unweighted ERA average were larger (16 countries in Clusters 3 and 4) than the groups above the average (12 countries in Clusters 1 and 2). Cluster 3, the country group immediately below the ERA average, was particularly large (13 countries), while Cluster 4 was particularly small (3 countries).

This is one of the few indicators for which the ERA's largest economies all performed below the ERA average. GDP is heavily concentrated in Clusters 3 and 4. The two groups with the most performing countries (Cluster 1 and 2) comprised a few mid-size and small economies. However, as already mentioned, Associated Countries, most of which are small economies, are not included; the dynamic might have changed had they been present. Also note that this indicator has a country-size bias. Large economies (e.g. the US, China, Germany) have access to substantial collaboration opportunities domestically. Therefore, they are usually less dependent than smaller economies on international partnerships for capacity-building purposes (e.g. gaining specific expertise or accessing specific equipment); this potentially explains the positions of France, Germany, Italy and the UK.

Inequalities between ERA countries were moderate-to-high on this indicator, with a Gini coefficient value of 0.507 in 2016, which was a slight decrease relative to previous years. There was, however, a moderate correlation between performance and growth on this indicator (Pearson *r* of 0.45), which could suggest a slight tendency towards stronger inequalities. Given such contradictory signals, it is worth mentioning at this point that this indicator fluctuates considerably from one year to the next, making a compound annual growth rate perhaps unreliable to measure sustained change over time. For example, Greece's outstanding 194 % annual short-term increase is based on its particularly low score measured in 2014. Its long-term growth is much more modest (9 % annually). In fact, many countries in Table 8 have conflicting short-term and long-term trends.

Table 8 Member States participation (EUR) in Public-to-Public partnerships per FTE researcher in the public sector (2012–2016)

Country	Weight in GDP	Score (2016)	CAGR			Trendline
			Short-term (2014-16)	Lead/Gap to EU-28 CAGR	Long-term (2012-16)	
EU-28		**558**	**0.7%**	**N/A**	**19.4%**	
Cluster 1	7.3%	2 362	13.3%	12.7	54.1%	
Cluster 2	11.2%	1 153	-8.1%	-8.8	21.4%	
Cluster 3	79.5%	347	25.0%	24.3	32.7%	
Cluster 4	2.0%	113	-5.9%	-6.6	15.9%	
Cluster 1						
CY	0.1%	5 316	23.1%	22.4	101.4%	
LV	0.2%	2 070	18.3%	17.7	86.1%	
SE	3.1%	1 892	-6.5%	-7.2	27.2%	
AT	2.4%	1 824	2.5%	1.9	20.0%	
MT	0.1%	1 649	25.8%	25.2	:	
FI	1.4%	1 419	16.6%	15.9	36.0%	
Cluster 2						
NL	4.8%	1 266	3.8%	3.2	34.3%	
RO	1.1%	1 237	14.3%	13.7	33.2%	
DK	1.9%	1 222	-7.3%	-8.0	33.2%	
BE	2.8%	1 157	-8.1%	-8.8	27.1%	
LU	0.4%	1 123	-41.6%	-42.2	-14.0%	
SI	0.3%	912	-10.0%	-10.6	14.6%	
Cluster 3						
FR	14.9%	*556*	*45.2%*	44.6	*30.1%*	
DE	21.1%	531	-8.1%	-8.8	7.5%	
ES	7.5%	513	25.1%	24.4	30.4%	
IE	1.8%	498	3.5%	2.9	5.8%	
IT	11.3%	406	30.9%	30.2	13.2%	
PT	1.2%	345	22.1%	21.4	39.3%	
PL	2.9%	*310*	*-8.3%*	-8.9	*22.4%*	
EE	0.1%	309	-8.2%	-8.9	49.1%	
LT	0.3%	256	20.0%	19.4	46.8%	
UK	16.1%	236	-18.7%	-19.4	5.1%	
HR	0.3%	211	25.9%	25.2	110.2%	
HU	0.8%	187	-11.1%	-11.8	55.5%	
EL	1.2%	154	193.7%	193.1	9.1%	
Cluster 4						
SK	0.5%	153	-6.4%	-7.0	3.4%	
CZ	1.2%	124	10.6%	9.9	23.2%	
BG	0.3%	62	-22.0%	-22.7	21.2%	

Note: Break in time series: HR (2016); DE (2014, 2016); NL (2012); 2013 (PT, SE)
Definition differs: HR and NL (2012, 2013, 2014, 2015); DE (2015, 2016); SK (2012, 2013, 2014)
Estimated: AT (2012, 2014); DK (2016); IE (2013); IT (2015); SE (2012, 2013, 2014, 2015)
Provisional: 2016 (EU28, AT, CY, CZ, IT, LU, MT, NL, PT, SI, SE, UK); DK (2015); FR (2015)
Exception to reference year: 2015 (FR, PL)
Exception to reference period for long-term CAGR: 2012-2015 (FR, PL)
Exception to reference period for short-term CAGR: 2013-2015 (FR, PL)
Data unavailable: AL, AM, BA, FO, MK, GE, IS, IL, MD, ME, NO, RS, CH, TR, TN, UA
(:) = missing data
CY is more than four standard deviations away from the mean and was therefore not used in establishing the clusters' boundaries.

Source: Computed by Science-Metrix using Eurostat data (online data code: rd_p_persocc) and data from Optimat (2017) 3rd Annual Report on Public-Public Partnerships. Report prepared for the European Commission, Directorate-General for Research & Innovation. https://www.era-learn.eu/publications/other-publications/3rd-annual-report-on-p2p-partnerships.

Co-publications with other ERA countries

The second complementary EMM indicator for Sub-priority 2a is the number of co-publications involving a given ERA country and at least one co-author from another ERA country. The number of

ERA co-publications per 1 000 FTE researchers in the public sector is provided to account for size differences in the population of researchers across countries. This indicator is a good proxy to measure the outcomes resulting from transnationally allocated research funding as measured with the previous two indicators. Note that it can also be affected by a country-size bias and a country-location bias.

Typically, co-publications are counted using the full counting method, whereby each co-publication is counted once for each entity it represents, whether that be an institution, a country or the world, regardless of the number of authors affiliated with that entity. For instance, a co-publication between a French, a German and a Canadian researcher counts once for France, once for Germany and once for the EU-28 as an ERA co-publication, and therefore the sum across EU-28 countries amounts to two ERA co-publications (i.e. the sum of France and Germany). Because such an asymmetry is not present for researchers — that is, 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 1 000 researchers is underestimated for the EU-28 as a whole, relative to individual Member States, when using the full counting method. Also note that counting co-publications involving at least two ERA countries by considering the EU-28 as one large entity is conceptually problematic since the EU-28 is not a country but rather a region embedding multiple ERA countries. Thus, co-publications involving at least two ERA countries were counted using the fractional counting method 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. Also note that in this report, 'publications' (or 'co-publications') and 'papers' (or 'co-papers') are used interchangeably to encompass peer-reviewed (scientific) publications (or co-publications) in the form of journal articles and reviews indexed in the Web of Science (WoS). For more details on the computation of this indicator, refer to the companion Handbook to this report.

Since the last monitoring exercise, EU-28 Member States progressed moderately based on this indicator with an average annual increase of 3.3 % for the 2014-2016 period; this figure is broadly aligned with the EU-28 longer-term average annual growth (2007-2016) of 3.2 %. Positive and negative annual average growth rates for individual countries were distributed across all performance clusters, balancing out with a positive average except for Cluster 2 in terms of short-term growth.

The ordering of country scores in 2016 has generally remained close to that of 2014. Notable gains in ranking were made by Malta (ascending from 9th to 2nd position). Ireland's 17 % average annual decrease, responsible for a 9-position drop in its ranking since 2014, should be interpreted in light of the country's substantial increase in measurements of public sector researchers since 2013 which suggests a potential change in definition even though there are no such flags in Eurostat data. Note that only countries with imputable scores for both years based on the updated time series were considered in the analysis of rankings.

Per 1 000 peers, researchers from Cyprus published 339 articles in collaboration with other ERA partners, surpassing all other countries by a wide margin. Switzerland's score of 173 co-publications placed it in 2nd position, although it was based on data from 2012. Bulgaria and Turkey produced the fewest such publications, with 26 and 17 articles per 1 000 researchers, respectively. The EU-28 average stands at 71 articles. The group of countries just below the unweighted ERA average (Cluster 3) was slightly larger than expected on this indicator had the country scores been normally distributed. Distribution above and below the ERA average was quite even with 19 countries found below the average (Clusters 3 and 4) and 17 above (Clusters 1 and 2).

Except perhaps for Cluster 3, all country groups included similar shares of mid-size and small-size economies, resulting in no meaningful correlation between economic weight and performance. The best performances on this indicator were achieved by a subset of small and medium economies. Four of the ERA's largest economies (Germany, the UK, France and Spain), performed below the unweighted ERA average for this indicator. As was the case for, and as mentioned in the previous indicator, large countries are self-sufficient and, as a result, less reliant on foreign partnerships to conduct publishable research. Therefore, the large economies' below-average performances are not particularly surprising in this respect. Other potential biases relate to the fact that countries at the geographic centre of the ERA might have a higher share of intra-ERA cooperation, while countries at the periphery of the ERA or bordering non-ERA countries might have a higher share of non-ERA cooperation. There can also be a linguistic/historical bias: countries with international languages or countries that have been colonial powers might have a higher share of non-ERA cooperation.

There appears to be a growing disparity among ERA countries' ERA co-publications, despite strong short-term increases from two of the least performing countries (Latvia and Lithuania in Cluster 4). The score for the group of most performing countries (Cluster 1) collectively increased the most from 2014 to 2016 (unweighted average of 9.0 % annually), leading to a consolidation of their lead. Cyprus and Malta, in 1st and 3rd positions respectively, have increased the most among all countries

and played a key role in the strong growth of Cluster 1. Bosnia and Herzegovina's sharp 31 % annual decline (measure on the period from 2012 to 2014) accounts for Cluster 2's negative unweighted average growth. The Gini coefficient, an indicator of inequalities across countries, slightly increased over the long term, from 0.286 in 2007 to 0.327 in 2016. Figures for long-term growth also suggest slightly increasing inequality between ERA countries with respect to ERA co-publications. The highest long-term average annual growth was found for the country group with the highest performances (5.6 %).

Table 9 Co-publications with ERA partners per 1 000 researchers in the public sector (2007-2016)

Country	Weight in GDP	Score (2016)	CAGR			Trendline
			Short-term (2014-16)	Lead/Gap to EU-28 CAGR	Long-term (2007-16)	
EU-28		**71**	**3.3%**	**N/A**	**3.2%**	
Cluster 1	13.5%	168	9.0%	5.7	5.6%	
Cluster 2	17.9%	99	-0.8%	-4.1	3.3%	
Cluster 3	60.6%	59	2.4%	-0.9	3.1%	
Cluster 4	8.1%	31	4.3%	1.0	4.2%	
Cluster 1						
CY	0.1%	339	18.8%	15.5	12.3%	
CH	3.6%	*173*	:	:	*0.0%*	
MT	0.1%	152	17.8%	14.5	12.8%	
LU	0.3%	144	7.1%	3.8	5.4%	
AT	2.1%	138	3.4%	0.1	2.5%	
NL	4.3%	136	2.8%	-0.5	3.3%	
SE	2.8%	132	4.1%	0.8	2.1%	
SI	0.2%	129	9.3%	6.0	6.3%	
Cluster 2						
IS	0.1%	118	*1.6%*	-1.7	5.4%	
DK	1.7%	117	7.5%	4.2	1.7%	
BE	2.5%	110	-1.4%	-4.7	1.2%	
ME	0.0%	*101*	*-5.4%*	-8.7	*-1.6%*	
NO	2.0%	94	1.6%	-1.7	4.2%	
FI	1.3%	92	7.8%	4.4	6.3%	
IT	10.1%	91	5.3%	2.0	3.7%	
BA	0.1%	*84*	-31.1%	*-34.4*	:	
EE	0.1%	82	6.8%	3.5	5.6%	
Cluster 3						
CZ	1.1%	76	4.2%	0.9	4.3%	
HU	0.7%	73	4.0%	0.7	2.4%	
ES	6.7%	67	3.2%	-0.1	7.0%	
HR	0.3%	66	-1.0%	-4.3	6.1%	
DE	18.9%	63	1.5%	-1.8	0.5%	
FR	13.3%	*63*	*-0.6%*	-3.9	*2.0%*	
IE	1.7%	60	-16.9%	-20.2	-5.3%	
PT	1.1%	57	2.6%	-0.7	*6.7%*	
UK	14.5%	56	5.1%	1.8	4.5%	
RO	1.0%	53	0.8%	-2.5	3.4%	
EL	1.0%	51	7.5%	4.2	-0.9%	
MK	0.1%	45	12.1%	8.8	6.0%	
SK	0.5%	42	5.6%	2.3	3.1%	
Cluster 4						
LV	0.2%	40	17.1%	13.8	11.7%	
RS	0.2%	35	-2.0%	-5.3	*4.1%*	
PL	2.5%	*34*	*3.3%*	0.0	*3.8%*	
LT	0.2%	33	6.9%	3.6	5.3%	
BG	0.3%	26	-2.5%	-5.8	-2.9%	
TR	4.7%	*16*	*2.6%*	-0.7	*3.1%*	

Note: Break in time series: HR (2016); 2007 (DK, NO); 2011 (FI, EL, RO, SI); FR (2010); DE (2014, 2016); NL (2012); PT (2008, 2013); SE (2007, 2011, 2013); IS (2011, 2013). Definition differs: HR (2012-2015); FR (2007-2009); DE (2015, 2016); NL (2007-2015); SK (2007-2014); SE (2007); NO (2007-2009); CH (2008, 2010, 2012, 2014, 2015). Estimated: EU-28 (2008-2010); AT (2008, 2010, 2012, 2014); DK (2016); EL (2007); IE (2007, 2011, 2013); IT (2015); LU (2007); SE (2007-2015); UK (2007, 2008). Provisional: 2016 (EU-28, AT, CY, CZ, IT, LU, MT, NL, PT, SI, SE, UK); 2015 (DK, FR). Potential outlier: MT (2014); PT (2007); MK (2011). Exception to reference year: 2015 (FR, PL, ME, TR); BA (2014); CH (2012). Exception to reference period for short-term CAGR: 2013-2015 (PL, TR); IS (2013-2016); BA (2012-2014). Exception to reference period for long-term CAGR: 2007-2015 (FR, PL, TR); 2008-2016 (PT, RS); CH (2008-2012); ME (2011-2015). Data unavailable: AL, AM, FO, GE, IL, MD,

TN, UA. (:) = missing data. CY is more than four standard deviations away from the mean and was therefore not used in establishing the clusters' boundaries.

Source: Computed by Science-Metrix using WoS data (Clarivate Analytics) and Eurostat data (online data code: rd_p_persocc).

Comparing Headline to complementary EMM indicators

The Headline indicator for Sub-priority 2a, GBARD allocated to transnationally coordinated research, shows weak correlation (Pearson *r* of 0.23) with the complementary indicator participation in Public-to-Public Partnerships (such as ERA-NETs). The Headline is slightly more correlated with the number of ERA co-publications per 1 000 researchers (Pearson *r* of 0.36) but the correlation remains weak. These findings suggest that the Headline and complementary EMM indicators are tracking distinct behaviours, and accordingly that the various facets of transnational cooperation (Sub-priority 2a) cannot be reliably tracked using the Headline indicator alone.

Noting that all three indicators were normalised by the number of FTE researchers in the public sector, it is worth mentioning that, on average for EU-28, public funding has been increasing in the short and long terms for GBARD allocated to transnationally coordinated research. It also increased sharply for Public-to-Public Partnerships (such as ERA-NETs) when considering the long-term growth (2012-2016). In both cases, these overall increases were led by standout countries that have been stepping up their investments in transnational projects. Romania, for example, substantially increased its performance both for GBARD allocated to transnationally coordinated research and for Public-to-Public Partnerships.

For GBARD allocated to transnationally coordinated research, the strongest increases were mostly observed within the least performing clusters, while for Public-to-Public Partnerships, strong growth was observed across all performance clusters, especially for long-term growth. Collaborative research publications co-authored by ERA partners have also increased relative to the number of public sector researchers, although this finding should be interpreted in the context of a global ecosystem that is growing more internationally overall. Whether these increased investments and partnerships across national borders within the ERA are having an additional impact on collaborative publication output is a matter for further consideration. Also, to be considered is whether other research outputs beyond co-publications might also be valuable indicators for tracking the increasing level of integration within ERA.

3.2.4 Additional policy highlights 2a

Pooling of resources and research capacities to more effectively address common challenges remains the main perceived and actual added value of EU-level transnational cooperation instruments, such as JPIs, ERA-NET etc. A recent analysis of ERA-NET Cofund actions under Horizon 2020 found that the main motive of partners and national governments to take part in the ERA-NET Cofund instrument is the recognition that certain challenges can be dealt with better through joint transnational efforts. The stakeholders recognise that these instruments can create the necessary critical mass in both resources and research capacity. Strong evidence in fact confirms that ERA-NET Cofund contributes significantly to strengthening transnational cooperation by establishing lasting cooperation among countries and creating a critical mass of resources to tackle societal challenges (Gøtke et al., 2016). Recent evidence also shows that EU FP programmes not only contribute to pooling and rational distribution of resources among Member States but in some cases also affect the alignment and structuring of national funding priorities: members of the large collaborative networks are often key opinion leaders serving as advisers to policymakers and other stakeholders in charge of research policies and inform national funders about cutting edge research performed by the large international initiatives[19].

The recognition of the benefits provided by the Public-to-Public Partnerships is reflected by the latest strategic priorities set by a number of Member States: active participation in JPIs, ERA-NETs and similar instruments was one of the most frequently emphasised strategic goals in the latest national ERA NAPs among a number of countries (including Croatia, Spain, Czech Republic, Netherlands, Ireland, France, Estonia and others). The previously mentioned study revealed that the countries that are currently less involved in ERA-NET Cofund intend to increase their participation: whereas the vast majority of national representatives among EU-15 countries indicated that their countries will retain their current level of participation in ERA-NET Cofund, the majority of EU-13 national representatives stated that they plan to increase their involvement by a moderate amount.

[19] Assessment of the Union Added Value and the Economic Impact of the EU Framework Programmes FINAL REPORT.

Evaluation and monitoring of the impacts of participating in P2Ps are increasingly recognised as a catalyst for success by EU Member States. As was demonstrated by a recent Mutual Learning Exercise (MLE) on Alignment and Interoperability of National Research Programmes, where representatives from 10 European countries participated, the majority of countries agreed that the systematic monitoring and evaluation of outcomes and impacts from participation in Joint Programming networks is one of their key success factors: to complete the research programming cycle, it is necessary to review what is being achieved and, if appropriate, to adjust the strategy (Kolar et al. 2017). At the same time, however, all the participating countries recognised their weakness in terms of measuring impacts and dissemination of Joint Programming results. The countries recognise that a number of methodological and practical weaknesses exist in the way they measure the impacts of Joint Programming activities. This evidence indicates that there is a growing need to develop a robust and comprehensive framework of evaluating and monitoring the impacts of Joint Programming in research. The most promising good practice example in this area is provided by the H2020 ERA-LEARN 2020 project[20], which focuses on the development of a more systematic, and integrated, approach to the monitoring & assessment of Public-to-Public-Partnerships (P2P).

Literature shows that often there is still a lack of systemic coordination both between different EU research and innovation initiatives and between national research agendas and programmes. For instance, according to the Flemish ERA Roadmap 2016, currently, little systematic coordination exists within the Flemish administration between the different Research and Development and Innovation (R&D&I) funding agencies and the Department of Economy, Science and Innovation (DEWI) on aligning programmes with the Strategic Research and Innovation Agendas (SRIAs) of the Joint Programming Initiatives (JPIs). Similarly, evidence shows that coherence and coordination need to be improved among P2Ps in similar thematic areas, as well as between P2Ps and other relevant Union and national initiatives and priorities). This could be achieved by developing comprehensive strategy underpinning coordination in specific thematic areas, as well as by thematic workshops bringing together representatives of all relevant initiatives in a specific challenge/thematic area (Gøtke et al., 2016).

An often-perceived difficulty in participating fully in EU R&I partnerships is the complexity of the partnership landscape (see Interim Evaluation of H2020). In that context the instruments for supporting Public-to-Public Partnerships are being reviewed under the next MFF.

Analysis of national documents and data demonstrates that the lack of funding at national level is one of the key reasons preventing certain Member States from participating in EU-level research coordination initiatives and programmes. Greece's limited involvement in Joint Programming Initiatives, for instance, was primarily due to the significant reduction in its national Public Investment Programme (PIP), which resulted in lower funding for international cooperation, as well as to the difficulty in securing 100% national PIP funding in the long term. Similarly, according to its national ERA Roadmap 2016, Latvia was involved in four JPIs as an observer and in one as a joint call partner, but in none as a member. In addition to the lack of information on JPI conditions, the main reasons for Latvia's low level of involvement are the limited R&D funding, as well as the non-existing or limited research budget of line ministries and their hesitation to participate in addressing grand social challenges at the European level. Still another similar case is provided by Malta, which previously focused on two JPIs (JPND and JPI Oceans) since these initiatives were clearly in line with the National R&I Strategy and the smart specialisation priorities. However, due to resource constraints and the timing of the calls, a decision was taken to focus on strengthening participation in JPI Oceans only.

3.2.5 Headline indicator 2b — European Strategy Forum for Research Infrastructures (ESFRI)

The European Strategy Forum for Research Infrastructures (ESFRI) supports 'a coherent and strategy-led approach to policymaking on Research Infrastructures in Europe' (ESFRI, n.d.). ESFRI enables the identification of long-term needs for research infrastructure (RI) for European researchers covering all scientific areas, regardless of their location; it also facilitates 'multilateral initiatives to support the better use and development of RIs' (ESFRI, n.d.). The ESFRI Roadmap is a significant incentive for ERA countries to formulate their own national priorities in terms of RI needs and ambitions. Recent evidence indicates that strategic priorities have been defined, albeit to varying degrees, in most ERA countries surveyed. Furthermore, when considering national funding for RIs, these roadmaps appear to provide a valuable input into the decision-making process and, in fact, the final decisions are often in line with these roadmaps (Maessen et al., 2016). In practice, however, decision-making powers vary across countries, depending on the size of their economy and the complexity of their R&I system. Although open calls are the most frequent mechanism used to

[20] https://www.era-learn.eu/

allocate funding, the funding instruments and procedures for RI differ considerably and are often used in combined forms; moreover, national funding instruments are frequently selected to suit the RI selection processes (Maessen et al., 2016).

The indicators identified by ERAC to assess progress on Sub-priority 2b are the availability of national roadmaps for ESFRI projects, the participation in ESFRI projects (i.e. early development phase projects aiming to establish RIs) and the participation in ESFRI landmarks (implementation phase RIs requiring continued financial support for operation). Of these three, the availability of national roadmaps is the Headline indicator; full results are presented in Table 10. This indicator shows the year in which each national roadmap came into effect, whether the roadmap identifies specific ESFRI projects in which the country will participate, and whether the funding requirements for this country's participation are also identified. Note that a country's availability of a roadmap, its identification of ESFRI projects and its identification of funding requirements are all binary variables (i.e. yes/no); therefore, the presentation of results takes a different form from the presentation of results for the other indicators, the results of which are scalar quantities (i.e. a range of numerical results). As such, it does not provide information on the actual value of the financial contribution and does not enable the tracking of progress over time; in fact, it simply communicates that an effort is ongoing.

Since the last *ERA Progress Report*, Hungary has produced its first roadmap containing information and policy orientations on both ESFRI projects and funding requirements. A roadmap for Montenegro addressing both dimensions and dating from 2015 was also retrospectively identified. A further eight countries have updated their roadmaps in the intervening time (in chronological order: Sweden, Slovenia, Israel, the Netherlands, Bulgaria, Greece, Italy and Romania), sometimes identifying funding requirements for the first time (Israel, Greece and Italy). Sweden's update from 2014 has been retrospectively added to the data set. Also, the Netherlands has updated its roadmap since the 2016 report but removed funding requirements from the new policy.

By 2018, there were 16 countries that had roadmaps in place with both ESFRI projects and funding needs identified. These countries were — ordered according to the year in which the national roadmap came into effect — Germany, Croatia, Estonia, Finland, Sweden, Denmark, Montenegro, Switzerland, France, Slovenia, Israel, Bulgaria, Greece, Italy, Romania and Hungary. Additionally, six countries had roadmaps identifying ESFRI projects but no funding requirements (Austria, Poland, Portugal, the Czech Republic, Lithuania and the Netherlands). Norway had a roadmap with funding requirements identified but no ESFRI projects identified. Ireland, the UK and Spain all had a roadmap in place but identified neither ESFRI projects nor the funding needs associated therewith. The remaining 18 countries had no national roadmap in place. This last set of countries represented almost 10 % of ERA's GDP (for countries with a valid GDP score in the reference year, 2016). By contrast, the 15 countries that had projects and funding explicitly identified in their roadmap accounted for 55 % of ERA's combined GDP (again for countries with a valid GDP score in the reference year).

Table 10 Availability of national roadmaps with identified ESFRI projects and corresponding investment needs

Country	Weight in GDP	Roadmap year	ID'd ESFRI projects	ID'd funding requirements
DE	19.1%	2013	Yes	Yes
HR	0.3%	2014	Yes	Yes
EE	0.1%	2014	Yes	Yes
FI	1.3%	2014	Yes	Yes
SE	2.8%	2014†	Yes	Yes
DK	1.7%	2015	Yes	Yes
ME	:	2015	Yes	Yes
CH	3.5%	2015	Yes	Yes
FR	13.4%	2016	Yes	Yes
SI	0.3%	2016†	Yes	Yes
IL	:	2016†	Yes	Yes†
BG	0.3%	2017†	Yes	Yes
EL	1.0%	2017†	Yes	Yes†
IT	10.0%	2017†	Yes	Yes†
RO	1.1%	2017†	Yes	Yes
HU	0.7%	2018*	Yes*	Yes*
AT	2.2%	2014	Yes	
PL	2.7%	2014	Yes	
PT	1.1%	2014	Yes	
CZ	1.1%	2015	Yes	
LT	0.2%	2015	Yes	
NL	4.3%	2016†	Yes	†
NO	2.1%	2016		Yes
IE	1.7%	2007		
UK	13.6%	2012		
ES	6.8%	2013		
BE	2.6%	*No roadmap*		
CY	0.1%	*No roadmap*		
LV	0.2%	*No roadmap*		
LU	0.3%	*No roadmap*		
MT	0.1%	*No roadmap*		
SK	0.5%	*No roadmap*		
AL	:	*No roadmap*		
AM	:	*No roadmap*		
BA	:	*No roadmap*		
FO	:	*No roadmap*		
MK	0.1%	*No roadmap*		
GE	:	*No roadmap*		
IS	0.1%	*No roadmap*		
MD	:	*No roadmap*		
RS	0.2%	*No roadmap*		
TR	4.4%	*No roadmap*		
TN	:	*No roadmap*		
UA	:	*No roadmap*		

Note: † roadmap updated since ERA Progress Report 2016;
* new roadmap;
the cut-off date used to produce these data were 21 September 2018.
(:) = missing data.

Source: Data provided by the ESFRI Executive Secretary. For more information, visit: http://ec.europa.eu/research/infrastructures/index.cfm?pg=esfri-national-roadmaps.

3.2.6 Complementary EMM indicators

ERA countries participation in ESFRI developing Projects and operational Landmarks

Participation in ESFRI infrastructures has been divided into two components: nascent projects currently in their development phase (ESFRI Projects) and operational projects (ESFRI Landmarks). Developing ESFRI Projects are expected to enter a full implementation phase within a 10-year term, at which point they are granted the status of operational Landmark. From then on, they are expected to routinely offer services and platforms to the ERA science community. Given the continuity between developing Projects and Landmarks, the two indicators will be jointly analysed in this section. The transition from developing Project to Landmark does not represent any 'loss' for ERA countries, but rather, by definition, a consolidation of capacities. Full results are presented in Table 11.

Since the last *ERA Progress Report*, growth in ESFRI participation (i.e. share of ESFRI Projects and/or Landmarks in which a Member State/Associate Country is a partner) has shown clear increases. Firstly, ESFRI Projects and Landmarks, on average, included more countries in 2018 than they did in 2016. Projects involved an average of 6.6 countries in 2016 and 9.1 in 2018. For Landmarks, that figure is 11.7 in 2018, up from 9.9 in 2016. In 2016, EU-28 Member States had an average participation of 21 % in developing projects and of 30 % in operational Landmarks. These EU-28 averages increased to 29 % (38 % increase from 2016) and 37 % (23 % increase from 2016), respectively, in 2018. The growth figure being higher for developing projects than for operational Landmarks is indicative of a continued expansion potential for ESFRI initiatives and services, as well as of increased inclusion among ERA countries.

For instance, the Gini coefficient, a common metric used in economics to quantify inequalities in the wealth of various groups, decreased from 0.47461 in 2016 to 0.375 in 2018 for this indicator (Projects and Landmarks combined). This apparent decrease in the inequalities across countries appears to be attributable to high growth in the participation of countries immediately below the ERA average (Cluster 3[21]; see the guide to reading the quantitative results tables on page 20), indicating that these countries are catching up with the leaders. On average, the share of participation in Projects plus Landmarks doubled in 2018 relative to 2016, for countries in this cluster. Bulgaria, Croatia, Luxembourg and Slovakia at least doubled their ESFRI participation rates (Projects plus Landmarks) in 2018 relative to 2016 (as did Hungary and Slovenia near the bottom of Cluster 2). For Cyprus, increases have been very large, with a roughly 400 % increase in 2018 relative to 2016. Only Malta experienced a decrease in relative participation (share of Projects plus Landmarks), and Sweden's share of Projects plus Landmarks did not change.

Another set of ERA countries was noteworthy for its growth pattern: those with an increase in their share of participation in Landmarks but a decrease in their share of developing Projects. Despite high scores in 2018, such countries are possibly at risk of future stagnation in their total share of ESFRI participation (Projects plus Landmarks) as other ERA states continue to expand their relative participation in ESFRI Projects. This set of countries includes Norway and Ireland. Norway participated in 18 out of 37 Landmarks (48.6 %) in 2018, up from 10 out of 29 Landmarks (34.5 %) in 2016. Its share of developing Projects declined, however, from 6 out of 21 in 2016 to 1 out of 18 in 2018. For Ireland, its share of participation in operational Landmarks tripled, from 2 out of 29 in 2016 to 8 out of 37 in 2018, while the share of projects decreased by about 30% in 2018 relative to 2016. In other words, participation went from involvement in 3 out of 21 projects in 2016 to 2 out of 18 projects in 2018. However, absolute participation is never at risk of a decline as Project participation will shift to Landmark participation when projects reach their implementation phase.

The five largest ERA economies took up the top rankings in ESFRI participation (Projects plus Landmarks), with the group of leaders (Cluster 1) being rounded out by Czech Republic and Greece. The scores for these leaders were scattered over a relatively broad range, extending from 78 % for France to 47 % for Greece. With the exception of FYR Macedonia, the group of countries with the fewest participations (Cluster 4) did not participate in any ESFRI Projects/Landmarks. More countries fell below the ERA average (25 in Clusters 3 and 4) than above it (19 in Clusters 1 and 2) in terms of combined ESFRI participations (projects plus Landmarks). Cluster 3, sitting just below the ERA average with scores between 25 % and 2 %, was especially large, with 17 countries. This distribution indicates a concentration of scores towards the lower end of the scale, reflective of some inequalities between the most performing and the least performing groups; for instance, the ERA average of 25 % was closer to the lower (0 %) than the upper (78 %) limit of observed values for this indicator. That said, the above finding on growth pointed towards a reduction of these inequalities, especially for countries in Cluster 3.

[21] Performance Clusters were established based on the combined participation in ESFRI Projects and Landmarks.

There is a clear relationship between the extent of participation in ESFRI Projects/Landmarks and the economic strength of ERA countries. The strength of the relationship between performance and GDP is larger than for any of the other indicators reported in this study. This is not surprising as the total number of ESFRI developing Projects and Landmarks is the same across countries. Accordingly, it is to be expected that larger countries with larger financial capacities will participate in a greater share of these ESFRI Projects/Landmarks. In future EMM indicators, ERAC could perhaps consider normalising ESFRI participations by country population or GDP to better account for country size differences. As mentioned above, the largest economies within the ERA were found within the group of most participating nations (Cluster 1). Together, they account for almost 70 % of the ERA GDP (for those countries with a GDP score in Table 11). Cluster 2, sitting just above the ERA average (scores between 25 % and 47 %), was made up of nine middle economies and two small economies. The group of countries performing immediately below the ERA average (Cluster 3) included small economies with three middle ones.

Table 11 Share of developing ESFRI Projects and operational ESFRI Landmarks in which a Member State/Associate Country is a partner (2018)

Country	Weight in GDP	Score (2018)			CAGR (2016–18)		
		Projects + Landmarks	Projects	Landmarks	Projects + Landmarks	Projects	Landmarks
EU-28		**35%**	**29%**	**37%**	**15.0%**	**18.6%**	**11.3%**
Cluster 1	69.5%	60%	54%	64%	9.7%	11.8%	9.1%
Cluster 2	20.6%	36%	24%	42%	19.8%	16.2%	15.0%
Cluster 3	9.7%	12%	12%	11%	48.1%	23.0%	34.3%
Cluster 4	0.2%	0%	1%	0%	:	:	:
Cluster 1							
FR	13.3%	78%	67%	86%	2.8%	-0.6%	2.2%
IT	10.0%	71%	67%	73%	8.7%	12.8%	5.5%
UK	14.4%	65%	50%	73%	4.4%	-13.4%	15.0%
NL	4.2%	58%	56%	59%	7.9%	20.8%	0.7%
DE	18.8%	56%	39%	65%	4.1%	16.7%	-3.0%
ES	6.7%	55%	50%	57%	16.8%	-2.3%	35.2%
CZ	1.1%	53%	44%	57%	14.8%	24.7%	8.4%
EL	1.0%	47%	61%	41%	17.9%	35.4%	8.4%
Cluster 2							
BE	2.5%	45%	44%	46%	4.0%	15.5%	-2.4%
PT	1.1%	44%	39%	46%	29.6%	42.9%	21.7%
FI	1.3%	44%	22%	54%	4.4%	-18.4%	9.8%
SE	2.8%	40%	11%	54%	0.0%	-23.6%	-1.0%
PL	2.5%	36%	28%	41%	6.6%	-8.7%	14.3%
DK	1.7%	35%	22%	41%	0.8%	8.0%	-4.9%
NO	2.0%	35%	6%	49%	3.9%	-55.9%	18.8%
AT	2.1%	33%	28%	35%	43.0%	:	12.9%
SI	0.2%	33%	28%	35%	52.9%	141.5%	30.3%
HU	0.7%	27%	11%	35%	65.1%	52.8%	59.6%
CH	3.6%	25%	22%	27%	7.6%	8.0%	5.8%
Cluster 3							
RO	1.0%	22%	33%	16%	16.8%	32.3%	8.4%
SK	0.5%	22%	22%	22%	65.1%	52.8%	77.1%
IL	:	22%	22%	22%	16.8%	52.8%	2.2%
BG	0.3%	18%	22%	16%	50.8%	52.8%	53.3%
IE	1.6%	18%	11%	22%	34.8%	-11.8%	77.1%
CY	0.1%	18%	28%	14%	201.5%	:	98.0%
EE	0.1%	15%	11%	16%	10.1%	:	-11.5%
LV	0.1%	13%	17%	11%	:	:	:
HR	0.3%	7%	6%	8%	90.7%	:	53.3%
LT	0.2%	7%	6%	8%	10.1%	:	-11.5%
LU	0.3%	7%	0%	11%	90.7%	:	77.1%
RS	0.2%	7%	6%	8%	34.8%	:	8.4%
TR	4.7%	7%	11%	5%	34.8%	52.8%	25.2%
MT	0.1%	4%	0%	5%	-4.7%	:	-11.5%
IS	0.1%	4%	0%	5%	34.8%	-100.0%	:
MD	:	4%	11%	0%	34.8%	52.8%	:
UA	:	4%	6%	3%	:	:	:
Cluster 4							
MK	0.1%	2%	6%	0%	:	:	:
ME	0.0%	0%	0%	0%	:	:	:
AL	0.1%	0%	0%	0%	:	:	:
BA	0.1%	0%	0%	0%	:	:	:
FO	:	0%	0%	0%	:	:	:
AM	:	0%	0%	0%	:	:	:
GE	:	0%	0%	0%	:	:	:
TN	:	0%	0%	0%	:	:	:

Note: Observer countries were not counted as partners. Between 2016 and 2018, eight developing ESFRI Projects became Landmarks and five new Projects were initiated. There were a total of 21 developing ESFRI Projects and 29 operational ESFRI Landmarks in 2016. For 2018, there were 18 Projects and 37 Landmarks.

Source: Data provided by the ESFRI Executive Secretary. For more information, consult the ESFRI Roadmap 2018 at www.esfri.eu

Comparing Headline to complementary EMM indicators

The analysis indicates that countries that have a national roadmap policy in place are more likely to be participating in a greater share of ESFRI Projects in the preparatory phase as well as operational

Landmarks. Moreover, the presence of a roadmap that includes explicit details about the specific ESFRI Projects targeted and about the funding requirements needed for this participation coincides with higher levels of participation in ESFRI developing Projects and operational Landmarks. Across ERA, participation in ESFRI Projects, both those in development phases and those that are already operational, is led primarily by a small group of countries, chiefly the largest European economies.

3.2.7 Additional policy highlights 2b

There is a persistent need for more cooperation and synchronisation of national research infrastructures in terms of their inclusion into the pan-European RI landscape. Literature review shows that key RI stakeholder groups in Europe still see the lack of cooperation among ERA countries as a challenge for pooling of research infrastructures and building a common RI landscape that would help sharing of infrastructures and avoid duplication of funding efforts. An online consultation targeting a number of different RI stakeholders in Europe revealed that the majority of them felt national processes still need to be better inserted into a common European strategy for RI. For this purpose, the European Commission should take a greater role in monitoring, supporting and facilitating the whole exercise. In addition, the same online consultation revealed that more support to the international outreach and visibility of pan-European RI is required to boost the coherence of the European RI landscape: the main identified instruments that could serve for this purpose include improvement of the communication strategies and networking events, increasing numbers of international outreach events and more dedicated funding/support to ESFRI and European Research Infrastructure Consortia (ERIC) (European Commission, 2016). In addition, recent policy recommendations highlight the use of site visits during the assessment of RIs and invitation of international experts to the self-assessment procedure of RIs: all these measures should contribute to the exchange of information and good practices in the development of RIs, as well as to better understanding of the specific country's/regions' or organisation's place in the overall European landscape of RIs (Maessen et al., 2016).

To boost the harmonisation of RI in Europe, information on the actual RI capacities, funding priorities, plans and strategies must be exchanged not only between countries/regions but also between research organisations themselves: this gives all actors (including the cases where more than one party is involved in RI funding in a country) with RI funding the opportunity to investigate who else might be considering funding of comparable research facilities (Maessen et al., 2016). Similarly, recent country-specific policy recommendations emphasised the need to open the available R&I infrastructures to the business sector and the regional economic systems in which they operate, as well as to update the country's research infrastructure mapping with a systematic prioritisation (2017 European Semester, Country Report Lithuania 2017; Country Report Bulgaria).

Country-level analysis shows an increasing recognition of the need to specialise in several areas while allocating funding for national RIs. A number of recent national-level R&I strategies and roadmaps recognise that, because RIs are becoming increasingly costly, the country's future needs must be evaluated and their funding of research infrastructures prioritised accordingly. This is especially evident among smaller ERA countries with fewer resources. As was noted by the latest Danish RI roadmap, for instance, although traditionally in Denmark, the universities and research institutions have assumed independent responsibility for the development of and investment in research infrastructure and research facilities, due to the emergence of costly RIs, such as supercomputers, in the future national coordination of RI development will become more and more dominant. Similarly, according to Malta's latest R&I strategy 2020, Malta will adopt a strategic approach towards participation and collaboration with major research infrastructures, focusing primarily on those infrastructures which are closely linked to specialisation areas identified. At the same time, in its national RI roadmap Greece recognised that the recent economic crisis and the related shortage of research funds was a turning point helping to set clear priorities in the country's RI funding. Similarly, the National Research, Development and Innovation Policy of Czech Republic 2016–2020 defines performance evaluation of large infrastructures and R&D&I centres in terms of sustainability as one of the key milestones in ensuring sustainability of the RDI financing system.

The above qualitative evidence provides further details and confirms earlier quantitative findings, which show that smaller EU economies with fewer resources have fewer opportunities to participate in large RI projects, such as ESFRI projects.

Main findings

Sub-priority 2a

1. A number of different EU P2P (Public-to-Public) initiatives currently contribute towards the joint effort of European countries in better coordination and common addressing of grand societal challenges. These initiatives include Joint Programming Initiatives — JPIs, Art 185 initiatives, ERA-

NET Cofund actions, European Joint Programme (EJP) Cofund actions. Each of these actions has a different rationale behind it and different implementation modalities.

2. GBARD allocated to transnationally coordinated research (Europe-wide, transnational public R&D programmes and bilateral or multilateral public R&D programmes) expressed in euros per FTE researcher in the public sector was chosen as the Headline indicator for sub-priority 2a. The study found that although there was still an increase in international cooperation in EU-28 countries over the recent period from 2014 to 2016, EU-28 Member States (France excluded) have seen a slowdown in growth on GBARD allocated to transnationally coordinated research since the previous monitoring exercise. While average annual growth stood at 7.2 % for EU-28 from 2012 to 2014, this figure was reduced to 3.9 % for the period from 2014 to 2016. Similarly, although there has been an overall progress over a longer period of 2012 to 2016, reduction in growth since the previous ERA Progress Report was still found with a figure of 5.6 % annual average growth. Several countries contributed to these decreases in scores, including Croatia (which displays a 27-point gap in growth to the EU-28 annual average), Greece (25-point gap), Bulgaria (23-point gap) and Ireland (21-point gap).
3. Pooling of resources and research capacities to more effectively address common challenges remains the main perceived and actual added value of EU-level transnational cooperation instruments, such as JPIs, ERA-NET and other P2P instruments. Active participation in JPIs, ERA-NETs and similar instruments was one of the most frequently emphasised strategic goals in the latest National Action Plans (NAPs) among a number of Member States.
4. Evaluation, monitoring and impact assessment of the instruments for transnational cooperation in research is increasingly recognised as a catalyst for success of these instruments by EU Member States. In addition, a lack of systemic coordination both between different EU transnational research cooperation instruments and between these instruments and national research agendas and programmes, together with the lack of funding in some Member States, remain the main hindrances for successful coordination of national R&I policies and participation in P2P actions by Member States.

Sub-priority 2b

1. In 2018, there were 16 countries that had roadmaps in place with both ESFRI projects and funding needs identified. These countries were — ordered according to the year in which the national roadmap came into effect — Germany, Croatia, Estonia, Finland, Sweden, Denmark, Montenegro, Switzerland, France, Slovenia, Israel, Bulgaria, Greece, Italy, Romania and Hungary. Additionally, six countries had roadmaps identifying ESFRI projects but no funding requirements (Austria, Poland, Portugal, Czech Republic, Lithuania and the Netherlands). Norway had a roadmap with funding requirements identified, but no ESFRI projects identified. Ireland, the UK and Spain all had a roadmap in place but identified neither ESFRI projects nor the funding needs associated therewith. The remaining 18 countries had no national roadmap in place;
2. Countries that have NAPs in place are more likely to be participating in a greater share of ESFRI projects in the preparatory phase and operational landmarks. Moreover, the presence of a roadmap that includes explicit details about the specific ESFRI projects targeted and about the funding requirements needed for this participation coincides with higher levels of participation in ESFRI developing projects and operational landmarks;
3. There remains the need for more cooperation and synchronisation of national research infrastructures in terms of their inclusion into a harmonious pan-European RI landscape. Instruments that could serve for this purpose include improvement of the communication strategies and networking events, increasing numbers of international outreach events and more dedicated funding/support to ESFRI and ERIC.

3.3 Priority 3 – Open labour market for researchers

3.3.1 Policy context

Open labour markets and improvements of career development opportunities for researchers have been the most important priorities since the development of the ERA concept: free movement of researchers across Europe as well as attracting talented researchers from non-European countries have been seen as the key catalysts for excellence in research and the development of ERA. Since mobility is only appealing if attractive living and working conditions for researchers are offered, the opening up of labour markets for researchers is inherently connected to the improvement of research career conditions, including open, transparent and merit-based recruitment of researchers. Overall, to enhance open labour markets for researchers in Europe, the European Commission invited the Member States to:

- Remove legal and other barriers to the application of open, transparent and merit-based recruitment of researchers;
- Remove legal and other barriers which hamper cross-border access to and portability of national grants;
- Support implementation of the Declaration of Commitment to provide coordinated personalised information and services to researchers through the pan-European EURAXESS network;
- Support the setting up and running of structured innovative doctoral training programmes applying the Principles for Innovative Doctoral Training;
- Create an enabling framework for the implementation of the HR Strategy for Researchers incorporating the Charter & Code, which first of all requires employer organisations to apply the principles of transparent and merit-based recruitment of researchers.

The EURAXESS initiative has a special place in enhancing an open labour market for researchers. It is a unique web portal providing access to a complete range of information and support services for European and non-European researchers, wishing to pursue research careers in Europe. Among other services EURAXESS includes an electronic recruitment tool allowing for posting CVs, getting useful information, announcing vacancies for universities/companies. In this way it functions as a direct proxy and platform for open labour markets for researchers in Europe.

3.3.2 Headline indicator

The Headline indicator for Priority 3 is the number of researcher job postings from a given country that are advertised through the EURAXESS job portal per 1 000 researchers in the public sector in that country. It measures active international recruitment efforts by a given country's institutions that are conducted using open, transparent and merit-based processes. It therefore directly relates to the Priority 3 action aiming at fostering open, transparent and merit-based recruitment, and relates to the goal of creating an open labour market for researchers that was established by the Commission for reinforcing ERA (European Commission, 2012). Indeed, evidence suggests that researchers who have migrated 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 (European Commission & Directorate-General for Research and Innovation, 2014a). This indicator carries a number of drawbacks. Since some Member States/Associated Countries have their own national job portals, these may be preferred by their institutions such that job offers cannot be captured in a comprehensive manner by relying exclusively on EURAXESS; companies will also advertise a portion of relevant jobs. Furthermore, as jobs can be advertised on multiple platforms, merging data from EURAXESS and national portals would lead to multiple counting.Furthermore, because some vacancies are not published (i.e. they are not open), it can be argued that a better denominator for this indicator would be the total vacancies for researchers instead of the total number of researchers in a given country. However, such data are not currently available. Thus, it is recommended that this indicator be only considered as a proxy of how open, transparent and merit-based recruitments actually are in a given country, acknowledging that it does not provide a comprehensive overview of such recruitment efforts. As mentioned by the ERAC Secretariat (2015), 'The EURAXESS portal should be considered mainly as a "trend reference tool" as it provides information solely about the number of job adverts published on a yearly basis.' Full results are detailed in Table 12 and mapped in Figure 3.

With the addition of data sets for the year 2015 and 2016 to those already presented in the previous report, the EU-28 Member States appeared to be positioned in a downward trajectory — annual average declines of 5 % were measured for the group since the last ERA monitoring exercise. This average annual decline reversed a previous course of positive growth over the 2012 to 2014 period (CAGR of 7.3 % based on the updated time series). Results at the aggregate level contrasted sharply with a few very strong growth rates that stood out from the portrait of individual countries (i.e.

Finland, Germany, Latvia, Turkey and Luxembourg). Decreases were driven by Bulgaria (61 % average annual decrease), Greece (45% decrease) and Sweden (44% decrease).

There has been a moderate amount of movement in ranks since the last report, with 10 countries experiencing changes by more than three positions. Finland moved up from 24th to 13th position, although its 2016 datapoint is a clear break of previous trends and has been flagged as a potential outlier by Eurostat. Greece lost 10 positions in the rankings while Ireland lost 9 places, movements that resulted from combinations of sharp increases in these countries' researcher counts as well as clear decreases in EURAXESS usage. Other notable movements include Sweden's drop from 2nd to 11th position, Estonia's drop from 17th to 22nd, Luxembourg's increase from 8th to 3rd, or Belgium's increase from 12th to 7th.

Scores obtained on this indicator are dispersed, with a single top performer considerably extending the range of values covered. Croatia is the standout performer for this indicator, with a score that is more than five standard deviations above the unweighted ERA average. Data sets for the country appear to be robust. Croatia was joined by Poland, Luxembourg, Cyprus, the Netherlands and Norway in Cluster 1. In 2016, these countries advertised more than 75 job postings through EURAXESS per 1 000 public sector researchers. A handful of countries used EURAXESS sporadically for recruitment, with the lowest levels of participation observed by Turkey, Bulgaria and Serbia, which advertised less than one job through EURAXESS for every 1 000 public sector researchers. Country groups remained unbalanced even if Croatia was not considered in establishing their boundaries. There were a significant number of countries in the sole group formed for scores under the ERA average (Cluster 3, with 22 countries out of 36). The group of countries just above the ERA average (Cluster 2) was also undersized given the total number of countries examined for this indicator. Taken together, these observations on distribution of countries into performance groups indicated a high level of inequalities, which is translated by the highest Gini coefficient observed in this study (0.632 in 2016).

The relationship between GDP and performance for this indicator was insignificant, with large and small economies having roughly an equal chance of being observed among any given cluster. The six countries in the most performing group (Cluster 1, representing 17 % of countries) accounted for 10 % of ERA GDP, the nine countries in the second most performing group (Cluster 2, 25 % of countries) accounted for 48 %, and the remaining countries (61 % of countries) accounted for 42 % of GDP. Germany was the only one among the four largest economies (Germany, the UK, France and Italy, which each account for more than 10 % of ERA GDP) to place below the unweighted ERA average score; the three others ranked in the group of countries situated just above the ERA average (Cluster 2).

Country inequalities for this indicator were the highest observed in this study. The Gini coefficient, a common metric used in economics to quantify inequalities in the wealth of various groups, was found to be 0.632 in 2016, up from 0.566 in 2012. The correlation between performance and recent growth was significant when Croatia was included in the calculations, but not significant if the country's scores were excluded. Given the size of Cluster 3, its average annual growth, which was considerably below those of the top country groups, also seemed to capture growing inequality. Despite this moderate growth in the aggregate, multiple countries in this group showed noteworthy growth: Germany (91-point lead over EU-28 CAGR), Latvia (71 points) and Turkey (56 points).

The long-term average annual growth rates provide even clearer evidence of growing inequalities. In this period, the group of most performing countries (Cluster 1) shows an average growth of 28 %, compared to 3.5 % and 1.5 % for Cluster 2 and Cluster 3, respectively.

Discrepancies between the short-term and long-term growth rates calculated for this indicator show that caution is generally warranted in the interpretation and use of findings on this indicator. It is important to mention that two countries — Switzerland, and Bosnia and Herzegovina — only had a single year of data available (2012), in which case no trend is presented. Three others — FYR Macedonia, Montenegro and Malta, — only had two years of data. Out of these three, only Malta's CAGR is presented since the two years of available data in its case, 2012 and 2016, were those used to calculate the CAGR of most other countries.

Table 12 Number of researcher postings advertised through the EURAXESS job portal, per 1 000 researchers in the public sector (2012-2016)

Country	Weight in GDP	Score (2016)	CAGR			Trendline
			Short-term (2014-16)	Lead/Gap to EU-28 CAGR	Long-term (2012-16)	
EU-28		**42.1**	**-5.0%**	**N/A**	**1.0%**	
Cluster 1	9.5%	175.5	14.6%	19.6	28.1%	
Cluster 2	48.1%	51.0	16.0%	21.0	3.5%	
Cluster 3	42.4%	10.4	6.0%	11.0	1.5%	
Cluster 1						
HR	0.3%	460.5	12.8%	17.8	114.6%	
PL	2.5%	*155.3*	*1.7%*	6.7	:	
LU	0.3%	141.2	42.6%	47.7	1.2%	
CY	0.1%	114.0	20.1%	25.1	7.9%	
NL	4.3%	103.9	4.3%	9.3	7.9%	
NO	2.0%	77.8	6.1%	11.1	8.6%	
Cluster 2						
BE	2.5%	75.0	21.2%	26.2	10.1%	
AT	2.1%	63.8	-4.0%	1.0	3.9%	
FR	13.3%	*54.6*	*8.7%*	13.8	:	
UK	14.5%	49.5	-10.5%	-5.5	-3.9%	
SE	2.8%	49.2	-43.8%	-38.8	-18.9%	
IT	10.1%	39.5	21.9%	26.9	16.4%	
FI	1.3%	39.4	169.9%	174.9	38.1%	
IE	1.7%	37.4	-35.6%	-30.6	-21.2%	
Cluster 3						
IS	0.1%	25.5	*0.4%*	5.5	:	
RO	1.0%	24.4	19.9%	24.9	-11.6%	
EL	1.0%	24.1	-44.7%	-39.7	-29.0%	
SI	0.2%	23.2	-9.0%	-4.0	5.0%	
DK	1.7%	21.6	13.3%	18.3	6.3%	
DE	18.9%	19.2	85.5%	90.5	42.2%	
ES	6.7%	18.7	19.9%	24.9	20.6%	
CH	3.6%	*16.1*	:	:	:	
EE	0.1%	14.7	-18.0%	-13.0	-3.5%	
CZ	1.1%	9.0	-10.2%	-5.1	-26.0%	
LV	0.2%	7.4	65.7%	70.7	69.0%	
PT	1.1%	6.7	-5.4%	-0.4	12.2%	
MK	0.1%	*3.9*	:	:	:	
ME	0.0%	*3.1*	:	:	:	
MT	0.1%	2.9	:	:	-32.9%	
LT	0.2%	2.4	21.3%	26.3	-1.0%	
BA	0.1%	*2.1*	:	:	:	
HU	0.7%	1.8	31.9%	36.9	-3.5%	
SK	0.5%	1.2	-9.3%	-4.3	38.6%	
TR	4.7%	*0.7*	*51.2%*	56.3	:	
BG	0.3%	0.2	-61.4%	-56.4	-28.3%	
RS	0.2%	0.2	-49.5%	-44.5	-33.4%	

Note: Break in time series: HR (2016); DE (2014, 2016); NL (2012); 2013 (PT, SE, IS)
Definition differs: 2012-2015 (HR, NL); DE (2015-2016); SK (2012-2014); CH (2012)
Estimated: AT (2012, 2014); DK (2016); IE (2013); IT (2015); SE (2012-2015)
Provisional: 2016 (EU-28, AT, CY, CZ, DK, FR, IT, LU, MT, NL, PT, SI, SE, UK)
Eurostat country flags have been retained in the EU-28 aggregate
Potential outlier: FI (2016)
Exception to reference year: 2015 (FR, PL, TR); 2012 (BA, CH); 2014 (MK, ME)
Exception to reference period for short-term CAGR: 2013-2015 (FR, PL, TR); 2013-2016 (IS)
Data unavailable: AL, AM, FO, GE, IL, MD, TN, UA
(:) = missing data
HR is more than four standard deviations away from the mean and was therefore not used in establishing the clusters' boundaries.

Source: Computed by Science-Metrix from EURAXESS historical data and from Eurostat data (online data code: rd_p_persocc).

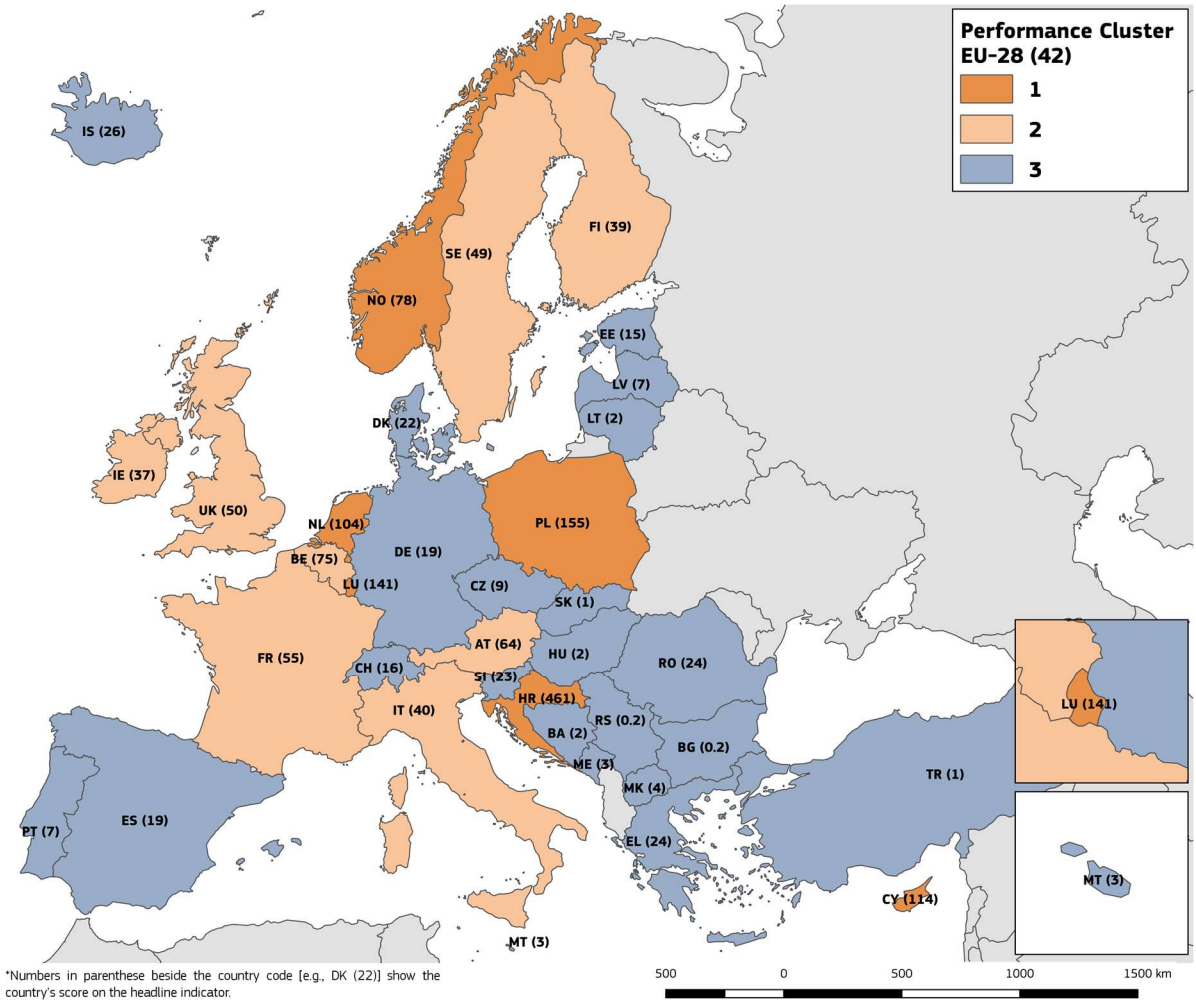

Figure 3 Map of number of researcher postings advertised through the EURAXESS job portal, per 1 000 researchers in the public sector (2016)

Note: As per Table 12.
Source: Computed by Science-Metrix from EURAXESS historical data and from Eurostat data (online data code: rd_p_persocc).

3.3.3 Complementary EMM indicators

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

Under Priority 3, Member States and Associated Countries are expected to expand structured doctoral training programmes and remove barriers for cross-border mobility to help retain highly skilled Europeans rather than have them pursue career goals in other competitive economies. For instance, it is expected that by promoting an open academic system, Member States and Associated Countries will be in a better position to attract and retain skilled students who will eventually contribute to the R&I workforce either in academia or the industrial sector. As a result, the first complementary EMM indicator for Priority 3 is the share of doctoral students in a given country who hold a citizenship of another EU Member State. 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 facilitates the transition to a new academic institution in another country). Note that this measure assesses the degree to which opportunities for international student mobility between ERA countries are being taken up, which of course depends on the availability of such opportunities, as well as other factors. Also note that this indicator does not link to open, transparent and merit-based recruitments, which is the key action under Priority 3 (ERAC Secretariat, 2015a), and that it can be affected by a country-size bias and country-location bias. Full results are found in Table 13.

The previous *ERA Progress Report* included data sets for the year 2013. This update includes a fully updated time series covering the years 2013 to 2016. The EU-28 average score has increased at an average annual rate of 3.9 % since 2013 moving from 6.4 % to 7.1 %.

There has been a moderate number of changes in rank positions on this indicator since 2013. Cyprus gained 12 ranks, moving from 21st position up to 9th. Latvia and Iceland respectively moved up 6 and 5 ranks, while Portugal moved down by 6 positions and Lithuania by 5 places.

Scores were found to be skewed on this indicator, with smallish groups of most performing countries (Clusters 1 and 2). The top-performing country for this indicator was Luxembourg, where more than half of doctoral students held citizenship from another EU country. Luxembourg was followed by Switzerland, Iceland, Austria, Denmark and the Netherlands. The lowest result was observed in FYR Macedonia, the only country to have no PhD student from an EU country in 2016. Cyprus had the strongest rate of increase in scores between 2013 and 2016, going from 3.5 % to 10.6 % in shares of EU doctoral students. Distribution of countries within groups led to only three groupings. Relative to expectation under a normal distribution of the scores, the group just above the ERA average (unweighted; Cluster 2) was hollowed out to the benefit of Cluster 3, being one very large group below the ERA average containing 20 out of 34 countries. This split between the most performing country group (Cluster 1) and a large group of fair-to-middling performances (Cluster 3) is indicative of inequalities between ERA countries on this indicator. Indeed, the Gini coefficient for 2016 was 0.548, a figure that is moderate in the abstract but one of the highest obtained in this study.

There was no relationship between the economic weight of ERA countries and performance on this indicator. The group just below the ERA average (Cluster 3) represented half of ERA's total GDP and included multiple small economies as well as Germany, Italy and a few middle economies. The most performing country group (Cluster 1) accounted for only 12 % of ERA GDP, containing four medium economies and two small economies. As was the case for all indicators in Sub-priority 2a, larger countries might be disadvantaged due to smaller countries being more dependent on external resources. This, however, is not necessarily an issue, since larger economies are, as a result, in a better position to attract talent from abroad and are more likely to retain their own PhD students.

ERA country scores ultimately appeared to be quite concentrated on this indicator, but short-term growth has slightly reduced inequalities between the states under consideration. The Gini coefficient for 2016 was 0.548, a figure that is slightly smaller than it was in 2013 (0.577). This is consistent with Cluster 2 and Cluster 3 having higher annual average growth rates (8.5 % and 6 %) than the group of most performing countries (Cluster 1; 4.5 %). Cyprus increased its average annual growth the most, with a lead of 41 percentage points above the EU-28 reference level of growth. Many countries whose score was below the unweighted ERA average also showed positive yearly average growth rates. This includes Bulgaria, Serbia and Latvia. This group of countries also included a pronounced drop for Lithuania, which found itself 48 points below the EU-28 average.

Table 13 Share of doctoral candidates with citizenship of another EU Member State (2013-2016)

Country	Weight in GDP	Score (2016)	CAGR (2013-16)	Lead/Gap to EU-28 CAGR	Trendline
EU-28		**7.1%**	**3.9%**	**N/A**	
Cluster 1	12.1%	27.3%	4.5%	0.6	
Cluster 2	37.9%	10.3%	8.5%	4.6	
Cluster 3	50.1%	2.9%	6%	1.6	
Cluster 1					
LU	0.3%	55.6%	*-4.3%*	-8.2	
CH	3.6%	37.2%	3.2%	-0.7	
IS	0.1%	20.6%	23.1%	19.2	
AT	2.1%	17.7%	1.8%	-2.1	
DK	1.7%	17.1%	5.6%	1.8	
NL	4.2%	15.8%	-2.5%	-6.4	
Cluster 2					
UK	14.4%	13.4%	1.3%	-2.6	
BE	2.5%	12.8%	5.1%	1.2	
CY	0.1%	10.6%	44.8%	40.9	
SE	2.8%	10.3%	7.4%	3.5	
IE	1.6%	9.6%	-7.8%	-11.7	
CZ	1.1%	9.6%	4.9%	1.1	
NO	2.0%	8.3%	6.6%	2.8	
FR	13.3%	7.8%	5.6%	1.7	
Cluster 3					
SK	0.5%	7.0%	0.6%	-3.3	
FI	1.3%	6.3%	3.8%	-0.1	
LV	0.1%	6.2%	28.5%	24.6	
DE	18.8%	5.3%	11.6%	7.7	
HU	0.7%	4.7%	4.5%	0.6	
MT	0.1%	4.4%	-5.0%	-8.9	
EE	0.1%	3.9%	11.2%	7.3	
ES	6.7%	3.8%	-0.2%	-4.1	
IT	10.1%	3.4%	11.6%	7.8	
SI	0.2%	*3.1%*	*-2.6%*	-6.5	
PT	1.1%	3.1%	-7.9%	-11.8	
BG	0.3%	2.3%	34.5%	30.6	
HR	0.3%	1.5%	14.8%	10.9	
RO	1.0%	0.8%	-2.5%	-6.4	
EL	1.0%	0.7%	:	:	
RS	0.2%	*0.4%*	*30.9%*	27.0	
TR	4.7%	0.4%	*9.2%*	5.3	
PL	2.6%	0.3%	0.7%	-3.2	
LT	0.2%	0.3%	-44.0%	-47.9	
MK	0.1%	0.0%	:	:	

Note: Definition differs: EU28 (2014, 2016); DE (2016); EL (2015, 2016); PL (2014)
Estimated: LU (2014)
Eurostat country flags have been retained in the EU-28 aggregate
Imputed data in EU-28 aggregate for: EL (2013-2014); LU (2013); SI (2016); ES (2014-2015)
Exception to reference year: 2015 (SI, RS)
Exception to reference period: 2014-2016 (LU, TR); 2013-2015 (SI, RS)
Data unavailable: AL, AM, BA, FO, GE, IL, MD, ME, TN, UA
(:) = missing data

Source: Source: Computed by Science-Metrix using Eurostat data (online data codes: educ_uoe_mobs02, educ_uoe_enrt01).

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

The MORE3 Higher Education Institutions (HEI) survey, which interviewed over 10 000 individual researchers, collected data on mobility patterns, career paths and working conditions of researchers working in HEI. The second complementary indicator for Priority 3 is derived from the survey data and consists of the share of researchers that answered the three following questions positively:

(1) Are you satisfied with the extent to which research 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 institution is sufficiently merit based?

This measure assesses the degree to which hiring opportunities are perceived to be truly orientated towards selecting the best available candidate for the job using open, transparent and meritocratic processes. In this regard, it can serve as a direct measure of the outcomes of Priority 3's core action of promoting open, transparent and merit-based recruitments. Note that the MORE study is updated every three years. As a result, there is an issue of timeliness associated with these data that makes it difficult to study trends. Full results can be found in Table 14. These only cover the years 2012 (obtained from MORE2) and 2016.

The last *ERA Progress Report*, based on MORE survey results for 2012, found that 49 % of respondents in EU-28 Member States, were satisfied with the hiring procedures in their institution. This score increased to 65 % in the 2016 edition of the survey. Average annual growth in between two timepoints, assuming exponential growth, is estimated to be 7.5 % at the EU-28 level. Growth in scores could be seen across the ERA countries included, with the exception of Spain, which saw a slight decrease.

Country rankings have been fully reshuffled on this indicator since the last report, with 14 out of 31 ERA countries associated with movements of more than 3 positions (some countries are excluded since they do not have scores in 2016). As many as 8 countries experienced changes of 10 or more positions in ranking. To take just a few examples, Romania moved up from 20th to 3rd position, while Spain, Norway and Ireland dropped by 13 places.

The ERA average (61 %) was, compared to some of the indicators with the strongest country inequalities, located near the mid-range of observed values (35 % to 77 %) on this indicator. This resulted in rather low inequalities between ERA countries on this indicator with a Gini coefficient of 0.098 in 2016. Country scores were clustered on a relatively narrow range on this indicator, and there were more countries in the most performing country groups (19 in Cluster 1 and 2) than in the least performing groups (14 in Cluster 3 and 4) in 2016. In particular, the group immediately above the unweighted ERA average (Cluster 2) was quite large, with 14 countries. Malta and the UK obtained the highest satisfaction scores of 77 %. In a third of the countries surveyed, 70 % or more of researchers expressed satisfaction. The least performing countries (Cluster 4) were the only ones where a minority of researchers surveyed expressed satisfaction in recruitment practices. The two most performing groups (Cluster 1 and Cluster 2) included 19 out of 33 countries.

Economic weight was well distributed across performance groups and no relationship could be found between GDP and performance. The group of countries immediately above the ERA average showed the highest concentration of GDP at 44 %, but as already mentioned, it also contained the most countries among the four groups. Each of the four country groupings included one of the four largest ERA economies.

Further examination showed that inequalities decreased in recent years, the Gini coefficient having decreased from 0.151 in 2012 to 0.098 in 2016. Although no correlation could be found between recent growth and performances, it is worth noting that the two groups with least performing countries (Cluster 3 and 4) showed higher annual average growth rates than Cluster 2, the largest of the four clusters. Since the last report, Italy (Cluster 4) has made the largest gains on this indicator, with a growth of 29.2 percentage points above EU-28 growth. Spain, on the other hand, has shown a gap of 8.5 points in relation to the EU-28 reference. Both countries had scores that placed them in the group of least performing countries. Other scores of note include robust growths by Romania (Cluster 1), Austria (Cluster 2) and Bulgaria (Cluster 3).

Table 14 Share of researchers expressing satisfaction that the hiring procedures in their institution are Open, Transparent and Merit-based (2012-2017)

Country	Weight in GDP	Score (2016)	CAGR (2012-16)	Lead/Gap to EU-28 CAGR
EU-28		**65%**	**7.5%**	**N/A**
Cluster 1	16.7%	75%	11.2%	3.7
Cluster 2	43.9%	68%	7.8%	0.3
Cluster 3	16.4%	55%	12.7%	5.2
Cluster 4	22.9%	42%	11.2%	3.7
Cluster 1				
MT	0.1%	77%	14.0%	6.5
UK	15.1%	77%	1.4%	-6.1
RO	1.1%	74%	18.5%	11.1
CZ	1.1%	74%	13.8%	6.3
LV	0.2%	73%	8.1%	0.6
Cluster 2				
PL	2.7%	72%	5.5%	-2.0
DE	19.8%	71%	12.5%	5.0
AT	2.2%	71%	16.6%	9.1
IS	0.1%	70%	9.5%	2.0
CH	3.8%	70%	6.7%	-0.8
LU	0.3%	70%	2.6%	-4.9
SE	2.9%	70%	9.1%	1.6
DK	1.7%	68%	7.0%	-0.5
BE	2.7%	67%	9.4%	1.9
NL	4.5%	67%	5.5%	-2.0
EE	0.1%	67%	4.4%	-3.1
IE	1.7%	65%	3.7%	-3.8
FI	1.4%	65%	12.8%	5.3
NO	2.1%	62%	3.5%	-3.9
Cluster 3				
CY	0.1%	61%	9.4%	1.9
FR	14.0%	61%	12.8%	5.3
EL	1.1%	57%	12.2%	4.7
BG	0.3%	52%	17.3%	9.8
LT	0.2%	51%	13.3%	5.8
HR	0.3%	51%	14.3%	6.8
PT	1.2%	51%	9.3%	1.9
Cluster 4				
IT	10.6%	49%	36.7%	29.2
SI	0.3%	48%	13.9%	6.4
SK	0.5%	47%	5.9%	-1.6
ES	7.0%	41%	-1.0%	-8.5
TR	4.7%	*39%*	:	:
MK	0.1%	*38%*	:	:
HU	0.7%	35%	0.5%	-7.0

Note: Exception to reference year: MK (2012); TR (2012)
Data unavailable: AL, AM, BA, FO, GE, IL, MD, ME, RS, TN, UA
(:) = missing data
Source: Computed by Science-Metrix using MORE2 and MORE3 Survey data.

Comparing Headline to complementary EMM indicators

Looking at the connection between the indicators presented for Priority 3, there was no meaningful correlation between performance on the Headline indicator and the proportion of PhD students in a given country holding citizenship of another EU Member State (Pearson *r* of 0.11). This is not very surprising since the latter indicator is not related to the use of open, transparent and merit-based recruitments, which is the key aspect captured by the Headline indicator on EURAXESS job postings.

If openness, transparency and meritocracy of the hiring processes are increased with the use of EURAXESS, one would expect a positive correlation between the Headline indicator and the share of researchers expressing such satisfaction. A factor that could blur such a signal with the data currently available is that the indicator using EURAXESS usage data might not be sufficiently comprehensive because many countries have their own national platforms for advertising job vacancies for researchers. There was no correlation between the two (Pearson *r* of 0.05).

Although the EURAXESS data might offer a good proxy for the subsequent satisfaction that recruitments are sufficiently open, transparent and merit based, the above findings suggest that the Headline indicator on its own does not offer a broad-based reflection of performance along all dimensions of Priority 3.

Use of the EURAXESS platform seems to be growing strongly in a handful of countries, while only just taking root in others. Meanwhile, roughly 1 out of every 12 PhD candidates in ERA comes from another European country, and 65 % of EU-28 researchers expressed satisfaction in the hiring processes in their home institutions. There is, however, strong diversity between countries for these indicators as well, suggesting that the landscape of researcher mobility has a varied topography. In such a circumstance, it comes as little surprise that a single indicator would be less effective in tracking overall behaviour than in a circumstance of greater consistency across national contexts.

3.3.4 Additional policy highlights

The literature review confirmed that a large gap still exists between the EU countries in terms of the openness of labour markets and career development opportunities provided to researchers. In general, there are very large differences between the attractiveness of research careers among different countries and regions of Europe. A recent study found that there is generally a consensus among European researchers concerning the conditions for an attractive environment for research careers: long-term career perspectives, research autonomy, working with leading scientists, an appropriate balance between time for teaching and time for research, sufficient funding to allow the implementation of research agendas were universally seen as the conditions for a successful/attractive research career. At the same time, the study found that a large gap exists between different EU regions and countries in terms of attractiveness of research careers measured by the availability of opportunities for learning, research funding, financial security and shares of fixed-term contracts. This heterogeneity in terms of research career conditions between different Member States is not just a result of different higher education systems and career structures, but also of differing economic developments influencing public budgets for research and hence salaries of researchers and other conditions (MORE3 study, 2017).

Recent evidence also shows that the main action governments can take to increase the international mobility of researchers and attract talents from abroad is to improve the effectiveness of national/regional research ecosystem in terms of excellence in cutting edge research, availability of top-level infrastructures, ensure efficient interactions between public and private actors and a highly innovative business sector, as well as attractive career conditions and salaries for researchers (Calbet 2018). Similarly, the lack of research funding and the limited availability of researcher positions were identified as the two biggest barriers to researchers' international mobility in the MORE3 study: improving them would reduce barriers to mobility and make it easier to become mobile. Other factors enhancing mobility of researchers include working with leading scientists and long-term career perspectives (e.g. a tenure track model), research autonomy and the balance between teaching and research offered by host country/institution.

The analysis also shows that career stage is a crucial factor in attracting foreign talents from abroad. Efforts aimed at recruiting the most promising researchers at early stages of their career rather than at later stages are likely to be more successful, whereas trying to recruit leading researchers during later career stages will be costlier by comparison, as they are less likely to move. Thus, the most effective policy choice would involve offering attractive career perspectives to early-stage researchers e.g. based on a tenure track career model (MORE3, 2017). Similar findings were provided by an earlier study on research careers, which analysed the most important factors in motivating researchers to stay in their research career and not to switch to an alternative career path. The study concluded that experienced researchers tend to value the stability and security of a research position as well as the compatibility of research work/academic career with personal life more positively than early-stage researchers. On the other hand, such factors as availability of international/intersectoral mobility opportunities offered to young researchers, transparency and equal opportunities in the researcher recruitment processes, relevance of PhD training for the needs of industry/employment opportunities in the private sector were more important aspects of research careers for researchers at early-career stages (PPMI, 2016).

Interviews with the representatives of research performing organisations also revealed that different employment statuses of researchers across different European countries and the resulting limited

portability of social security and pension schemes across borders is one of the key barriers for international mobility of researchers. In some countries, researchers have a special status of civil servants with the corresponding special social security and pension packages attached. There are a number of administrative and legal difficulties, which limit the portability of these social security provisions in the case of a researcher's mobility to countries where researchers do not have this status and are employed on the basis of a usual employment contract. To overcome these difficulties, necessary administrative instruments should be adopted allowing the portability of social security provisions for researchers across European countries.

Finally, although European researchers in academia still perceive intersectoral mobility as rather unimportant for their career progression, a number of Member States increasingly introduced more schemes supporting intersectoral mobility of researchers. On the one hand, interest in intersectoral mobility or industry experience among academic researchers currently working in EU HEI remains low, not just in terms of dual positions, or mobility stints, but also in terms of whether industry exposure or intersectoral mobility is perceived as important for PhD training, recruitment and career progression, or whether entrepreneurship and IPR rights are important skills for a research career. On the other hand, country-level analysis shows that over the last years there has been a growing interest among European universities, publicly funded research institutes and companies themselves in using intersectoral mobility as a mechanism to strengthen cooperation (Whittle et al., 2018). Moreover, evidence shows that there has been an increasing supply of different intersectoral mobility schemes offered in the Member States over the last few years (Kohl, 2017).

Main findings

1. In terms of the number of researcher job postings from a given country that are advertised through the EURAXESS job portal per 1 000 researchers in the public sector, the EU-28 Member States appeared to be positioned in a downward trajectory with annual average declines of 5 % for the whole country group since 2014. This average annual decline reversed a previous course of positive growth over the 2012 to 2014 period (CAGR of 7.3 %). Results at the aggregate level contrasted sharply with a few very strong growth rates that stood out from the portrait of individual countries (i.e. Finland, Germany, Latvia, Turkey and Luxembourg), whereas decreases were driven by Bulgaria (61 % average annual decrease), Greece (45% decrease) and Sweden (44% decrease).
2. In terms of the share of doctoral candidates with citizenship of another EU Member State, the data for 2013-2016 show that the EU-28 average score has moderately increased since 2013, from 6.4 % to 7.1 % in 2016. In addition, there has been a moderate number of changes in ranks on this indicator since the last ERA Progress Report. Cyprus gained 12 ranks, moving from 21st position up to 9th. Latvia and Iceland respectively moved up 6 and 5 ranks, while Portugal moved down by 6 positions and Lithuania by 5 places.
3. Qualitative analysis confirmed that a large gap still exists between the EU countries in terms of the open labour market and career development opportunities provided to researchers measured by availability of opportunities for learning, research funding opportunities, financial security, salaries and shares of fixed-term contracts. This heterogeneity reflects different higher education and research systems, as well as economic developments influencing public budgets for research and hence research funding and salaries of researchers. In addition, different employment statuses of researchers across different European countries and the resulting limited portability of social security and pension schemes across borders are key barriers for international mobility of researchers.

3.4 Priority 4 – Gender equality and gender mainstreaming in research

3.4.1 Policy context

Guaranteeing a balanced gender representation in all aspects of research contributes to excellence, positively influences research outcomes and impact, and promotes the acceptance of scientific insights (EIGE, 2016a). More gender diversity is being recognised as having a positive impact on innovation policies (Lee & Pollitzer, 2016), financial stability (Diouf & Pépin, 2017), analysis of research content (EC, 2014) and innovation (Díaz-García et al., 2013). The previous ERA Progress Report (2016) indicated different levels of gender equality progress within and between ERA countries, including gender balance policies and initiatives. This section will present the level of implementation of ERA Priority 4 across Member States, and ongoing efforts that countries have set in place, both at national and institutional levels, to enhance incentives and strategies for gender equality in research content, and to address the persistent inequalities in research careers, imbalance in senior positions, top-level decision-making within research organisations and gender bias.

At the European level, the Commission has developed and adopted the 'Strategic Engagement for Gender Equality 2016-2019' framework which sets out actions to be undertaken at European, national, regional and local levels in order to continue the promotion of gender equality. In the area of R&I, the framework – first defined in the ERA Communication (EC, 2012) and restated in the Council conclusions of 1 December 2015 on Advancing gender equality in the European Research Area – has three main related objectives, namely, gender equality in careers (to remove possible bias and discrimination and ensure equal opportunities); gender balance in decision-making bodies, and integration of the gender dimension in research content. Based on the literature review, more gender initiatives addressing different issues (e.g. unconscious/implicit gender bias; inclusion of gender aspects in research, etc.) have been adopted across ERA countries in recent years with various degrees of progress. However, to date under EU laws it is not mandatory in all countries to adopt specific policy tools to implement gender equality initiatives. Effectiveness of quotas or targets increases when such measures are implemented as part of national law or strategy and supported by institutional leadership (EC, 2018a). Additionally, the implementation of a monitoring and assessment system to evaluate the impact of such measures is a key driver of quotas and targets initiatives' efficiency (EC, 2018a).

Good practice sharing among RFOs and RPOs across ERA countries remains an ongoing process. For example, in 2017 Science Europe released a practical guide for improving gender equality in research organisations. The European Commission, through FP7 and Horizon 2020, has supported the implementation of Gender Equality Plans (GEPs) in over 130 RPOs and RFOs, and is now also supporting the development of GEPs communities of practice. Nonetheless, specific provisions requiring RPOs to implement structured GEPs exist only in Austria, Finland, Germany, Hungary, Italy, Spain, Sweden and the UK (EIGE, 2016b).

Gender bias remains a major cause of less favourable assessment of women's academic capacities in research, teaching and leadership and one of the most difficult issues to tackle. Implicit gender bias, such as gender-science stereotypes (e.g. associate science with men more than women) are still present worldwide even in countries with high levels of gender equality (Miller, Eagly & Linn, 2015; Reuben, Sapienza & Zingales, 2014; Riffle et al., 2013; Steintórsdóttir, Heijstra & Einarsdóttir, 2017; Van der Lee & Ellemers, 2015). The League of European Research Universities (LERU) published in 2018 a paper addressing gender bias, examples of good practices and in May 2017 the European Commission's Directorate-General for Research and Innovation held a workshop on Implicit Gender Biases during evaluations, discussing research evidence for the existence of implicit gender biases and practices that help tackle it. The qualitative data collection identified some good practices being implemented in different countries addressing implicit bias: (1) Production of recruitment and selection guidelines for professorial appointments and training on gender bias; (2) Awareness and communication activities, aimed at all academic community to enhance awareness regarding gender equality and unconscious bias; (3) Learning and teaching (exploring teaching evaluations by gender, grade and ethnicity, include different aspects of equality and bias in their programmes, courses on the impact of gender stereotypes on career paths and research); and (4) Monitoring and evaluating (measure the impact of training; report their progress on equality yearly). In September 2018, the ERAC Standing Working Group on Gender in Research and Innovation (SWG GRI) also published a policy brief on gender bias in research evaluation with recommendations for action for EU Member States (WK 9979/2018 INIT).

The ERAC SWG GRI, the ERA-related group with responsibility for ERA Roadmap Priority 4 created in 2017, building on the work carried out by the Helsinki Group on Gender in research and innovation, plays a key role in the development of the gender dimension in ERA, as it complements the activities of individual Member States and of the Commission in shaping EU policymaking in gender equality and gender mainstreaming in R&I.

GENDERACTION (2018), a project funded by Horizon 2020 supporting the networking of national representatives and resource centres on gender in R&I and working in complementarity with ERAC SWG GRI, analysed the implementation of gender equality in NAPs. Results indicated different levels of implementation of gender equality policies, with NAPs even differing in the concept of gender equality used. Not all NAPs focused on the three objectives under Priority 4 and/or included targeted measures or actions. Differences were also found when comparing EU-15 with newer Member States. Results show that new Member States have more difficulties with developing Priority 4 and fewer links with other priorities. The project also identified good practices and recommendations for country NAPs and measures: (1) NAPs should be based on an empirical baseline assessment; (2) contain objectives and targets which are derived from the baseline assessment and consistently formulated; (3) an interlink between priority 4 and all other priorities should be present; (4) concrete budgets and resources should be included; (5) define responsibility for the implementation of NAPs or specific actions and include a coordinator responsible for the six priorities, as well as, for concrete measures within each priority; (6) to use consultation in writing NAPs (stakeholder involvement); and (7) include concrete deadlines for implementing measures and actions and a description of monitoring and/or planned evaluation activities. Measures should be: (1) based on an empirical baseline assessment, (2) explicitly aim to contribute to at least one of the three main gender equality objectives, (3) formulate concrete targets and target groups, (4) be based on a theory of change/programme theory (a formulated set of assumptions why and how the policy should reach its targets and target groups, (5) ensure that relevant stakeholders are involved in the development of the measures.

3.4.2 Headline indicator

The 'Strategic Engagement for Gender Equality 2016-2019' framework emphasises that while progress has recently been achieved in the employment rate of women and their participation in decision-making, persistent inequalities remain in other areas (EC, 2015). In particular, the framework identifies a number of key actions to address lasting inequalities in research, some of which are at the core of Priority 4. Priority 4 actions aim to address gender inequalities in research institutions and decision-making bodies, and to promote the integration of the gender dimension in R&D policies, programmes and projects (ERAC Secretariat, 2015a). The Headline indicator identified by ERAC for Priority 4 is the share of women in Grade A research positions in the higher education sector, as a percentage of all such research positions (for further information on this indicator, see European Commission & Directorate-General for Research and Innovation, 2016d). This indicator is meant to assess the representation of women in the highest echelons of the research world, and longitudinal analyses (in combination with the share of female PhD graduates, see Section 3.4.3) can help to identify the degree to which a glass ceiling still limits the professional advancement of women in research.

A key strength of this indicator is that it has been refined over more than a decade within the She Figures context. Born through a 1999 meeting of the Helsinki Group on Gender in Research and Innovation (HG), a sub-group of Statistical Correspondents covering all ERA countries was given the responsibility of collecting national data for the creation of European statistics on gender equality in science and research. Since 2003, these statistics have been released every three years in the She Figures publication, with the next release being the latest iteration (European Commission & Directorate-General for Research and Innovation, 2019c).

Note, however, that there are a few drawbacks to using this indicator as the Headline figure. First, it does not capture two of the three core items in this priority: gender imbalances in decision-making bodies and the integration of the gender dimension in R&D policies, programmes and projects. Second, it only covers HEI such that researchers in other public research institutions (e.g. in government) are not covered. Last but not least, this indicator is affected by a 'periodicity' and 'balance' issue. For instance, the She Figures data collected by the HG and its Statistical Correspondents are updated every three years, which can lead to the presentation of outdated data. It can in some cases be updated more regularly, however. The year 2016 was retained as the reference year for this indicator to maximise its cross-country comparability. The 2016 data set also provides the empirical basis for the *She Figures 2018* report (European Commission & Directorate-General for Research and Innovation, 2019c). Additionally, growth figures were calculated by combining this data set with previous data from the 2016 ERA Progress Report for the years 2014 and 2015. The 'balance' issue relates to the fact that it can prove difficult to assess the performance of countries when higher scores do not always equate to better performance – that is, when there is a mid-range optimum across the possible values of an indicator. For the share of women in Grade A positions, the optimum might be established at 50 %. In that case, how far above the optimum must a share be to be considered worse than a score below 50 %? As laid out by ERAC, 'a high share of females does not necessarily mean fair recruitment processes etc., but could reflect the unattractiveness of posts for men, for example because of low pay' (ERAC Secretariat, 2015a). Additionally, is 50 % the best optimum? For instance, women may represent more or less than 50 % of the population and this can vary across countries. In this report, shares in the range from 40 %

to 60 % were considered as reflecting gender parity. Full results for this indicator are available in Table 15, and are plotted on a map in Figure 4.

On average, the share of women in Grade A positions in the higher education sector remained mostly unchanged at the EU-28 level (excluding Luxembourg and the UK due to missing data). The average EU-28 score moved up slightly to 24 % in 2016, from 23% in 2014 (CAGR = 1 %). Despite this, some EU-28 countries experienced relatively strong growth, two of which are already among the leaders on this dimension, namely Romania (with an average annual growth rate over the 2014-2016 period of 22.3 %, 21 percentage points ahead of the EU-28) and Lithuania (CAGR of 9.7 %, nearly 9 points lead over the EU-28).

Country rankings in 2016 remained very stable on this indicator relative to 2014. Only 3 countries (out of 26 for which scores in 2014 and 2016 could be imputed from data no more than one year from these reference years) have seen shifts in position by more than 3 places. These shifts were notable, however. Switzerland went from 19th to 13th, Romania from 6th to 1st, and Malta from 1st to 18th position. For Romania, note that the improved rank is strongly affected by a change in the reference population's definition (from academic staff to researchers). Romania's reference population in 2014 included about 4 600 individuals whereas it only included about 280 individuals in 2016. Thus, it is not surprising that we observe a large change in its score. Also note that the population size for Malta was rather small both in 2014 (173 academic staff) and 2016 (247) such that strong yearly fluctuations in its score are to be expected.

Dispersion of scores was moderate on this indicator, and one group of countries included almost two thirds of the covered ERA countries. Values observed ranged from shares of 13 % to 67 % of women in higher education sectors with Grade A positions. FYR Macedonia's high score of 67 % in 2012 must be interpreted carefully, as it is based on a very small population of only 9 researchers. Accordingly, if data were available for additional years, its score could easily exhibit strong yearly fluctuations. It should also be noted that at 67 %, it is starting to depart from gender parity on a side opposite to most countries (i.e. more women than men). Still, it is part of the top 6 countries with the smallest departures from perfect parity (i.e. 50 %). Romania, Latvia, Croatia and Lithuania round out the group of most performing countries (i.e. Cluster 1) with scores within the range reflecting gender parity (based on the 40-60 % criteria). While these countries achieved gender equality in grade A positions, it is very important to contextualise the findings and not to generalise misleading conclusions. A higher share of women in Grade A positions does not necessarily translate into better working conditions or other benefits associated with more senior positions (for more nuanced findings, refer to She Figures 2018). Israel, Czech Republic and Cyprus make up the group of least performing countries (Cluster 4) where shares of women in the higher education system with Grade A positions range from 13 % to 15 %. Scores were highly concentrated in the group of countries immediately below the unweighted ERA average (Cluster 3). That group included 21 out of 34 countries whose scores ranged from 17 % and 26 %. This leaves a very small group made of the three least performing countries, and also a relatively small number of countries above the unweighted ERA average (Cluster 1 and 2). This distribution suggests that the country inequalities are relatively small on this indicator.

ERA countries' economic weight was almost completely encompassed by the oversized Cluster 3. This country group included all large economies, as well as most medium economies. Small and medium economies obtained scores above the unweighted ERA average (Cluster 1 and 2), but they also made up Cluster 4. Therefore, overall, no conclusive relationship could be established between GDP levels and performance.

Recent growths have tended to be achieved by strong performers, showing that inequalities are increasing. The group of most performing countries (Cluster 1) has seen growth of 10.1 % over the 2014 to 2016 period, far above the other country groups at 3.9 % (Cluster 2), 1.5 % (Cluster 3) and -1.2 % (Cluster 4). This has translated into a Gini coefficient that increased from 0.169 in 2014 to 0.182 in 2016. Aside from some of the short-term growths presented in the opening paragraph, other observations on this dimension are noteworthy. Hungary, which obtained a relatively low absolute score, showed strong short-term annual average growth with a figure of 12.4 %. The countries immediately above it in the rankings, Malta and Ireland, showed marked decreases in growth (-22.6 % and -10.0 %, respectively).

Table 15 Share of women in Grade A positions in the Higher Education Sector (2014–2016)

Country	Weight in GDP	Score (2016)	CAGR (2014-16)	Lead/Gap to EU-28 CAGR
EU-28		**24%**	**1.0% w/o LU & UK**	**N/A**
Cluster 1	1.7%	48%	10.1%	9.1
Cluster 2	8.5%	30%	3.9%	2.9
Cluster 3	88.6%	22%	1.5%	0.4
Cluster 4	1.2%	14%	-1.2%	-2.3
Cluster 1				
MK	0.1%	*67%*	:	:
RO	1.0%	54%	*22.3%*	21.2
LV	0.1%	41%	*6.3%*	5.3
HR	0.3%	*41%*	*2.3%*	1.2
LT	0.2%	39%	9.7%	8.7
Cluster 2				
BG	0.3%	*37%*	*2.2%*	1.2
FI	1.3%	29%	2.6%	1.6
SI	0.2%	29%	7.6%	6.6
NO	2.0%	28%	3.1%	2.0
TR	4.7%	*28%*	:	:
Cluster 3				
UK	14.4%	26%	:	:
PT	1.1%	26%	*1.3%*	0.2
IS	0.1%	*26%*	:	:
SE	2.8%	*25%*	*4.2%*	3.1
SK	0.5%	25%	0.1%	-0.9
EE	0.1%	*24%*	*3.3%*	2.3
PL	2.6%	24%	3.0%	2.0
CH	3.6%	23%	*6.6%*	5.5
AT	2.1%	*23%*	*5.7%*	4.7
IT	10.1%	22%	2.0%	0.9
FR	13.4%	*22%*	*-4.6%*	-5.6
EL	1.0%	22%	2.9%	1.9
ES	6.7%	21%	0.7%	-0.3
DK	1.7%	21%	6.9%	5.9
MT	0.1%	*21%*	*-22.6%*	-23.6
IE	1.7%	*21%*	*-10.0%*	-11.1
HU	0.7%	*20%*	*12.4%*	11.3
DE	18.9%	19%	4.1%	3.1
NL	4.2%	19%	5.0%	4.0
BE	2.5%	18%	*5.5%*	4.4
LU	0.3%	*17%*	:	:
Cluster 4				
CZ	1.1%	*15%*	*2.2%*	1.2
IL	:	14%	:	:
CY	0.1%	*13%*	*-4.7%*	-5.7

Note: Definition differs (reference population = Academic staff): 2014, 2016 (BG, DE, EL, IT, LV, MT, NL, SI, SK, SE, IS); 2014 (ES, RO); 2016 (EE, IE, LT)
Exception to reference year: 2017 (BG, HR, MT); 2015 (AT, CY, CZ, EE, FR, HU, IE, SE); LU (2013); 2012 (MK, IS); TR (2007)
Exception to reference period: 2013-2016 (RO, LV, CH, BE); 2014–2017 (HR, BG, MT); PT (2012–2016); 2014–2015 (SE, AT, FR, HU, EE, CZ, CY); IE (2012–2015)
Change in reference population in the CAGR computation: researchers to academic staff (IE, EE, LT); Academic staff to researchers (ES, RO)
EU-28 performance score includes all MS but the growth excludes LU and UK due to missing data.
Data unavailable: AL, AM, BA, FO, GE, MD, ME, RS, TN, UA
Data prone to yearly fluctuations due to small denominator: MK (6/9 = 66.7%)
(:) = missing data

Source: Women in Science database, DG Research and Innovation (extracted 21 August 2018). Additional data covering years 2014 and 2015 were provided by the Helsinki Group in the context of the ERA Progress Report 2016. When divergence occurred between the two sources of data, the Women in Science database was prioritised.

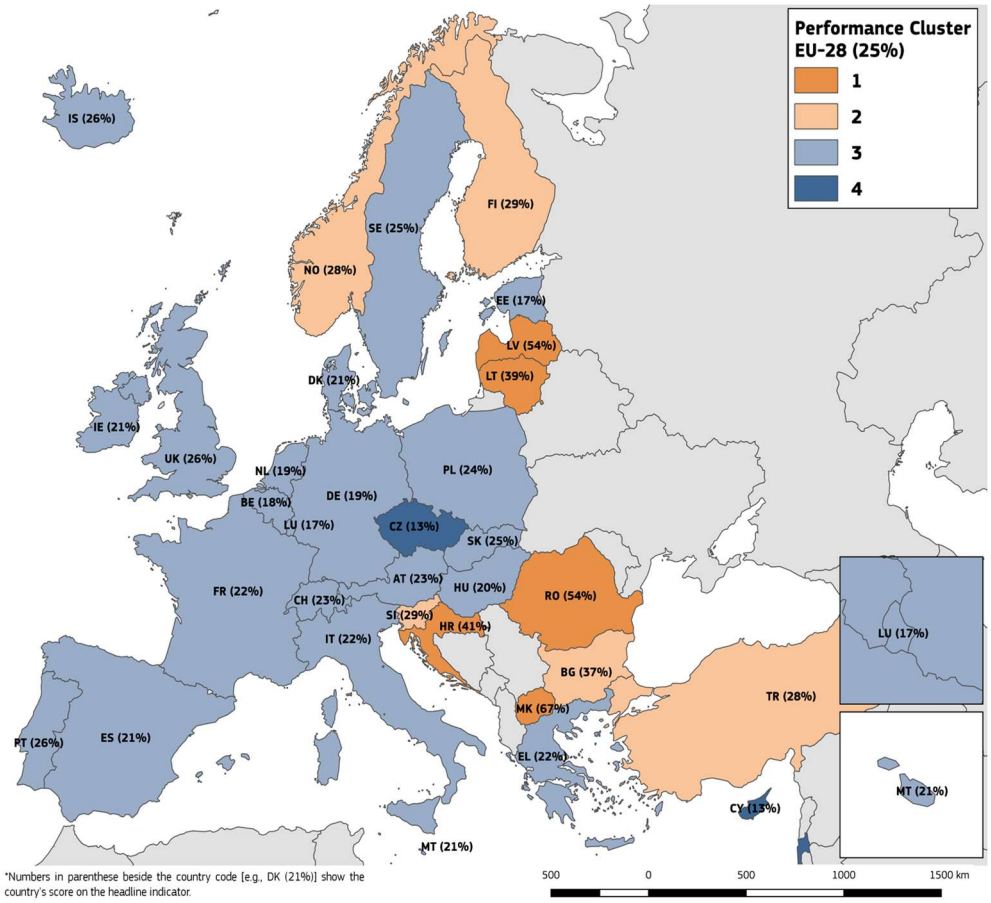

Figure 4 Map of share of women in Grade A positions in the Higher Education Sector (2016)

Note: As per Table 15.
Source: Computed by Science-Metrix from Women in Science database, DG Research and Innovation.

3.4.3 Complementary EMM indicators

Gender dimension in research content

As previously mentioned, one of the core actions under Priority 4 aims to promote the integration of the gender dimension in R&D policies, programmes and projects (ERAC Secretariat, 2015a). For instance, applicants to Horizon 2020 are now required to specify how they intend to integrate a gender dimension in their research content. This requirement makes it relevant to start monitoring the extent to which researchers in different countries incorporate this aspect into their research content to provide baseline figures against which to measure progress.

The first indicator used to measure the inclusion of a gender dimension in research content was developed for the 2015 instalment of the She Figures report (European Commission & Directorate-General for Research and Innovation, 2016c and 2016d). In that report, each country's scientific papers were assessed to determine the proportion integrating a gender dimension [22]; this assessment was divided by domains of research because the gender dimension is much more relevant (and therefore expected to be more frequently covered) in the social sciences than, for instance, subatomic physics.

For the purpose of the present study, findings will not be presented as a proportion of publications including the gender dimension for each domain. Instead, the global proportions (i.e. for the world in the bibliographic database of scientific papers used for computing the indicator [23]) have been established as the reference level and set to a value of 1.00. Accordingly, a score of 1.10 shows that research from the country in question integrates a gender dimension 10 % more often than the

[22] The proportion of scientific papers accounting for the biological characteristics or the social and cultural features of both women and men (Campbell et al., 2016).

[23] The Web of Science™ (WoS) database produced by Thomson Reuters was used.

global norm, while a score of 0.90 shows that research from the country in question integrates a gender dimension 10 % less often than the global norm. These scores have been weighted to accommodate the different levels of relevance of gender dimensions across domains of research, so that a country publishing many papers in physics will not be penalised for integrating the gender dimension less frequently than a country publishing many papers in social sciences, where gender dimension is more relevant and therefore integrated more frequently[24]. Note that this indicator does not capture the integration of the gender dimension in R&D policies and programmes; it only captures this aspect within the outputs of research projects (i.e. in scientific publications). Additionally, this indicator is affected by a question of 'optimum' (see Table 2). For instance, what is the appropriate/adequate level of integration of the gender dimension in research projects? Obviously, this level varies across fields of research and can be difficult to establish. The present indicator uses the world level by scientific subfield as the baseline value for comparative purposes. However, this value is likely below the optimum. Refer to the 2018 ERA Monitoring Handbook for further details on the computation of this indicator. Full results are presented in Table 16.

As a starting point for interpretation, it is worth recollecting the global tendencies to integrate a gender dimension into research content, as these are the reference value against which scores are compared in the present report. As outlined in the *She Figures 2015* report (for the 2010-2013 period; see Table 7.10 in European Commission & Directorate-General for Research and Innovation, 2016c), approximately 0.2 % of publications in the natural sciences took into account the biological characteristics or the social and cultural features of both women and men, while roughly 0.1 % of publications in engineering & technology did, as did 3.9 % of scientific articles in the medical sciences, 0.0 % of publications in agricultural science, 7.2 % of publications in the social sciences, and finally 3.9 % in the humanities. These findings can help to give some perspective on the degree to which the gender dimension is integrated, at least in terms of order of magnitude as well as differences across the domains of science all over the world.

EU-28 Member States' researchers have moderately increased their attention to gender dimensions since the last ERA monitoring exercise with an average annual growth measured at 2.5 % from 2011–2014 to 2014–2017 (data for this indicator is presented using 4-year moving averages). The EU-28 score has actually gone up, from 0.97 for the 2011–2014 period examined in the last report, to 1.05 in the recent period (2014–2017). This is an improvement over the longer-term growth (from 2007–2010 to 2014–2017) that has been negligible (CAGR of 0.3%) due to a decrease in 2011–2014. Notable performances that contributed to recent growth on this indicator include Bulgaria (48 % average annual growth), Romania (37 % CAGR) and Luxembourg (30 % CAGR).

There have been quite a number of shifts in country positions on this indicator since the last monitoring exercise, with 27 out of 44 countries changing ranks by at least three positions from 2011–2014 to 2014–2017. Romania, the most performing country in this edition, previously held the 20th rank. Bosnia and Herzegovina, Estonia, Luxembourg and Bulgaria all moved up by at least 20 places (for Bosnia and Herzegovina, one can see from the longer-term trend that its strong growth is due to a punctual decrease in 2011–2014 rather than to a stable trend). On the other hand, Tunisia, Serbia and Greece dropped by more than 20 places.

Aside from Romania, the group of most performing countries (Cluster 1) was made up of Slovenia, Turkey, Bosnia and Herzegovina and Slovakia. The sizes of the two most performing groups (Cluster 1 and 2) were roughly similar to that of the two least performing ones (Cluster 3 and 4), at 20 and 24 countries respectively. The country groups immediately above and below the unweighted ERA average (Cluster 2 and 3) were particularly large for this indicator. Such a distribution of the scores is indicative of low inequalities driven by convergence around the ERA average; the ERA average (1.05), relative to indicators revealing strong country inequalities, stood near the mid-range of observed values for this indicator (0 to 2.72). This is confirmed by a relatively small Gini coefficient of 0.261 in 2014–2017.

ERA economic weight was quite concentrated in Cluster 3 with countries just below the ERA average. This group of 17 (out of 37) countries accounted for almost 76 % of ERA GDP. It included four large economies, France, Germany, Italy and the UK. Cluster 1, in contrast, was made up of two middle and three small economies. Excluding Cluster 4, there is in fact a very weak negative correlation between the size of economies (GDP) and their performance on this indicator (*Pearson r* = -0.20).

[24] Note also that as scores on this indicator can sometimes fluctuate strongly year-over-year, especially for countries with a relatively small annual publication output, the scores for this indicator are computed on 4-year rolling windows. The reference years are 2011-2014, and the individual bars of the trendlines refer to 2005-2009, 2006-2010, 2007-2011, and so on up to 2011-2014.

While the inequalities between countries appeared to be small in terms of integration of the gender dimension in research content, short-term growth rates (from 2011–14 to 2014–17) suggest that an increase in the inequalities might be slowly building up. Indeed, Cluster 1 showed an unweighted average annual growth of 14.5 %, and this figure decreased linearly moving towards Cluster 4, which obtained an average annual decline of 15.9 %.[25] Contrary to this finding, the trend in Gini coefficient, as well as in the standard deviation of the scores, rather suggest a recent decline of inequalities which is also valid in the longer-term trend. This latter result is consistent with the longer-term growth patterns across performance clusters (i.e. higher average growth for countries below rather than above the ERA average). We therefore conclude that inequalities in the integration of the gender dimension in research content were slowly declining. This conclusion is reinforced by the fact that scores on this indicator are quite volatile, for a given country, from year-to-year. Accordingly, long-term growth figures are perhaps to be favoured over short-term ones.

[25] Countries with the strongest declines in the groups of least performing countries included Moldova (54 percentage points gap to EU-28 average annual growth), Armenia (37 points gap) and Tunisia (25 points gap). Slovakia and Lithuania, otherwise placed in the groups of most performing countries, also experience sizable annual average decreases in score in the recent period.

Table 16 Gender dimension in research content (2007–2014)

Country	Weight in GDP	Score (2014-17)	CAGR			
			Short-term (2011-14 to 2014-17)	Lead/Gap to EU-28 CAGR	long-term (2007-10 to 2014-17)	Trendline (2007-10 to 2014-17
EU-28		**1.05**	**2.5%**	**N/A**	**0.3%**	
Cluster 1	6.5%	2.12	14.5%	12.0	4.1%	
Cluster 2	17.6%	1.22	5.9%	3.4	0.6%	
Cluster 3	75.8%	0.88	-0.6%	-1.8	3.9%	
Cluster 4	0.1%	0.26	-15.9%	-25.0	3.6%	
Cluster 1						
RO	1.0%	2.72	36.9%	34.4	-0.6%	
SI	0.2%	2.21	18.1%	15.6	20.5%	
TR	4.7%	2.11	3.7%	1.2	1.0%	
BA	0.1%	1.91	31.2%	28.7	-5.7%	
SK	0.5%	1.65	-17.3%	-19.8	5.4%	
Cluster 2						
HU	0.7%	1.51	-0.1%	-2.6	-11.4%	
PT	1.1%	1.50	-7.4%	-9.9	11.7%	
IS	0.1%	1.45	4.8%	2.3	1.8%	
EE	0.1%	1.27	23.3%	20.8	2.7%	
LT	0.2%	1.26	-21.8%	-24.3	-9.1%	
SE	2.8%	1.25	-2.0%	-4.5	-7.4%	
HR	0.3%	1.24	9.3%	6.8	-1.1%	
NO	2.0%	1.17	0.7%	-1.8	-3.2%	
FI	1.3%	1.16	-4.1%	-6.6	-1.0%	
DK	1.7%	1.10	0.7%	-1.8	-0.7%	
IL	:	1.10	-6.4%	-8.9	1.0%	
LU	0.3%	1.10	32.5%	30.0	13.0%	
ES	6.7%	1.08	8.4%	5.9	1.9%	
MT	0.1%	1.08	2.0%	-0.5	6.4%	
BG	0.3%	1.07	48.3%	45.8	5.3%	
Cluster 3						
NL	4.2%	1.05	-1.3%	-3.8	-0.4%	
CH	3.6%	1.04	-0.2%	-2.7	3.8%	
IT	10.0%	1.04	10.2%	7.7	3.8%	
UK	14.4%	1.03	-2.8%	-5.3	-1.0%	
AT	2.1%	1.02	1.3%	-1.2	-1.7%	
PL	2.5%	1.01	-9.3%	-11.8	1.3%	
LV	0.1%	0.98	14.7%	12.2	8.3%	
BE	2.5%	0.95	-6.5%	-9.0	-4.7%	
EL	1.0%	0.92	-17.8%	-20.3	-0.5%	
CZ	1.1%	0.91	1.7%	-0.8	7.4%	
DE	18.8%	0.89	6.7%	4.2	1.2%	
CY	0.1%	0.88	10.4%	7.9	3.7%	
RS	0.2%	0.81	-17.0%	-19.5	1.5%	
TN	:	0.75	-22.7%	-25.2	-8.9%	
FR	13.3%	0.73	2.8%	0.3	1.2%	
ME	0.0%	0.70	22.1%	19.6	57.8%	
IE	1.6%	0.62	-8.6%	-11.0	-0.2%	
MK	0.1%	0.56	6.1%	3.6	-2.0%	
Cluster 4						
GE	:	0.39	22.5%	20.0	9.3%	
AL	0.1%	0.37	-17.6%	-20.1	-12.3%	
UA	:	0.35	1.5%	-1.0	34.6%	
FO	:	0.34	:	:	:	
AM	:	0.09	-34.4%	-36.9	12.7%	
MD	:	0.01	-51.4%	-53.9	-26.1%	

Note: Note: A four-year rolling window was applied in order to maximise the number of countries covered as well as to minimise the impact of the strong yearly fluctuations of this indicator on the analysis of growth. Due to very large fluctuations, the following data were not included in the computation of this indicator: AL(2011), FO(2014-2015), LV(2015), MK(2013) and MT(2011). Therefore, the windows associated with the combination of these countries and years are less than four years.
For more details on the methodology, please refer to the companion Handbook.
(:) = missing data

Source: Computed by Science-Metrix using WoS data (Clarivate Analytics).

Share of female PhD graduates (2013–2016)

As was the case for the Headline indicator on the share of women researchers in Grade A positions, the second complementary EMM indicator — the share of female PhD graduates to the total number

of PhD graduates — aims to monitor progress in achieving gender balance in research careers. However, it captures the state of play at a much earlier phase in the career progression (i.e. at the entry phase). Paired with the Headline figure, this indicator is relevant to monitor progress towards 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). Note that this indicator is affected by the same 'balance' issue as the Headline indicator (see Table 15). Here again, shares in the range from 40 % to 60 % were considered as reflecting gender parity. Results for this indicator are presented in Table 17.

Growth in country shares of female PhD graduates has generally been slow since the last ERA monitoring exercise. However, this is to be expected since the EU-28 was already close to perfect parity (assuming a proportion of women of 50% in the general population) back in 2013. A figure very different from that observed at higher echelons of academic careers (see Table 15). On average at the EU-28 level, 48 % of PhD graduates were women in 2016, up by less than 1 % since 2013.

Shifts in country rankings since the last Report have been both numerous and quite large for this indicator. Out of the 42 countries for which a score is available both in 2013 and 2016 (imputed by a maximum lag of one year), 21 had shifted by more than three positions, and 5 by more than 10. Malta, Tunisia and Estonia had all lost at least 14 places in the ranking. This is consistent with the largest decreases in scores observed for Malta (6.8 % average annual decline from 2013 to 2016), Tunisia (CAGR = -3.9 %) and Estonia (CAGR = -3.0 %). Of these three countries, only Malta got closer to the bottom limit of the gender parity range (i.e. 40 %) on this indicator in 2016; the other two are still at parity. On the other hand, Cyprus and Serbia had both advanced by at least 14 positions with some of the highest average annual growth (CAGR of 5.8 % and 6.4 %). Despite these changes, both countries scored near parity in both 2013 and 2016.

Scores in share of female PhD graduates were mostly found on a relatively narrow range of values of between 40 % and 60 %; i.e. within the current report's range considered to reflect gender parity. With 68 % and 64 % of female PhD graduates, Montenegro and Iceland scored so highly on this indicator that they actually fell outside the parity range. Armenia did so at the other end of the spectrum with 37 % of female PhD graduates. This questions the report's comparative approach when most countries have reached the optimal target as in this case. Nevertheless, even though countries were clustered using the same approach as for the other indicators in this report, we will avoid comparing them in terms of best and least performers since being slightly above the target (e.g. 55 %) is neither better nor worse than being slightly below it (e.g. 45 %). The grouping of countries in the four performance clusters resulted in a distribution of countries that closely followed a normal distribution. There was an equal number of countries above and below the ERA unweighted average (51 %) which was almost perfectly at the mid-range of observed values for this indicator (37 % to 68 %). Such a distribution of scores is often indicative of low inequalities across countries which is supported, in this case, by a very small Gini coefficient in 2016 (0.068).

The economic weight of countries was mostly found among the lower end of the scale on this indicator. The two country groups below the unweighted ERA average (Cluster 3 and 4) accounted for 75 % of the ERA countries' combined GDP. Cluster 1 was composed of five small economies, which together took up less than 1 % of GDP. The five large economies were distributed across the remaining three country groups.

As reported above, the inequalities between ERA countries on their shares of female PhD graduates were very low in 2016 (Gini = 0.068), remaining roughly unchanged since 2013 (0.070). Altogether, it seems that there are few inequalities in the share of female PhD graduates across ERA and that parity has broadly been achieved on this dimension; a result that has still not been reached at the higher echelons of academic careers. Additionally, it is worth mentioning that horizontal segregation between disciplines persists even at the entry stage of an academic career. For example, while there were roughly 50% of women PhD graduates in 2012, women remained under-represented in some areas such as in engineering, manufacturing and construction (EC and DG-RTD, 2016c; for more recent data, refer to the forthcoming She Figures 2018 publication).

Table 17 Share of female PhD graduates (2013–2016)[26]

Country	Weight in GDP	Score (2016)	CAGR (2013-16)	Lead/Gap to EU-28 CAGR	Trendline
EU-28		**48%**	**0.4%**	**N/A**	
Cluster 1	0.9%	61%	2.7%	2.2	
Cluster 2	17.5%	55%	0.6%	0.1	
Cluster 3	74.5%	47%	0.5%	0.1	
Cluster 4	7.2%	41%	0.5%	0.1	
Cluster 1					
ME	0.0%	68%	:	:	
IS	0.1%	64%	*3.0%*	2.6	
SI	0.2%	61%	4.5%	4.1	
CY	0.1%	60%	6.3%	5.8	
LV	0.1%	58%	0.2%	-0.2	
LT	0.2%	58%	-0.7%	-1.1	
Cluster 2					
MD	:	57%	-1.9%	-2.3	
GE	:	57%	2.0%	1.5	
UA	:	57%	0.0%	-0.5	
MK	0.1%	56%	1.2%	0.8	
AL	0.1%	56%	0.6%	0.2	
PT	1.1%	55%	0.0%	-0.4	
HR	0.3%	55%	0.2%	-0.3	
RS	0.2%	55%	*6.9%*	6.4	
RO	1.0%	55%	1.6%	1.1	
EE	0.1%	54%	-3.0%	-3.5	
PL	2.5%	54%	-0.7%	-1.2	
BG	0.3%	53%	1.0%	0.6	
SK	0.5%	52%	0.6%	0.2	
IT	10.0%	52%	-0.1%	-0.6	
FI	1.3%	52%	0.6%	0.2	
Cluster 3					
ES	6.7%	51%	0.6%	0.2	
NO	2.0%	50%	1.6%	1.1	
IL	:	*50%*	-2.4%	*-2.8*	
EL	1.0%	49%	2.8%	2.4	
NL	4.2%	*49%*	3.1%	*2.6*	
DK	1.7%	48%	2.4%	2.0	
TN	:	48%	-3.9%	-4.4	
IE	1.6%	48%	-0.7%	-1.1	
HU	0.7%	47%	0.4%	0.0	
BE	2.5%	47%	3.1%	2.6	
TR	4.7%	46%	*-1.5%*	-1.9	
UK	14.4%	46%	-0.2%	-0.6	
SE	2.8%	45%	-0.6%	-1.1	
DE	18.8%	45%	0.7%	0.3	
BA	0.1%	45%	2.3%	1.9	
FR	13.3%	45%	0.5%	0.1	
Cluster 4					
CH	3.6%	44%	0.4%	0.0	
CZ	1.1%	43%	-0.1%	-0.5	
AT	2.1%	42%	-1.1%	-1.5	
MT	0.1%	41%	-6.8%	-7.2	
LU	0.3%	40%	1.0%	0.5	
AM	:	37%	9.7%	9.2	

Note: Definition differs: EU28 (2015, 2016)
Exception to reference year: NL (2015); IL (2015)
Exception to reference period: 2013-2015 (NL, IL); 2014-2016 (IS, RS, TR)
Data unavailable: FO
(:) = missing data

Source: Computed by Science-Metrix using Eurostat data (online data codes: educ_uoe_grad02) and UNESCO data (Tertiary graduates by level of education) for AL, BA, AM, GE, IL, MD and UA.

[26] For Ireland, we consider 48% to be the 2015 data, while the correct data for 2016 is 51.5%. This correction of Eurostat data arrived after the report was prepared for publication and therefore is mentioned in the footnote.

Comparing Headline to complementary EMM indicators

A weak correlation (*Pearson r* of 0.25) was found when comparing country performances on the Headline indicator (share of Grade A positions held by women in the higher education system) with those on the inclusion of gender dimension in research content. This is not necessarily surprising as the two indicators are designed to capture different phenomena: gender equality in academic careers on the one hand, and accounting for gender differences in resolving research questions on the other hand. A stronger but still moderate correlation was found between the Headline indicator and the share of female PhD graduates (Pearson *r* of 0.45). Here, on the contrary, one would expect a high correlation if progress towards gender equality were uniformly distributed across the academic ladder. The study results demonstrated that while gender parity was nearly reached by all ERA countries at the entry stage of an academic career, women remain largely under-represented in higher academic echelons (i.e. based on the Headline indicator). The complementary EMM indicators are therefore highly relevant to draw relevant conclusions towards the question of gender equality in research. In fact, additional indicators would be warranted to obtain a more complete picture of the situation, many of which can be found in the forthcoming She Figures 2018 report. For example, it is worth mentioning that while women PhD graduates were nearly as represented as men in 2012, women remained under-represented in some areas such as in engineering, manufacturing and construction (EC and DG-RTD, 2016c). Accordingly, horizontal segregation remains an important issue at the entry stage of an academic career, especially in STEM fields.

3.4.4 Additional policy highlights

Gender in research programmes and training: Based on the qualitative data, RFOs in Austria, Germany, Spain, Finland, Ireland, Italy, Norway and Sweden have implemented measures regarding gender equality for scientists and/or the integration of the gender dimension in research content in their evaluation criteria. Regarding the integration of a gender dimension in research content and/or teaching, even though few countries have implemented policies to promote it (Belgium, Czech Republic, Spain, France, Croatia, Hungary, Portugal, Slovenia, Finland and the UK), in most ERA countries universities and accreditation agencies have been identified as key actors for mainstreaming gender analysis in curricula (Austria, Belgium, Switzerland, Czech Republic, Germany, Estonia, Spain, Finland, Croatia, Israel, Iceland, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Sweden, Slovenia, Turkey, the UK) (EIGE, 2016b). Turkey in particular has achieved major progress in terms of including the gender dimension in research content and in Cyprus, France and Romania, the government became an essential partner in the inclusion of gender mainstreaming in teaching and research (EIGE, 2016b).

Gender action plans/policies: Qualitative data documented higher adoption of Gender Equality Plans (GEPs) and related policies financed either at national or EU level. For example, in Germany, RPOs are obliged by law to adopt GEPs, while in Austria the obligation applies only to universities. From 2016, Flemish universities adopted their first official monitoring of GEPs. In the UK through the Athena SWAN Charter, over 400 local-level GEPs were adopted and 731 awards distributed. Recently, France took legal measures adopting an integrated and transversal approach to gender in research, mirroring the one promoted at EU level. In 2016, EIGE in cooperation with the EC developed a very comprehensive and practical Gender Equality in Academia and Research (GEAR) online tool[27] to inform and guide RPOs setting up and implementing Gender Equality Plans, which builds on existing good practices across Member States and Associated Countries, many of them developed through EC-funded GEPs-related projects. RFOs in almost all ERA countries promote the adoption of gender action plans and in Estonia, Luxembourg, Slovenia, Finland and the United Kingdom RFOs take into account gender equality when granting funds. For example, the United Kingdom Research Council integrated the assessment of gender equality policies in its research excellence framework to accede funding and the National Institute for Health Research includes scores in the Athena SWAN charter as eligibility criteria for funding (EIGE, 2016b). A higher number of countries are trying to improve transparency in recruitment, promotion and appointment and including such initiatives in their NAPs. However, progress is still needed in order for it to become an integral element of human resources strategies (EC, 2018a).

Wage Gap: Reduction in gender pay gap remains uneven among ERA countries and therefore one of the key priorities at both EU and national levels. The strategic engagement for gender equality 2016-2019 adopted by the European Commission highlights 'reducing the gender pay, earnings and pension gaps and thus fighting poverty among women' as one the key priorities of the framework.

Figure 5 illustrates the unadjusted gender pay gap in 2014, providing an overall picture of gender inequality in hourly pay in the total economy and for those working in the scientific R&D field. It represents the difference between the average gross hourly earnings of men and women, expressed

[27] https://eige.europa.eu/gender-mainstreaming/toolkits/gear

as a percentage of average gross hourly earnings of men. Gender pay gap in favour of men can be observed in all ERA countries (except Turkey) for the whole economy and an even wider pay gap was found for scientific research and development activity in the majority of countries. Considerable differences regarding gender pay gap between ERA countries can be observed in both, the whole economy and within scientific research and development services. For the whole economy, the gap ranged from below 7%, in Romania, Luxembourg, Italy and Belgium; from 10% to 15% in countries such as Malta, Lithuania, Hungary and France; between 18% to more than 20% in the UK, Austria, Germany, and Finland, reaching 28.1% in Estonia. Consequently, the Estonian government has put forward a series of measures (e.g. promoting wage transparency, increased access to childcare, etc.) to address gender pay gap in the country and included gender equality objectives in the Welfare Plan 2016-2023. The Finnish government equality programme for 2016-2019 also includes measures to reduce the wage gap between men and women. Within scientific R&D activities, in Italy, Lithuania and Slovenia men earned from 3.5% to 6.5% more than women, while in Norway, Belgium, Latvia and Sweden the gap is higher than 15% in favour of men. Ireland and Turkey had the highest pay gaps with women's average gross hourly earnings being at least 30 % lower than those of men.

As can be observed in Figure 5, a small number of countries (Macedonia, Romania, Luxembourg, Bulgaria and Serbia) had a negative gender pay gap for scientific R&D activities, meaning that on average women were paid more than men. Results illustrated in the graph do not provide a detailed account of the current situation in ERA countries and do not account for other factors or characteristics that can explain such differences. Factors such as the lack of competitive and stable remuneration in scientific R&D activities in those countries can explain the high proportion of women in the sector. Furthermore, women working in scientific R&D mostly engage in social sciences and humanities which are considered to be the non-profitable sciences and not related to access to public resources. Finally, it is also important to highlight the most extreme differences (more than 30%), registered between the gender pay gap in the scientific R&D and total economy, in Macedonia and Turkey. Even though in opposite directions, both countries had the most pronounced gap between earnings of female and male employees in scientific research and development and in the whole economy.

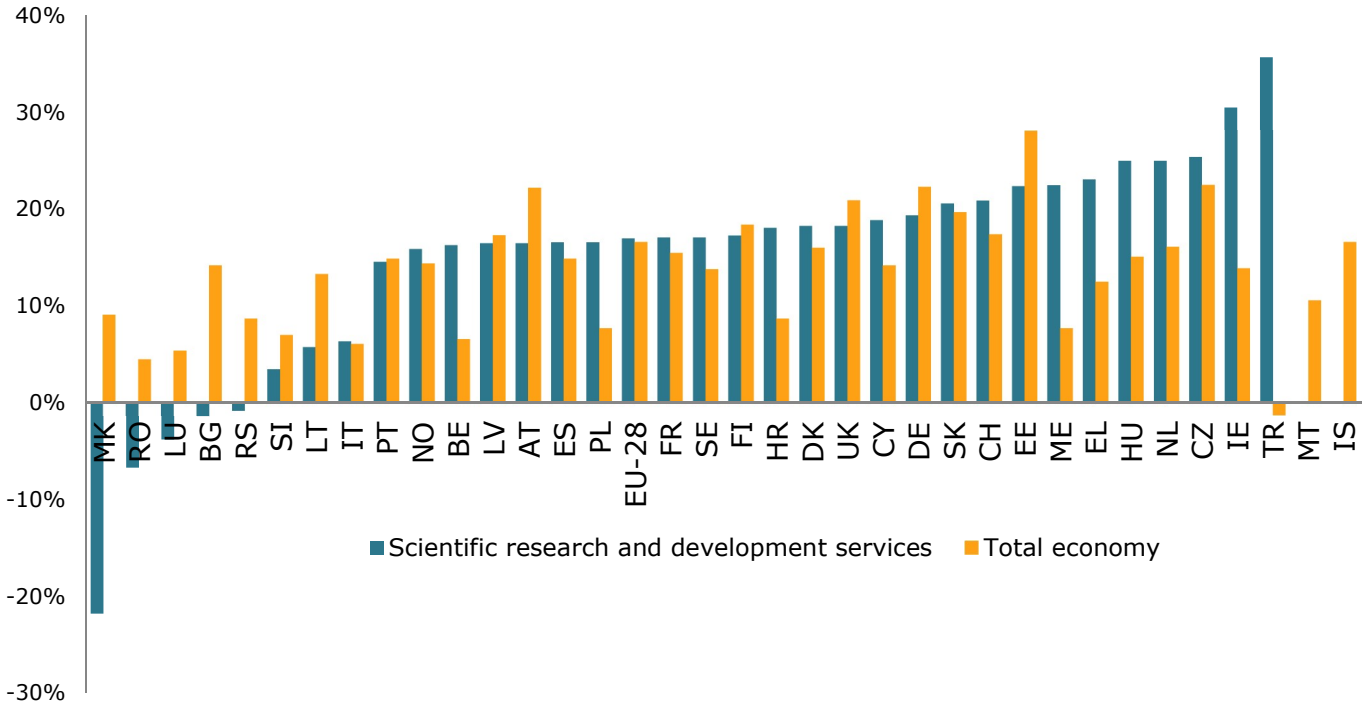

Figure 5 Gender pay gap (%) in 'Scientific research and development' and in the total economy (2014)

Note: Reference year: 2014 (latest available data from SES); Data unavailable for: MT, IS (Sci. R&D services).

Others: Data are unavailable for MT and IS for economic activity 'Scientific research & development;' EU-28 calculation for Sci. R&D services does not include MT as no data were available; Scientific research & development services ('Sci. R&D services') is based on NACE Rev. 2 Division 72; Total economy is based on NACE Rev. 2 Sections B to S excluding O (public administration and defence; compulsory social security); Data were computed by Eurostat (NACE 72 data are not available online).

Source: Eurostat – Structure of Earnings Survey (SES) (custom extraction based on online data code: earn_ses14_12).

Resources for career progression: The literature review revealed that several initiatives, programmes and policies have been adopted to promote the enrolment and retention of women in science. In France and Spain work-life balance was made explicit in policy documents (EIGE, 2016c) and in Malta the adoption of work-life balance related measures has increased (e.g. extension of maternity leave allowance, additional free childcare centres, etc.) and the National Commission for the Promotion of Equality (NCPE) launched a variety of projects aimed at fighting gender stereotypes. Work and life balance measures and initiatives are crucial to enhancing equality in research careers. Family characteristics have a disproportionate effect on women's careers (Mason et al., 2013; Science Europe, 2017a) (e.g. single women and women without children are more likely to advance in their academic careers when compared to women with children). Female researchers with children also seem to miss out on other opportunities that would benefit their career advancement, such as mentoring, networking, and that can ultimate impact their career (Howe-Walsh et al., 2016; Science Europe, 2017a). RFOs and RPOs in different ERA countries have adopted measures to increase work-life balance for researchers. In Switzerland an extension of the contract due to maternity leave is not guaranteed if the researchers work under fixed-term contracts, the Swiss National Science Foundation (SNSF) has introduced mobility grants (early and advanced postdocs) for new fathers where they can be granted paid paternity leave of up to four months in the course of a fellowship. Some RFOs allow for the extension or suspension of fellowships during parental-related leaves. For example, the Research Foundation Flanders (FWO) allows PhDs and postdoctoral fellowships to be suspended during pregnancy/maternity or parental leave, in which case a no-cost extension is automatically granted. Fellowships granted by the German Research Foundation (DFG) can be extended by three months for new mothers, based on the three-month national statutory maternity leave and research fellows with children can also extend their fellowships for up to 12 months. Additionally, grant holders can reduce working hours up to 50 % due to family reasons. The Research Council UK and Science Foundation Ireland provide additional funding to RPOs to supplement statutory maternity pay to 100 % of the employee's salary.

Gender balance in decision-making: The low representation of women in decision-making bodies together with unconscious/implicit bias in evaluation remains a central factor for gender inequality. Funding programmes for women are not equally viewed and adopted and can even face legal barriers

in some countries due to schemes being perceived as disadvantageous to male researchers (Science Europe Working Group on Research Careers, 2016). Nevertheless, positive results have been identified as a consequence of initiatives and programmes adopted in different countries. Montenegro has promoted female participation in decision-making processes, having a good representation of women as deans, directors and rectors of RPOs. The German Federal Ministry of Education and Research has been implementing the Federal Programme for Women Professors ("Professorinnenprogramm") since 2008, which continues to demonstrate effective and positive results, for instance the increase of tenured female professors. Its approach is twofold: higher education institutions submit gender equality plans and if positively assessed, the institution is granted funding for up to three professorships held by women for the course of five years. To tackle unconscious bias, the Swedish Research Council uses reports from the gender equality observation panels to train review panels, on decision-making bodies, and research council staff. In 2016, Science Foundation Ireland held unconscious bias trainings and the results led to changes and improvements in different processes: the incorporation of a gender initiative under the Starting Investigator Research Grant (SIRG) Award Programme, ensuring that half of eligible applicants are women, led to an increase of women applicants and female awardees.

Main findings

1. Policies and initiatives at EU, country and institutional level have been adopted to tackle inequality issues such as unconscious gender biases, integration of the gender dimension in research programmes and training and promoting programmes and resources for equal opportunities in career progression. Positive results have been identified as a consequence of such initiatives and programmes across ERA countries.
2. Despite some progress towards gender equality in research and innovation, gender inequality in research and academia is still evident. Efforts towards increasing the enrolment and retention of women in science, implementation of work-life balance policies, reducing gender pay gap and removing obstacles to women's career progression are still needed in order to achieve gender equality and gender mainstreaming in the ERA.
3. Gender parity was nearly reached by all ERA countries at the entry stage of an academic career. The aggregate score for EU-28 Member States remained mostly unchanged for the share of women in Grade A positions in the higher education sector and for the share of female PhD graduates since the last ERA monitoring exercise, however. Therefore, a glass ceiling effect still persists in ERA countries, as gender parity remains at early stages of research career (balance between men and women among doctoral graduates) and decreases as women move up the academic career ladder.
4. Recent growths in the share of women in Grade A positions in the higher education sector have tended to be achieved by strong performers, showing that inequalities are increasing. The group of most performing countries (Cluster 1) has seen growth of 10.1 % over the 2014 to 2016 period, far above the other country groups at 3.9 % (Cluster 2), 1.5 % (Cluster 3) and -1.2 % (Cluster 4). This has translated in a Gini coefficient that went up from 0.169 in 2014 to 0.182 in 2016.

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

3.5.1 Policy context

Sub-priority 5a

Knowledge transfer is a driver for modernising the economy and the implementation of policies and initiatives that support it have proven to be very beneficial. However, much closer cooperation between business and academia is needed across ERA countries. A combination of financial incentives and supportive regulatory frameworks are identified as essential factors to strengthen collaboration between industry and academia (European Semester Country-Specific Recommendations, 2016). At European level, FP7 and Horizon 2020 enhanced intersectoral research mobility and contributed towards commercialisation of research results which was otherwise not possible at national or regional level alone (EC, 2017b). R&I policies directed at companies and general economic context

also seem to influence mobility schemes for researchers in the private sector, indicating that availability of tax incentives for research and development activities increase the number of such schemes (EC, 2018b).

More schemes and initiatives regarding open innovation and knowledge transfer are being adopted across ERA countries, with a specific focus on joint participation of public research organisations and the private sector. Different ERA countries are now adopting regulatory frameworks for protecting intellectual property (Ireland, Greece and Montenegro). Nevertheless, diverse IP rules are still applied across countries, for example in specific domains such as life science or pharmaceutical research, Swedish and Norwegian researchers and inventors can benefit from individual ownership of the invention. Whereas in countries like the UK and Ireland, employer organisations or institutions in principle hold IP rights (Science Europe, 2017b). Progress in Sub-priority 5a has been noted with an increase in the collaboration of product or process innovative firms with academia. A decrease of funding contributions from the private sector to publicly funded R&D, however, has also been observed over the last few years.

Sub-priority 5b

Open access to publications is a policy either widely implemented or at least discussed (for example, Montenegro, Slovakia, Romania) across ERA countries. The literature review indicates significant progress, with some countries having adopted legal measures on OA, OS and open data practices (see Table 18 for more information). However, even in countries where legal measures have been adopted, its enforcement varies greatly.

Disparity in the implementation of OA policies among countries and fields is also reflected in the type of OA preferred among countries. Examples are the 2014 clause for secondary publication of the German Act on Copyright and Related Rights, which allows third-party funded researchers to self-archive their work under certain conditions, and the 2016 French Law for a Digital Republic Act, which created a new right for researchers to self-archive their work even if they had previously granted exclusive rights to the publisher as well as ensuring rights to Text and Data Mining. Widespread OA to publications is considered to convey considerable economic, social and academic benefits (Tennant et al., 2016). The type of open access promoted varies across ERA countries, some show a tendency to promote gold OA (Hungary, Netherlands, Romania, Sweden, the United Kingdom) while the rest of the countries encourage the green route (self-archiving in repositories) (Belgium, Cyprus, Denmark, Estonia, Greece, Ireland, Lithuania, Malta, Norway, Portugal, Slovakia, Spain), or a combination of both (Austria, Bulgaria, Croatia, Czech Republic, Finland, France, Germany, Israel, Italy, Latvia, Luxembourg, Poland, Slovenia, Switzerland).

In the case of Research Data Management (RDM), policies have generally been introduced more recently. However, an increasing number of countries have adopted them, and policies adopted by different RFOs in ERA countries are generally in line with the Commission's policy. Greater coordination and harmonisation across countries is still needed. A range of challenges preventing full move to an Open Science environment remains, including copyright, licensing policies, costs, data privacy, perceptions of lower quality of OA journals, complexities of embargo, insufficient training on OA, publications organisations/employers encouraging publication in traditional, nonetheless the hardest one to overcome might be the cultural change (LERU, 2018b).

Table 18 Presence or absence of legal and non-legal measures/policies on OA across ERA countries

Country	Presence of specific laws related to OA provisions, RDM and OS	Research data	Research publications	Presence of Non-legal policies/guidelines on OA, RDM or OS	Research data	Research publications	Most recent non-legal Policies/guidelines
Austria	Yes	Yes	Yes	Yes	Yes (2012)	Yes (2012)	Recommendations by Open Access Network Austria (OANA) and Universities Austria on Transition to Open Access in Austria and the call for scholarly publications to be OA by 2025 (Gold OA). Active development of data management policies by national research institutions, but the process is not formalised.
Belgium	Yes	Yes	Yes	Yes	Yes	Yes (2007)	The Belgian Federal Science Policy office (BELSPO) Open Access Policy promotes gold and green OA routes for scientific publications. No national or regional policies and guidelines related to research data management adopted yet.
Bulgaria	No	No	No	Yes	Yes (2013)	Yes (2006; 2010; 2011)	National Strategy for Development of the Scientific Research in the Republic of Bulgaria adopted in 2016 recommends green OA for publishing results of publicly funded research.
Croatia	Yes			Yes	Yes (2015)	Yes (2006)	In 2015 a digital infrastructure, Digital Academic Archives and Repositories (DABAR), was established as a key component of the data layer of the national e-infrastructure.
Cyprus	Yes	Yes	Yes	Yes	Yes (2013)	Yes	Cyprus adopted a National Policy for Open Access on the 25th February 2016.
Czech Republic	No	N/A	N/A	Yes	Yes	Yes (2010)	Recommendations on Open Access to Scientific Publications establish key areas on which the government and other stakeholders need to focus in promoting OA in Czech Republic. Czech National Strategy for Open Access to Research Information for 2017-2020 aims to promote OA, OS and open data.
Denmark	No	N/A	N/A	Yes	No	Yes (2012)	Denmark's National Strategy for Open Access supports the green OA route but also allows the gold route. The National Strategy for Data Management aims to ensure a better and more competitive research environment through efficient collection, security, dissemination, and re-use of relevant research data.
Estonia	Yes	N/A	Yes (2012)	Yes	Yes	Yes	The Ministry of Education and Research prepared the Estonian Research and Development and Innovation Strategy 2014-2020 'Knowledge-based Estonia' (R&D&I strategy). The Implementation Plan 2016-2019 sets out guidelines for the implementation of the actions foreseen in the strategy. The main indicator used for the assessment of progress in this area is the proportion of gold and green OA papers in Estonia.
Finland	No	No	No	Yes	Yes (2014)	Yes (2014)	Open science and research roadmap 2014–2017 is the main document guiding Finland's transition to OA and promotes both gold and green OA routes.
France	Yes (2016)	Yes	Yes	Yes	No	Yes (2013)	The National Research Agency (ANR) open access policy promotes green OA. Currently there are no national or regional policies and guidelines, or policies related to research data management.
Germany	Yes	No	Yes	Yes	No	Yes	The Federal Ministry of Education and Research (BMBF) strategy paper on Open Access in Deutschland. Both – green and gold types of OA are encouraged. Some regional governments have also adopted OA strategies. BMBF has not adopted a policy on research data management yet. OA is supported by the German rector's Conference (HRK) which has also adopted recommendations on the management of research data.
Greece	No	N/A	N/A	Yes	No	Yes	As of early 2016, only two HEIs had adopted an open access policy, the International Hellenic University (IHU) and the Technical University of Crete (TUC). IHU's open access policy, in effect since 10 October 2015, is mandatory for publications, while it encourages researchers to
Hungary	Yes (2012)	N/A	Yes	Yes	No	Yes (2012)	OA mandate of the National Research, Development and Innovation Fund (NRDI Fund) promotes gold OA. No guidelines on research data management have been adopted yet. Hungarian Academy of Sciences (HAS) OA mandate supports both the gold and green routes. No guidelines on research data management have been adopted by HAS.
Iceland	Yes (2003/2012)	N/A	Yes	Yes	No	Yes	The Science and Technology Council of Iceland signed the Berlin Declaration on the 27th of May 2010. In line with the Icelandic government's Policy on the Information Society 2004-7, the Ministry of Education, Science and Culture and The Science and Technology Policy Council have made statements that include support of Open Access.

Country	Presence of specific laws related to OA provisions, RDM and OS	Research data	Research publications	Presence of Non-legal policies/guidelines on OA, RDM or OS	Research data	Research publications	Most recent non-legal Policies/guidelines
Ireland	No	No	No	Yes	Yes	Yes	National Principles for Open Access Policy Statement favours the green OA model. Research data and its metadata should be deposited in a repository whenever feasible.
Italy	Yes (2013)	N/A	Yes	Yes	Yes (2013)	Yes (2013)	OA Policy of the Ministry for Education, University and Research calls for OA to publications and research data in line with the Horizon 2020 mandate. Both OA routes accepted. The Italian Rectors' Conference (CRUI) Guidelines on institutional OA policies for publications and research data promote both OA routes. The new set of 'Guidelines on RDM policy' is currently being drafted.
Latvia	No	No	No	Yes	Yes	Yes	Latvia has to move towards the principles set within 'Horizon 2020' on the policy of open access publications and research data, which state that in order to increase knowledge circulation and use, open access must be provided to research publications and data arising from research projects financed from public funds.
Lithuania	Yes	No	Yes	Yes	Yes (2012)	Yes (2012)	Lithuanian Research Council's Guidelines on Open Access to Scientific Publications and Data promote green OA. Data sharing is also encouraged and
Luxembourg	No	No	No	Yes	Yes (2013)	Yes (2013)	The National Policy on Open Access has been issued (although not yet adopted by the government). Green mode is preferred (but gold and hybrid also allowed). FNR (National Research Fund) Policy on Open Access accepts all types of OA, although hybrid is not recommended. The policy encourages depositing research data in data repositories that implement the FAIR principles.
Malta	No	No	No	Yes	N/A	Yes	Currently there are no national OA, OS or RDM strategies adopted in Malta. The University of Malta adopted an Open Access policy that recommends green OA.
Montenegro	No	No	No	No	No	No	Only those institutions participating in H2020 projects will use Horizon 2020 as an instrument for publishing their research according to Open Access Principles, this being a mandatory requirement. Namely, all projects receiving Horizon 2020 funding will have the obligation to ensure that any peer-reviewed journal article they publish is openly accessible, free of charge.
Netherlands	No	No	No	Yes	Yes (2013)	Yes (2012)	The Netherlands Organisation for Scientific Research (NWO) OA policy recommends gold OA. NWO Data Management Protocol stipulates the required data management practices (although no repository is specified). DMPs are required. National Plan Open Science (NPOS) aims to achieve 100% OA and addresses other aspects of RDM and OS.
Norway	No	No	No	Yes	Yes	Yes	Norwegian Government's national guidelines for OA to research articles support both gold and green OA. The Government aims to make all publicly funded research articles openly available by 2024. National Strategy on access to and sharing of research data states that publicly funded research data should be shared and reused more widely, research data must be as open as possible and as closed as necessary. The Research Council of Norway (RCN) Principles for Open Access to Scientific Publications promotes both types of OA. RCN's policy on Open Access to research data states that data should be made accessible as soon as possible. DMPs are required.
Poland	Yes	N/A	Yes	Yes	Yes (2015)	Yes (2015)	The document 'Directions of the development of open access to research publications and research results in Poland' promotes both types of OA. No strategy on RDM has been adopted.
Portugal	Yes (2016)	Yes	Yes	Yes	Yes (2014)	Yes (2014)	The Fundação para a Ciência e Tecnologia (FCT) adopted in 2014 a mandatory open access publications policy and a research data management sharing policy statement.
Romania	No	No	No	No	No	No	Open access in only encouraged in the national strategy for R&I 2014-2020.
Serbia	Yes (2014)	N/a	Yes	Yes (2018)	No	Yes	Serbia has adopted a national science policy on July 14th, 2018, called the 'Open Science Platform.'
Slovakia	No	No	No	No	No	No	Currently there are no national policies or guidelines on OA, OS or RDM in Slovakia. However, there are efforts at country level to initiate OA policy.
Slovenia	Yes	N/A	Yes	Yes	Yes	yes	The National Strategy for Open Access to Scientific Publications and Research Data in Slovenia for 2015-2020 promotes green OA. No explicit repositories recommended. The strategy requires DMPs and opening of the research data.

Country	Presence of specific laws related to OA provisions, RDM and OS	Research data	Research publications	Presence of Non-legal policies/guidelines on OA, RDM or OS	Research data	Research publications	Most recent non-legal Policies/guidelines
Spain	Yes (2016)	Yes	N/A	Yes	N/A	Yes	The Spanish Foundation for Science and Technology (FECYT) has published guidelines for the implementation of the requirement for open access. It allows both OA routes. No national policies or guidelines on research data management have been adopted.
Sweden	Yes	Yes	Yes	Yes	Yes	Yes (2010)	The Swedish Research Council (VR) develops criteria to assess the extent to which research data complies with the FAIR principles. VR Mandate on OA was adopted in 2010. Both routes are accepted.
Switzerland	Yes (2012)	Yes	Yes	Yes	Yes	Yes	The National Open Access Strategy promotes both types of OA. The strategy envisages that all publicly funded publications must be openly accessible by 2024. SNSF (Swiss National Science Foundation) Open Access Policy also accepts both types of OA. SNSF Open Research Data policy encourages research data sharing in a FAIR-compliant repository. DMPs are also required.
Turkey	No	No	No	Yes	N/a	Yes	The TUBITAK Science Archive will give open access to the output of every project supported by the agency.
United Kingdom	Yes	N/A	Yes	Yes	Yes (2013)	Yes (2012)	Higher Education Funding Council for England (Hefce) policy for open access requires OA to publications published after 1 April 2016. The Concordat on Open Research Data calls upon researchers to, wherever possible, make their research data open and usable within a short and well-defined period. DMP submission is recommended.

Source: Compiled by PPMI based on desk research.

The European Commission established two Working Groups related to OS. The Working Group on Rewards under Open Science provides recommendations to improve and remove obstacles for all researchers, assuring that they are recognised and rewarded for practising Open Science. The Working Group on Education and Skills under Open Science identifies and provides recommendations regarding OS skills to be obtained by the research community. The Commission is currently in the process of establishing two expert groups in H2020: the expert group on Future of Scholarly Publishing and Scholarly Communication will aim to assure an economically viable transition towards open access; and the expert group on Turning FAIR Data into Reality will advise on the operationalisation and facilitation of the transition to make FAIR (findable, accessible, interoperable and reusable/re-producible) data sharing a default for scientific research by 2020.

3.5.2 Headline indicator 5a – Knowledge circulation

Under Sub-priority 5a (knowledge circulation), the European Commission (2012) aims to foster the potential for knowledge transfer and open innovation between the public and private sectors across all ERA countries. Indeed, a higher rate of private firm engagement with public research and higher education institutions should better facilitate the transfer of research results to the market, in line with the goal of optimising the circulation of access to and transfer of scientific knowledge. In turn, this should help maximise the positive returns from public investment in research to the economic and social prosperity of European countries. As a proxy for measuring the willingness of private firms to collaborate with public research and higher education institutions, ERAC selected the share of product and/or process innovative firms cooperating with universities (as well as other higher education institutions), government, public or private research institutes as the Headline indicator for Sub-priority 5a. Because the community innovation survey (CIS) data on firms cooperating with universities, and on firms cooperating with government, public or private research institutes, were only available in their merged form for 2014, two distinct approaches were used in measuring performance and growth for this Headline indicator[28]. Performance in 2014 was assessed based on the share of firms cooperating with universities, government, public or private research institutes. The analysis of growth was divided into two sub-indicators: the share of firms cooperating with higher

[28] The data underlying the Headline indicator for Sub-priority 5a was gathered through two questions (one for cooperation with universities and one for cooperation with government, public or private research institutes) asked to firms in the CIS. Since Eurostat only provides aggregated data (i.e. the microdata on firms is not readily available), and because aggregated data combining the results from the above two questions are only available for 2014, it was not feasible to combine results from the above two questions in building the Headline indicator for earlier years. Indeed, this would have led to double counting of firms responding yes to the two questions (refer to the 2018 ERA Monitoring Handbook for further details on the computation of this indicator.

education institutions and the share of firms cooperating with Ggvernment or research institutes (in the public or private sector).

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. Also note that the above two sub-indicators do not distinguish between large and small firms; however, the former were more likely to partner with public research or higher education institutions given their R&D capacities (ERAC Secretariat, 2015a). Countries with a smaller share of large firms might, therefore, be disadvantaged due to economic structure bias. These indicators cover all forms of cooperation, not just the financial ones. For further details on the computation of this indicator, refer to the *2018 ERA Monitoring Handbook*.

This edition of the *ERA Progress Report* presents for the first time a score combining firm cooperation with higher education institutions, government, public or private research institutes
(
Table 19, Figure 6). For comparisons in scores since the last ERA monitoring exercise, findings for the two sub-indicators will be presented.

At the aggregate EU-28 level, for the year 2014, 15 % of firms were found to cooperate with either universities, government, public or private research institutes. Cooperation with universities and higher education institutions progressed slowly since the last ERA monitoring exercise with an average annual growth of 0.7 % for EU-28 in 2012-2014. Cooperation with government, public or private research institutes grew faster (CAGR of 4 %).

On the sub-indicator for industrial cooperation with universities, changes in country rankings have been quite pronounced, with 12 out of 31 shifts being more than 3 places in position. Lithuania lost 18 places in the ranking moving from 7th to 25th. Greece similarly dropped from 6th to 23rd place. Croatia went from 11th to 25th. These movements are in line with the computed average annual growth rates which all point towards pronounced decreases for these countries. Serbia moved up sharply, from last place (31st) to the 13th rank with an average annual growth rate of 139 %.

Considerable movement among country rankings was also recorded for firm cooperation with governmental, public or private research institutes, with 12 out of 26 countries seeing shifts in positions of more than 3 places (note that only countries with scores in 2012 and 2014 are considered). Lithuania slipped from 7th to 20th, Croatia from 9th to 22nd and Greece from 2nd to 14th rank. These changes are in line with the computed average annual growth rates which are all strongly negative for these countries. Estonia, Serbia and Turkey all moved up by more than 10 positions from 2012 to 2014 with average annual growth rates near 30 % for Estonia and Turkey (the CAGR is undefined for Serbia since it started from a share of 0 % in 2012).

Scores on the combined indicators were found in a narrow spectrum of performances, ranging from 5 % to 29 %. FYR Macedonia occupied the top spot by a good margin, with Austria, Finland, Belgium and Slovenia rounding out the most performing country group (Cluster 1). Latvia, Italy, Cyprus, Malta and Bulgaria obtained lowest scores for this indicator, with figures between 5 % and 8 %. The group of countries immediately below the unweighted ERA average (Cluster 3) was quite large with 14 countries. Given the restricted range of scores, this skew towards Cluster 3 (i.e. just below the ERA average) might be indicative of a fair degree of inclusion among ERA countries on this indicator; in fact, the ERA average (14.6 %) was near the mid-range of observed values (4.6 % to 29.3 %).

No correlation could be established between country-level scores on the combined indicator and GDP. Still, most of the ERA combined GDP is concentrated above the ERA average (i.e. 67 % in Cluster 1 and 2). The most performing group of countries (Cluster 1) was formed from small economies, together accounting for only a little more than 6 % of the included ERA combined GDP while including 15 % of the covered countries. Major economies such as the UK, Germany and France converged in the group of countries with scores just above the unweighted ERA average (Cluster 2) which, altogether, accounted for roughly 60 % of the ERA combined GDP despite including only 30 % of countries. The other large ERA economies, Spain and Italy, were found below the ERA average, respectively in Cluster 3 and 4. Cluster 3 is worthy of mention for including roughly 40 % of countries while accounting for only 22 % of ERA combined GDP.

Inequality appeared to be low between ERA countries on this indicator. No correlation of significance could be established between performance and growth. The Gini coefficient, a common metric used in economics to quantify inequalities in the wealth of various groups, was found to be low, at 0.219 on the combined indicator. For the industrial cooperation with universities, growth rates were higher for the country groups under the unweighted ERA average (average of 7.3 % for Cluster 3 and 4 combined) than for those above (1.2 % for Cluster 1 and 2 combined), pointing towards a reduction in country inequalities. Indeed, the Gini coefficient went from 0.279 in 2012 to 0.217 in 2014. Such

a clear pattern could not be found for the second sub-indicator. Nevertheless, the Gini coefficient went down from 0.321 to 0.280. However, note that in that case many countries were not accounted for due to missing data.

Table 19 Share of product and/or process innovative firms cooperating with universities, government, public or private research institutes (2012–2014)

Country	Weight in GDP	Firms coop with univ, gov, res inst (2014)	CAGR (2012-14)			
			Coop with univ	Lead/Gap to EU-28 CAGR	Coop with gov, res inst	Lead/Gap to EU-28 CAGR
EU-28		**15.0%**	**0.7%**	**N/A**	**4.0% (w/o DE, IE, NL, SI, SE)**	**N/A**
Cluster 1	6.3%	25.0%	-4.1%		-3.9%	
Cluster 2	60.8%	17.0%	3.5%		7.1%	
Cluster 3	22.1%	12.0%	9.8%		-5.1%	
Cluster 4	10.9%	6.5%	1.0%		2.6%	
Cluster 1						
MK	0.1%	29.3%	:	:	:	:
AT	2.1%	24.6%	2.1%	1.4	-2.5%	-6.6
FI	1.3%	24.4%	-6.2%	-6.9	-11.6%	-15.6
BE	2.5%	23.3%	-0.9%	-1.6	2.4%	-1.6
SI	0.2%	23.3%	-11.5%	-12.2	:	:
Cluster 2						
IS	0.1%	19.1%	:	:	:	:
UK	14.5%	18.9%	-1.8%	-2.4	7.8%	3.7
NO	2.4%	18.8%	5.5%	4.9	-0.5%	-4.5
EE	0.1%	17.2%	15.9%	15.3	47.0%	43.0
DE	18.6%	16.8%	-0.6%	-1.2	:	:
SE	2.8%	16.7%	-6.7%	-7.4	:	:
NL	4.3%	16.6%	14.7%	14.1	:	:
DK	1.7%	16.3%	1.9%	1.2	-21.2%	-25.3
FR	13.7%	14.8%	2.5%	1.8	2.2%	-1.8
PL	2.6%	14.6%	0.2%	-0.5	7.3%	3.3
Cluster 3						
RO	1.0%	14.4%	57.5%	56.9	4.0%	0.0
SK	0.5%	13.9%	0.2%	-0.5	6.1%	2.1
ES	6.6%	13.7%	2.9%	2.2	13.7%	9.7
CZ	1.0%	13.7%	-8.4%	-9.1	-0.5%	-4.5
HU	0.7%	13.6%	-17.6%	-18.2	-12.0%	-16.1
RS	0.2%	13.2%	138.8%	138.2	:	:
LU	0.3%	12.4%	25.3%	24.7	16.5%	12.5
TR	4.5%	11.0%	23.2%	22.6	32.1%	28.1
IE	1.2%	11.0%	-4.7%	-5.3	:	:
EL	1.1%	10.5%	-27.8%	-28.4	-35.9%	-39.9
CH	3.4%	10.4%	:	:	:	:
PT	1.1%	10.4%	-1.5%	-2.2	-12.8%	-16.8
HR	0.3%	9.8%	-26.2%	-26.9	-34.3%	-38.4
LT	0.2%	9.7%	-35.0%	-35.7	-33.0%	-37.1
Cluster 4						
LV	0.2%	8.1%	-2.9%	-3.5	-11.1%	-15.1
IT	10.3%	7.7%	12.3%	11.6	16.7%	12.7
CY	0.1%	7.1%	13.3%	12.6	-4.5%	-8.6
MT	0.1%	5.1%	-10.2%	-10.9	31.3%	27.3
BG	0.3%	4.6%	-7.7%	-8.3	-19.2%	-23.2

Note: For the 'Firms coop with univ, gov, res inst (2014)' column, the value reported for IE and the UK is only for firms cooperating with universities, whereas for ES it is only for firms cooperating with government, public or private research institutes. Note that the category (i.e. coop with universities OR coop with gov, res inst) with the largest score was used to minimise the underestimation of the value when both categories were aggregated (as for the other countries). Accordingly, the score of the EU-28, which includes the above exceptions for IE, ES and UK, might be slightly underestimated. Using the data for the MS where all data were available (i.e. merged and by sub-categories), we could estimate that the average underestimation of the scores using this approach roughly equalled 15 %. However, the underestimation varies substantially across countries.
In computing CAGR for 'Coop with gov, res inst,' the definition differs for innovative firms cooperating with government, public or private research institutes in 2012 (for all countries including EU-28 aggregate).
Data unavailable: AL, AM, BA, FO, GE, IL, MD, ME, TN, UA
(:) = missing data.

Source: Computed by Science-Metrix using Eurostat data (online data codes: inn_cis8_coop, inn_cis9_coop, inn_cis8_type and inn_cis9_type).

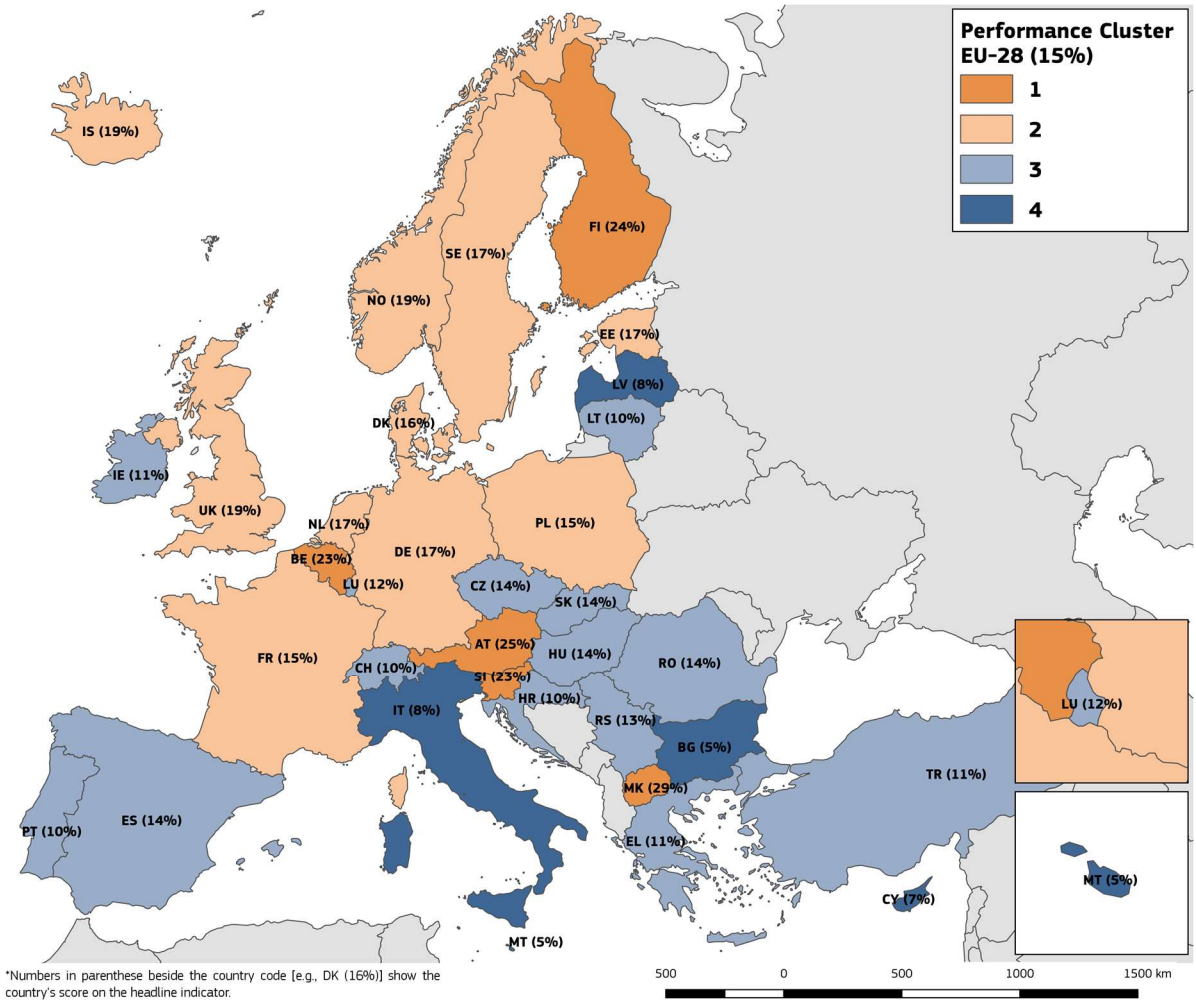

Figure 6 Map of the share of product or process innovative firms cooperating with universities, Government, public or private research institutes (2014).

Note: As per

Table 19.

Source: Computed by Science-Metrix using Eurostat data (online data codes: inn_cis8_coop, inn_cis9_coop, inn_cis8_type and inn_cis9_type).

3.5.3 Complementary EMM indicators

The two complementary EMM indicators for Sub-priority 5a are the share of publicly conducted research that is financed by the private sector and the number of public–private co-publications per million inhabitants.

Share of public research financed by the private sector

At the national level, financial incentives for collaboration within ERA are promoting joint participation of public research organisations and the private sector in competitive calls, requiring the involvement of both parties in the actual writing of the proposals. The use of innovation vouchers is also starting to spread throughout the region. In addition, some countries already have dedicated funding agencies in place to support public–private partnerships; examples include Switzerland's *Commission pour la technologie et l'innovation*, and Sweden's Vinnova. In countries such as Germany, research and technology organisations (RTOs) are tapping into their IP revenues to fund their research activities. New funding schemes are currently being implemented or considered, many of them through the European Investment Fund (EIF). Examples include the European Angels Fund, the Corporate Innovation Platform (CorIP), the Risk Sharing Instrument (RSI) for Innovative SMEs and Small Mid-Caps, the Growth Finance Initiative (GFI) and the Mid-Cap Initiative (MCI) (Debackere et al., 2014).

The first complementary indicator measures the share of publicly conducted research that is financed by the private sector. This indicator acts as a proxy measure of the extent to which public–private cooperation promotes open innovation and knowledge transfer between 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 (European Commission & Directorate-General for Research and Innovation, 2015c). Enterprises are therefore 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 does not account for the fact that knowledge transfer implies a bilateral exchange between the public and private sectors; it only focuses on the role of firms. Additionally, this indicator is, like the Headline indicator, potentially affected by an economic structure bias. For instance, countries that host the headquarters of large companies that have larger financial capacities, especially in relation to R&D, might be advantaged. Adding to this is the fact that 'some Member States have established a system with private or semi-private technological institutes providing commissioned R&D to industry, whereas in other Member States this remains a role of public research organisations' (ERAC Secretariat, 2015a). Full results are presented in Table 20.

EU-28 Member States did not progress since 2013, the latest available year in the previous monitoring exercise. The average share of public research financed by the private sector stood at 7.1 % in 2013, whereas it stood at 7 % in 2015. Pronounced decreases since the last monitoring exercise were found in the least performing countries (Cluster 4) on this indicator; in particular, Montenegro faced a decline of 82 % annually from 2013 to 2015 which contrasted heavily against the rather stable situation at EU-28 level. Malta and Luxembourg both experienced declines in the order of 25 % annually.

Ten countries out of 35 for which scores are available both in 2013 and 2015 have moved by more than 3 positions. The most notable change is for Bosnia and Herzegovina which moved from 29th to 1st place; note, however, that the time series for this country includes lots of missing data such that it is hard to assess the reliability of the data (see the discussion of this country's scores at the end of this section). Also worthy of mention is the drop observed for Montenegro (from 13th to 35th) which is in line with its strong rate of annual decline mentioned above.

There were slightly more countries below (20 in Cluster 3 and 4) than above (16 in Cluster 1 and 2) the ERA average. That said, the gap between Cluster 3 and 4 on the one hand, and Cluster 1 and 2 on the other hand, was more pronounced in terms of the share of ERA GDP they respectively accounted for (60 % vs 40 %). Bosnia and Herzegovina's top score is discussed in detail at the end of this section. Belgium was the next best performer, followed, by a wide margin, by another group of good performers that included Latvia, Lithuania, Germany, Turkey, the Netherlands and Romania. The least performing countries included Portugal, Luxembourg, Cyprus, Malta, FYR Macedonia and Montenegro. Note that the 14 countries included in the group just below the unweighted ERA average (Cluster 3) displayed scores in a limited range from 2.6 % and 6.4 %. In fact, countries in Cluster 1 alone doubled the scores' range on this indicator (going from 0-10 % to 0-20 % with Cluster 1; this is excluding Bosnia and Herzegovina). These findings suggest a fair degree of equality among ERA countries on this indicator.

Country inequalities, as measured by the Gini coefficient, appeared to be low-to-moderate on this indicator, with short-term growth acting to moderately increase inequalities. The Gini coefficient for country scores here was 0.315 for 2013 and 0.345 for 2015. The correlation between performance and short-term growth was moderate (Pearson *r* of 0.38), indicating that the countries that performed the best had a slightly greater likelihood of improving their score. This trend is also clearly shown by the average of short-term annual growth figures at the level of country groups: these were rather similar in the top 3 clusters, but strongly negative in the least performing group; this pattern is also observed for long-term growth although it is less pronounced in that case. Noteworthy growths were witnessed for Ireland (with an increase 19 points above the EU-28 annual average growth) and Greece (15 points above EU-28 level). At the same time, three countries experienced average annual declines well above 10 %: Montenegro, Luxembourg and Malta.

Bosnia and Herzegovina's very high score of 31 % annual average growth is expected to reflect flawed data sets, given not only the performance of other countries but also its own performance in previous years. Although abrupt year-to-year fluctuations are not necessarily out of the ordinary for countries of such a small size, caution was preferred by removing its CAGR from the table and from the CAGR average of Cluster 1. Its score was not taken into account for determining the boundaries of the clusters.

Table 20 Share of public research financed by the private sector (2007-2015)

Country	Weight in GDP	Score (2015)	CAGR			
			Short-term (2013-15)	Lead/Gap to EU-28 CAGR	Long-term (2007-15)	Trendline
EU-28		**7.0%**	**-1.2%**	**N/A**	**-0.8%**	
Cluster 1	31.0%	16.1%	-0.3%	0.9	0.6%	
Cluster 2	8.5%	8.6%	0.7%	1.9	-0.6%	
Cluster 3	58.9%	5.1%	-1.5%	-0.3	-1.9%	
Cluster 4	1.6%	0.8%	-27.7%	-26.4	-8.1%	
Cluster 1						
BA	0.1%	*31.0%*	:	:	:	
BE	2.5%	20.6%	5.2%	6.4	0.8%	
LV	0.1%	14.4%	1.5%	2.7	5.6%	
LT	0.2%	13.2%	-10.5%	-9.3	-2.0%	
DE	18.3%	12.7%	1.6%	2.9	-0.6%	
TR	4.6%	12.6%	4.4%	5.6	-5.5%	
NL	4.1%	12.2%	-1.2%	0.0	2.5%	
RO	1.0%	12.2%	-3.4%	-2.1	3.1%	
Cluster 2						
SI	0.2%	10.5%	1.2%	2.5	-2.4%	
CH	3.7%	*9.7%*	*-4.8%*	-3.6	*6.4%*	
HU	0.7%	9.6%	-3.0%	-1.7	-3.7%	
HR	0.3%	8.4%	-5.8%	-4.6	-0.4%	
BG	0.3%	8.2%	3.4%	4.7	1.5%	
CZ	1.0%	7.8%	8.1%	9.3	-0.9%	
EL	1.1%	7.3%	13.5%	14.8	:	
FI	1.3%	7.0%	-7.3%	-6.0	-4.9%	
Cluster 3						
ES	6.5%	6.4%	-2.2%	-1.0	-2.9%	
AT	2.1%	6.4%	2.6%	3.8	-1.6%	
RS	0.2%	6.1%	-12.3%	-11.1	*-5.8%*	
IS	0.1%	6.0%	-10.6%	-9.4	-7.9%	
UK	15.7%	5.9%	-11.1%	-9.9	-1.7%	
EE	0.1%	5.6%	5.2%	6.4	0.9%	
FR	13.2%	*5.4%*	*1.3%*	2.6	*4.0%*	
NO	2.1%	5.2%	-9.9%	-8.6	-3.2%	
SE	2.7%	4.7%	2.5%	3.7	-2.8%	
SK	0.5%	4.4%	-5.3%	-4.0	-10.7%	
IE	1.6%	4.3%	17.2%	18.5	6.4%	
DK	1.6%	4.3%	6.7%	7.9	5.8%	
PL	2.6%	3.6%	-4.6%	-3.4	*-7.3%*	
IT	9.9%	2.6%	-0.9%	0.4	-0.5%	
Cluster 4						
PT	1.1%	2.2%	3.5%	4.7	-0.2%	
LU	0.3%	1.2%	-27.4%	-26.2	-9.9%	
CY	0.1%	0.7%	-4.8%	-3.6	-11.4%	
MT	0.1%	0.6%	-26.1%	-24.9	*-10.9%*	
MK	0.1%	0.2%	:	:	:	
ME	0.0%	0.2%	-83.5%	-82.2	:	

Note: Break in time series: 2007 (DK, NO); FR (2010); EL (2008, 2011); LU (2009); NL (2012); PT (2008, 2013); 2011 (RO, SI); IS (2010, 2011, 2013); RS (2014); TR (2008). Definition differs: HR (2012-2015); 2007-2015 (DE, HU, NL); PL (2009, 2010); 2007-2014 (SK, UK); ME (2011-2014); CH (2008, 2010, 2012, 2014); TR (2007). Estimated: AT (2008, 2010, 2012, 2014); EL (2007-2010); IE (2009, 2011, 2013); IT (2014, 2015); LU (2007); SE (2008, 2010, 2012-2014); UK (2015); IS (2011). Provisional: DK (2015); FR (2015). Potential outlier: LV (2011); MT (2007); PL (2007). Exception to reference year: 2014 (FR, BA, CH). Exception to reference period for short-term CAGR: FR, CH (2012-2014). Exception to reference period for long-term CAGR: FR (2007-2014); MT, PL (2008-2015); CH (2008-2014); RS (2009-2015). The portion of R&D expenditures from the higher education sector financed by the foreign business sector is missing for BG (2009); NL (2011-2014); RO (2007). The portion of R&D expenditures from the government sector financed by the foreign business sector is missing for BG (2013, 2014); 2015 (LU, EE); PL (2011, 2013, 2015); TR (2007, 2008); UK (2007-2010). The portions of R&D expenditures from the government and the higher education sectors financed by the foreign business sector are 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). The missing portions of the R&D expenditures may result in a slight underestimation in the scores.
Data unavailable: AL, AM, FO, GE, IL, MD, TN, UA. (:) = missing data. BA is roughly four standard deviations away from the mean and was therefore not used in establishing the clusters' boundaries.

Source: Computed by Science-Metrix using Eurostat data (online data code: rd_e_gerdfund).

Number of public–private co-publications per million population

The second complementary EMM indicator for Sub-priority 5a is the number of public–private collaborative publications (or co-publications) per million population. Public–private co-publications

are scientific publications that were co-authored by at least one author from each of those two sectors. It serves as a proxy to measure whether or not, and to which extent, public–private partnerships in R&I lead to fruitful outputs. It should, however, be noted that it only captures one form of knowledge transfer. For example, it does not capture knowledge transfer leading to co-inventions/co-patenting. Furthermore, like all other indicators in Sub-priority 5a, this indicator is subjected to an economic structure bias. For instance, countries with a greater share of large companies having greater R&D capabilities will likely have more publications involving the private sector, thereby increasing their likelihood of producing public–private co-publications. Country-by-country results are found in Table 21.

EU-28 Member States have collectively experienced a very slight growth, both in the short- and long-term, in their numbers of public–private co-publications per million population. In 2014, the latest available year in the previous ERA monitoring exercise, EU-28 Member States registered on average of 40.4 such co-publications per million inhabitants (based on the updated time series). By 2017, this score was nearly left unchanged (40.9). Among EU-28 Member States, only Cyprus had a notable growth figure in recent years (CAGR of 15 %), while Malta (-100 %), Luxembourg (-23 %) and Slovenia (-15 %) had experienced notable declines in the short-term. FYR Macedonia obtained the single standout average annual growth rate from 2014 to 2017 among all ERA countries (51-point lead on the EU-28 average annual growth). Serbia (-22 %) also experienced a notable decline from 2014 to 2017.

Recent ranking changes, from 2014 to 2017, were limited on this indicator with only 4 out of 36 countries (those with data or imputable data in both years) having shifted by more than 3 positions. In fact, 18 countries maintained the very same ranking from one period to the next.

The distribution of scores was quite broad on this indicator and highly skewed, highlighting the strong country inequalities that prevail on this indicator; the Gini coefficient was equal to 0.598 in 2017, one of the highest across this study's indicators. The strongest performance for this indicator was from Switzerland, leading by a substantial margin, followed by Iceland, Denmark and Sweden, each of which published well above 100 public–private co-publications per million population in 2017. The eight countries in Cluster 2 obtained scores that ranged from 50 to 100, while the scores of the 22 countries in Cluster 3 ranged from 0 to 50. Only 12 countries performed above the ERA average (i.e. in Cluster 1 and 2). Due to this asymmetric distribution, whereby a few countries stand out strongly above the ERA average, the standard deviation was too large for any country to fall in Cluster 4, again pointing towards the strong inequalities on this indicator. No meaningful correlation was obtained between the economic weight of countries and their scores with respect to public–private co-publications. The country groups immediately below and above the unweighted ERA average (Clusters 2 and 3) each account for similar shares of combined ERA GDP (45 %-47 %), despite the second containing many more countries than the first. Cluster 2 is mostly made up of medium and large economies, while Cluster 3 puts together most small economies with a few middle and large ones. The group made up of the four most performing countries (Cluster 1) accounts for 8 % of ERA GDP.

Ultimately, inequalities between countries were pronounced on this indicator, and recent and long-term growth rates have not countered this situation. The Gini coefficient has generally been increasing since 2010 (G = 0.558 in 2010) to reach 0.598 in 2017. The two groups of most performing countries (Cluster 1 and 2) would have, on average, experienced slight growth if it was not for the negative performances of Iceland (Cluster 1; 7-point gap to EU-28 CAGR) and Slovenia (Cluster 2; 16-point gap). The least performing country group (Cluster 3 in this case) experienced a sizeable decline in the aggregate, driven by individual country performances from Malta, Luxembourg and Serbia. Among all these decreases, the group of least performing countries showed the most accentuated decline (at 4.1 % average annual decline), providing further evidence of a trend towards greater inequalities.

Examination of long-term average annual growth rates show, however, that growth in inequalities were more accentuated previously than in the recent period. The least performing group of countries has reduced its gap to the most performing countries in recent years as compared to the 2010-2017 period (7 % average annual decline for Cluster 3 over this period compared to 4 % average annual decline from 2014 to 2017 while the other clusters kept similar scores). When comparing long-term to short-term growth, Cyprus, Estonia, Lithuania, Latvia and Croatia stand out as having reversed declines in the recent period. Luxembourg, Slovenia, Serbia and Iceland, however, have seen acceleration of their declines.

Table 21 Number of public–private co-publications per million population (2010-2017)

Country	Weight in GDP	Score (2017)	CAGR			
			Short-term (2014-17)	Lead/Gap to EU-28 CAGR	Long-term (2010-17)	Trendline
EU-28		**40.9**	**0.4%**	**N/A**	**0.3%**	
Cluster 1	8.1%	184.3	-0.1%	-0.5	0.4%	
Cluster 2	45.3%	76.6	-0.8%	-1.3	0.0%	
Cluster 3	46.6%	14.7	-4.1%	-4.5	-7.0%	
Cluster 1						
CH	3.5%	260.6	3.2%	2.8	3.2%	
IS	0.1%	183.2	-6.2%	-6.7	-3.6%	
DK	1.7%	162.8	1.3%	0.9	0.5%	
SE	2.8%	130.6	1.3%	0.8	1.3%	
Cluster 2						
NL	4.3%	99.3	-0.3%	-0.7	-0.5%	
FI	1.3%	85.4	-2.6%	-3.0	-0.6%	
AT	2.2%	82.3	3.1%	2.7	1.8%	
NO	2.1%	82.2	1.8%	1.4	-1.1%	
BE	2.6%	80.0	1.1%	0.6	2.2%	
UK	13.6%	65.1	4.0%	3.6	1.0%	
DE	19.1%	62.4	1.2%	0.8	1.2%	
SI	0.3%	56.2	-15.2%	-15.6	-4.3%	
Cluster 3						
IE	1.7%	45.4	4.7%	4.3	5.6%	
FR	13.4%	42.8	-2.1%	-2.5	0.6%	
IL	:	*33.3*	*-1.0%*	-1.4	*-3.8%*	
HU	0.7%	29.6	-1.9%	-2.3	1.2%	
LU	0.3%	25.4	-22.8%	-23.3	-4.8%	
IT	10.0%	22.2	-4.3%	-4.7	-3.0%	
ES	6.8%	21.1	-0.3%	-0.7	0.3%	
CY	0.1%	21.1	14.8%	14.3	-4.0%	
CZ	1.1%	21.0	0.2%	-0.2	-3.2%	
HR	0.3%	17.3	3.9%	3.5	-7.8%	
PT	1.1%	13.2	-0.9%	-1.4	0.3%	
EE	0.1%	10.6	0.2%	-0.2	-11.7%	
EL	1.0%	10.5	-4.4%	-4.8	-4.0%	
SK	0.5%	10.3	-6.4%	-6.9	-4.7%	
PL	2.7%	5.4	-1.8%	-2.3	1.9%	
RS	0.2%	4.5	*-21.3%*	-21.8	-11.5%	
LT	0.2%	3.9	5.1%	4.6	-10.8%	
RO	1.1%	3.7	-6.7%	-7.2	-11.3%	
MK	0.1%	3.4	51.5%	51.0	19.4%	
BG	0.3%	3.0	-0.5%	-1.0	0.0%	
TR	4.4%	2.0	3.5%	3.0	-0.8%	
LV	0.2%	1.0	*2.4%*	2.0	-8.3%	
UA	:	*1.0*	*-9.3%*	-9.8	*-6.8%*	
MT	0.1%	0.0	-100%	-100	-100%	

Note: Exception to reference year: IL (2016); UA (2016)
Exception to reference period for short-term CAGR: 2015-2017 (LV, RS); 2014-2016 (IL, UA)
Exception to reference period for short-term CAGR: 2010-2016 (IL, UA)
Data unavailable: AL, AM, BA, FO, GE, MD, ME, TN
(:) = missing data

Source: Prepared by Science-Metrix using data from the European Innovation Scoreboard (EIS) 2018.

Comparing Headlines to complementary EMM indicators

Within Sub-priority 5a, there were no meaningful correlations between the Headline and complementary EMM indicators. The share of product and/or process innovative firms cooperating with universities, government, public or private research institutes correlated very weakly with the share of public research financed by the private sector (Pearson *r* of 0.10). The two indicators obviously depict different dimensions: the Headline indicator represents a count of cooperating enterprises (expressed as a share), whereas the complementary indicator reflects an amount of money invested. The two dimensions are not necessarily related — for example, a single enterprise

may finance public research to a large extent, and this will not be reflected in the Headline indicator enterprise count.

The Headline indicator correlated slightly more with the complementary indicator number of public–private co-publications per million population, but nevertheless the correlation was not very strong (Pearson *r* of 0.29). Again, the two indicators depict different dimensions of knowledge circulation; cooperation in enterprises does not necessarily result in scientific publications.

Given these tenuous interconnections between the Headline components and the complementary EMM indicators, it remains unlikely that the use of only one Headline figure would suffice to adequately account for the varied landscape that prevails down to the country level. The use of a single indicator cannot adequately account for all the relevant dimensions under Sub-priority 5a due to inter-country variability.

3.5.4 Additional policy highlights 5a

Industry–academia interactions: KT centres, TTOs, incubators: A growing number of organisations across ERA countries are promoting knowledge transfer and uptake of scientific findings. For instance, in Estonia technology development centres and clusters are being implemented fostering the cooperation of doctoral students with enterprises and businesses. Spain has designed a large number of support schemes to foster R&D activities. Hungary has held and continues to hold cooperation between business and academia as a priority of R&I policy which has resulted in a higher number of corporate research centres and R&D labs that work closely with academic partners.

Building collaboration through training and career development: According to the analysis of qualitative data, more initiatives have been put in place in ERA countries with the goal of helping researchers to learn about and gain experience with interactions involving research activities between the public and private sectors. In 2016, the Danish Ministry of Higher Education and Science renegotiated the university performance contracts for 2015-2017 introducing targets on regional knowledge transfer activities. However, collaboration between industry and academia, evaluation and monitoring of related research and innovation policies remain challenges for some ERA countries (e.g. Croatia, Czech Republic, Lithuania). The Erasmus+ Programme has established Knowledge Alliances to encourage knowledge exchange between higher education institutions and enterprises (OECD, 2016).

3.5.5 Headline indicator 5b – Open access

Related to Sub-priority 5a on knowledge circulation is the need to give access to and preserve scientific information, covering both scientific publications and research data (European Commission, 2012). Sub-priority 5b thus relates to the promotion of open access (OA) to scientific publications and research data. The EMM acknowledges the need to understand the differences between scientific publications and data, so that open access to these two categories calls for separate approaches, both at the policy level and the operational level. Moreover, a number of models to facilitate OA are currently being tested, each entailing different challenges, as well as varying costs for both the implementing organisations and the users of the data (ERAC Secretariat, 2016). The field of OA is rapidly evolving; the European Commission has carried out significant work through pilot projects in two framework programmes, FP7 and Horizon 2020 (ERAC Secretariat, 2016). The FP7 pilot focused on open access to scientific publications, which has become an underlying principle in H2020. In H2020 an Open Research Data Pilot was launched and recently extended to cover all thematic areas of H2020, while ensuring opt-out possibilities for issues such as IPR concerns, privacy or national security concerns. In addition to this work, since the establishment of ERA, both the Commission and the Council have issued notices and recommendations on the subject to Member States (ERAC Secretariat, 2016; European Commission, 2018d). Furthermore, the European Commissioner for Research, Science and Innovation issued a public statement in support of a new initiative of Science Europe, 'Coalition S,' aiming to make full and immediate OA an achievement to be reached by 2020[29].

The main driver for OA is linked to RFO activities, in particular, by promoting publication of research outputs in OA form, either by making the fees an eligible cost in a project grant, or by offering specific funding to cover those fees. These kinds of incentives are in some cases optional and in others mandatory, depending on the country; they continue to be implemented in a heterogeneous fashion. In some cases, in addition to financial incentives, RFOs proactively require funded publications to be OA.

[29] https://www.scienceeurope.org/coalition-s/

The Headline indicator for Sub-priority 5b (Open Access) is the share of a country's scientific publications available in OA. Note that 'publications and 'papers' are used interchangeably to encompass peer-reviewed (scientific) publications in the form of journal articles and reviews indexed in the Web of Science (WoS). In the 2016 ERA Progress Report, papers were defined as being available in OA relying on Peter Suber's definition[30] of gratis OA. In addition to the proportion of total OA, the indicator was also produced for two sub-types of OA: gold and green. The former referred and still 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).

The latter referred to 'papers made available for free by parties other than publishers, usually the authors themselves, who archive papers in institutional repositories, subject repositories such as arXiv, or commercial repositories such as ResearchGate' (Archambault et al., 2016). However, in the wake of litigations with scientific publishers, many papers have recently been removed from academic social platforms such as ResearchGate and Academia.edu. Additionally, many academic social platforms require registration for accessing the material they contain such that they do not align well with the Commission's definition of unencumbered open access. The papers posted on platforms such as ResearchGate and Academia.edu are therefore no longer recognised as valid cases of green OA in this edition of the ERA Progress Report. Accordingly, a notable difference in results obtained for the current edition of the ERA Progress Report and the 2016 publication is that green OA and gold OA sets of papers are now roughly at parity at the ERA-wide level (i.e. ratio of gold to green OA close to 1) while the ratio of gold to green OA in the 2016 ERA Progress Report was at 0.5.

In other words, scientific publications are considered OA if they are available on the internet in full text, for free, and without any registration required. Gold and green OA refer to the type of website through which the paper is made available; as a general rule of thumb, if the publisher is the one providing access, then the scientific publication is classified as gold, whereas if the paper is available through any other website (e.g. through a researcher's private page or a university's repository), then it is classified as green. For more details, refer to the *2018 ERA Monitoring Handbook*. Also note that these definitions of gold and green OA have been used in multiple publications measuring OA for the European Commission (Archambault et al., 2014; Science-Metrix, 2017; PPMI, DCC, Georg-August-Universität Göttingen and Science-Metrix, 2018).

As a single paper might be hosted in more than one location, a single paper can be available through both the gold and green routes, meaning that the two categories are not mutually exclusive. Neither are gold and green complementary: one cannot simply sum the two to determine the total level of OA for a given country. Note that when measuring total OA to scientific publications, double counting of papers accessible via both the green and gold routes is avoided. Accordingly, the sum of the shares of green and gold OA papers for a given entity can add up to more than its share of total OA papers. These shares all use the same units, each expressing how many of a country's scientific publications are available in total OA, in gold OA or in green OA as a share of their total scientific publications. The denominator of these figures corresponds to the number of peer-reviewed scientific papers published by a given country in a given year in a reference database (in this case, the Web of Science [WoS] produced by Clarivate Analytics). The numerator is obtained by performing an internet search for all scientific publications indexed in the WoS to see if each one is available in OA, and if yes, then in green and/or gold OA, using an advanced search engine tailored to the task ([31]). For more details on the computation of this indicator, refer to the 2018 ERA Monitoring Handbook.

The share of scientific 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,' 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 scientific 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 the publication year of the papers. While

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

[31] The OA index is produced by 1science and is freely accessible to search the scientific literature that is available in OA at: https://1findr.1science.com/home. Note that the 1findr platform also indexes non-OA literature.

one such snapshot was produced for the *2016 ERA Progress Report*, the 2016 and 2018 snapshots cannot be compared in measuring growth due to the change in the methodology used to retrieve OA publications (see above discussion of platforms such as ResearchGate). Such comparisons will only become possible as new snapshots of OA publications become available. However, given the speed with which the OA landscape evolves, it is not impossible that further changes to the methodology used in retrieving OA papers be required in future monitoring exercises.

Given the constraints and arguments just presented, growth was not measured at the country level. Nevertheless, the analysis of trends based on the publication year, presented at the ERA-wide level, revealed a drop in the share of OA papers in the two most recent years considered: 2015 and 2016 (Figure 7). This drop is only observed for green and total 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. Because researchers might be busy doing other things, however, it might take longer still before their papers become accessible to all via the latter route of green OA. This issue is of high relevance to the development of OA policies since embargoes significantly restrain access to the most recent scientific literature.

Keeping in mind these provisos, Figure 7 nonetheless shows steady consolidation of OA practices in ERA countries. Figures for articles published in 2016 now show that almost 50 % of ERA country publications (weighted average across countries) are available in some form of OA. The results also show that the green and gold routes contributed fairly equally to the release of ERA papers in OA and that, as of 2018, this remains true regardless of the publication year in the 2005–2016 period. Note that the shrinking of the small gap between green and gold OA papers observed in 2015 and 2016 is due to the 'delayed OA' phenomenon discussed above.

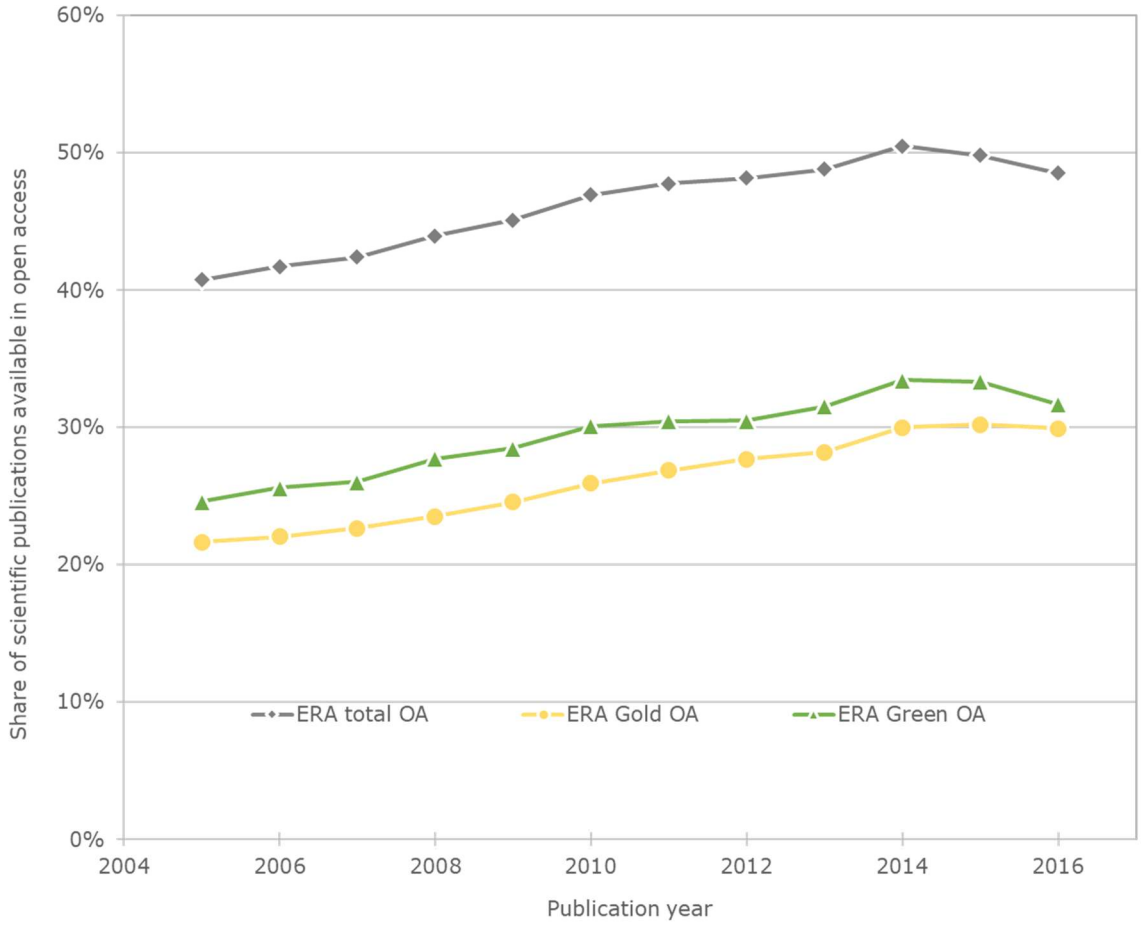

Figure 7 Trends in the share of scientific publications available in open access (total, green and gold) at the ERA-wide level (2005–2016)

Note: The trends are based on the publication year of papers instead of the production year of the data (see above text for explanation). ERA-wide level data here consists of a weighted average across ERA countries. Trends are very similar for the EU-28.

Because of recent litigation issues related to the illegal sharing of content on social platforms, and to align with open access definitions at the European Commission regarding unencumbered open access, content from platforms such as ResearchGate and Academia.edu are not accounted for in these statistics. This results in lower open access levels compared to those presented in the *2016 ERA Progress Report* as these platforms were included in 2016.

Source: Prepared by Science-Metrix using data from the Web of Science (Clarivate Analytics) and 1findr (1Science).

Total OA

The Headline indicator used to track performance and progress on Sub-priority 5b is the share of papers available in OA, regardless of the route by which they attain their OA status. In practical terms, this indicator helps to assess how much of a country's research is available to potential users, regardless of the mechanism by which it is made available. Full results for 2016 are presented in Table 22, covering total OA, gold OA and green OA.

It is worth noting that while data are available for publication year 2017 (data not shown), these findings are still significantly affected by embargoes (which typically last 6-12 months), and therefore do not adequately reflect the overall share of recent research that should soon be made available in OA. Given the decrease in OA observed in 2015 and 2016, relative to 2014, an open question remains as to how many years exactly embargoes influence the composition of datasets on OA papers. Perhaps the decrease in 2015 and 2016 is not attributable to delayed OA but is instead a reflection of a genuine decrease in OA availability. On the contrary, if the impact of delayed open access is longer than expected – as some journals have embargo periods longer than one year – it could still be an artefact of the delayed OA.

The EU-28 weighted average in the total share of OA papers was decimals away from reaching the 50% mark by 2018, for papers published in 2016. The leading countries in the share of research available in total OA are the UK, Georgia, the Faroe Islands, Croatia, Switzerland and the Netherlands. These countries together make up the group of most performing countries (Cluster 1) with shares of 2016 OA papers ranging from 55% to 64%. The two country groups above unweighted ERA average (Clusters 1 and 2) were larger than the group below (Clusters 3 and 4; 24 and 20 countries, respectively). The group of countries just above the unweighted ERA average (Cluster 2) was particularly large, at 18 countries. The distribution of country scores on this indicator is reflective of inclusion rather than disparities among ERA countries. Indeed, most countries were rather close to the ERA average; about 40 % of countries within one standard deviation above the ERA average and 32 % within one standard deviation below that average. Also, the Gini coefficient, a common metrics used in economics to quantify inequalities in the wealth of various groups, was at a very low level of 0.161 in 2016.

Economic weight was not closely associated with high scores here. The two country groups above unweighted ERA average (Cluster 1 and 2) accounted for 58 % of combined ERA GDP while roughly including the same share of ERA countries (55 %). Similarly, Clusters 3 and 4 accounted for 42 % of ERA GDP while including approximately the same share of ERA countries (45 %). Large economies were found across the three most performing country groups, with the UK having the top score on this indicator. Overall, neither the smaller nor the larger economies appeared to be at an advantage in terms of shares of total OA publications.

Gold and green OA

Bear in mind that Gold OA covers articles that are made available through publishers, while papers that are available through any other websites (e.g. through a researcher's private page or a university's repository), are classified as green OA. While subsets of total OA may be less relevant from a user's perspective, they can shed useful light on the different routes by which publications are made available; this is where the process is valuable to understand from a policy perspective (RFOs tend to promote the gold OA route by, for example, covering the cost of publishing in gold OA journals), even if it is the product (i.e. the resulting accessibility of research) that is of primary interest to users.

At the EU-28 level, the share of gold OA papers published in 2016 currently stands at 30.2 % while it currently stands at 32.5 % for green OA papers. While the ratio of gold to green OA was close to 1 for 2016, substantial variation in this ratio remains across individual countries. For instance, 23 % of ERA countries had a share of gold OA papers at least 5 percentage points greater than their share of green OA papers, while 32 % of ERA countries had a share of green OA papers at least 5 points greater than their share of gold OA papers.

While the gold OA scores of ERA countries correlate slightly less strongly with their total OA scores than green OA scores do with total OA scores (Pearson r = 0.77 for the former and 0.85 for the latter), there is a greater overlap in the top 10 based on gold and total OA (i.e. Austria, Croatia, Denmark, Faroe Islands, FYR Macedonia, the Netherlands, Switzerland and the UK) than based on green and total OA (i.e. Faroe Islands, Georgia, Hungary, the Netherlands, Switzerland and the UK).

While the UK ranked 1st in total OA, it placed 2nd both in gold (behind Bosnia and Herzegovina) and green (behind Georgia) OA. Montenegro, Serbia, Bosnia and Herzegovina, Poland and Albania scored comparatively higher in gold OA than they do on total OA, with gains of at least 10 positions in the ranking going from total to gold OA. Armenia, Hungary, Georgia, France and Luxembourg had notably strong reductions in their share of gold OA relative to total OA losing at least 10 places in the ranking going from total to gold OA. When examining shares of green OA relative to total OA, countries that notably improved their ranking moving up by at least 10 positions include Malta, Bulgaria and Armenia. Conversely, authors from multiple countries appear to strongly steer away from green OA routes (losing at least 10 places in the ranking): Bosnia and Herzegovina, FYR Macedonia, Montenegro, Austria, Croatia and Poland.

Table 22 Share of scientific publications available in Open Access (2016)

Country	Weight in GDP	Total OA	Gold OA	Green OA
EU-28		**49.3%**	**30.2%**	**32.5%**
Cluster 1	22.5%	58.8%	36.0%	40.5%
Cluster 2	35.6%	49.4%	29.7%	33.5%
Cluster 3	36.2%	41.7%	27.1%	23.4%
Cluster 4	5.7%	31.0%	19.4%	16.6%
Cluster 1				
UK	14.4%	63.7%	36.1%	48.3%
GE	:	63.6%	31.3%	52.7%
FO	:	58.3%	38.3%	35.0%
HR	0.3%	56.2%	37.6%	32.1%
CH	3.6%	55.5%	34.3%	38.7%
NL	4.2%	55.4%	38.1%	36.1%
Cluster 2				
HU	0.7%	54.2%	25.5%	43.1%
MK	0.1%	52.2%	35.7%	27.8%
AT	2.1%	51.8%	34.9%	29.0%
DK	1.7%	51.5%	34.1%	33.1%
NO	2.0%	51.3%	32.8%	36.1%
LU	0.3%	51.1%	28.0%	36.5%
SE	2.8%	51.0%	34.1%	32.7%
AM	:	50.9%	19.2%	45.5%
BE	2.5%	50.5%	29.9%	34.9%
IS	0.1%	49.4%	30.0%	34.9%
BA	0.1%	48.8%	39.2%	20.2%
IE	1.6%	47.9%	27.9%	33.3%
FI	1.3%	47.6%	29.0%	33.4%
FR	13.3%	46.7%	25.7%	32.0%
ES	6.7%	46.4%	26.6%	32.6%
MT	0.1%	46.3%	26.8%	35.1%
CY	0.1%	45.8%	25.5%	31.7%
EE	0.1%	45.8%	30.2%	30.4%
Cluster 3				
PL	2.5%	45.1%	33.1%	21.7%
SI	0.2%	45.0%	29.3%	24.1%
DE	18.8%	44.7%	29.3%	26.7%
ME	0.0%	44.3%	35.8%	14.6%
IL	:	43.2%	25.8%	25.1%
RS	0.2%	43.0%	32.9%	21.9%
PT	1.1%	42.9%	22.8%	30.1%
LT	0.2%	41.8%	27.8%	23.7%
IT	10.0%	40.8%	26.4%	22.7%
CZ	1.1%	40.5%	25.7%	22.9%
SK	0.5%	38.4%	24.3%	21.0%
EL	1.0%	38.2%	23.3%	23.0%
LV	0.1%	37.8%	22.3%	23.8%
BG	0.3%	37.4%	20.7%	26.0%
Cluster 4				
MD	:	36.1%	19.8%	21.8%
AL	0.1%	34.2%	26.1%	16.6%
UA	:	33.5%	16.1%	22.8%
RO	1.0%	32.7%	20.0%	17.5%
TR	4.7%	30.7%	22.4%	10.8%
TN	:	19.0%	11.6%	10.1%

Note: Because of recent litigation issues related to the illegal sharing of content on social platforms, and to align with open access definitions at the European Commission regarding unencumbered open access, content from platforms such as ResearchGate and Academia.edu are not accounted for in these statistics. This results in lower open access levels compared to those previously reported in the 2016 *ERA Progress Report*.
Gold OA may be overestimated, at the expense of green open access, because of recent efforts by 1science to codify sources of gold open access (e.g. publishers' websites), which are easier to identify than green OA sources.
EU-28 is computed as a weighted average of the MS share of OA and their publication output.
(:) = missing data

Source: Prepared by Science-Metrix using data from the Web of Science (Clarivate Analytics) and 1findr (1Science).

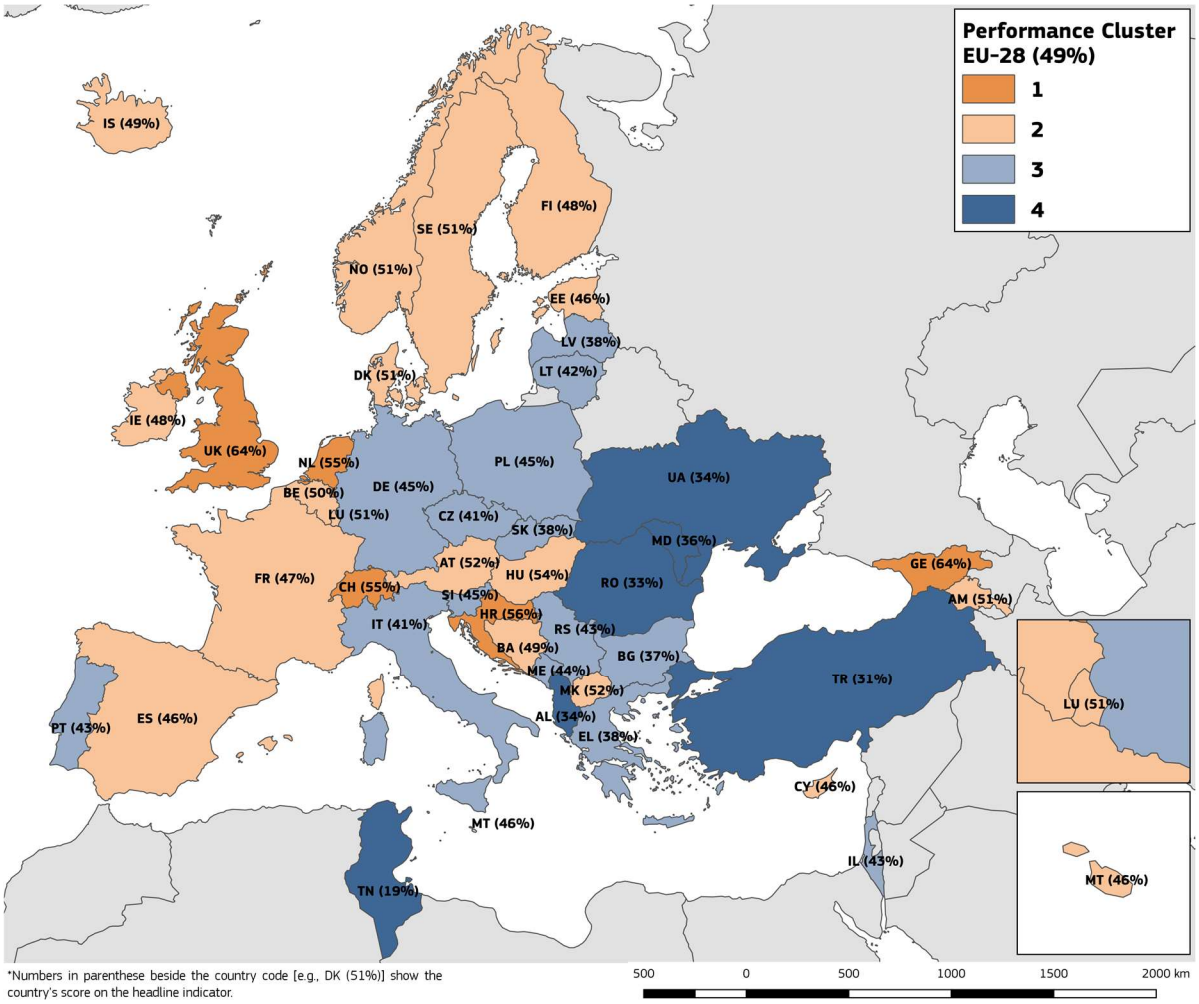

Figure 8 Map of the share of scientific publications available in Open Access (2016)

Note: As per Table 22.
Source: Prepared by Science-Metrix using data from the Web of Science (Clarivate Analytics) and 1findr (1Science).

3.5.6 Complementary EMM indicators

ERAC identified several complementary EMM indicators for Sub-priority 5b, most of which aim to capture various actions taken to increase OA to scientific publications (as measured with the Headline indicator) as well as to research data sets. These indicators include the share of research funding organisations (RFOs) that provide funds to cover the costs of making publications available in OA, the share of research performing organisations (RPOs) making their research data available in OA, and the inclusion of OA policies in RIO policy repositories. The latter indicator no longer appears in the EMM 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[32]. 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 data set in Figshare. The rationale for these changes is detailed in the *2018 ERA Monitoring Handbook*.

[32] Note that Research performed in the preparation of the 2016 ERA Progress Report had already found that the analysis of national OA policies faces a number of challenges. Using the NAPs, it is hardly feasible to count the number of such policies for OA to research data on the one hand, and to research publications on the other hand, as well as to identify the years of adoption of these policies. Indeed, the structure of NAPs varies substantially across countries and the absence of a common reporting structure for an OA policy or policies in these documents makes it such that the indicator, if it relied on this source, would have limited cross-country comparability.

RFOs (i.e. members of Science Europe or other important sources of national funding) providing funds to cover costs of OA publishing and their share of scientific publications that are available in OA

A new indicator has been elaborated for the *2018 ERA Progress Report* to fill a data gap in the previous monitoring exercise. It focuses on the main RFOs of each country, restraining the analysis to the members of Science Europe (an association of European RFOs and RPOs part of the ERA Stakeholders Platform) and other important sources of national funding covered in the MELIBEA and ROARMAP repositories of OA policies. Using this delineation, the sample contains 56 RFOs distributed in 24 Member States and 3 Associated Countries. Data on the coverage of article processing charge (APC) was mostly obtained from MELIBEA[33] and ROARMAP[34]. For 12 RFOs, further desk research was necessary to gather the information. Altogether 60 % of the countries covered for this indicator are represented by a single RFO.

Since this indicator takes a binary (yes/no) form, it cannot be analysed in the same manner as the quantitative indicators presented in this report. For instance, it is difficult to benchmark countries on the basis of this indicator since it does not reflect the number, breadth and strength of the implemented policies across countries, nor does it capture information on policies implemented on a national or regional level. Because countries differ in the extent to which they rely on a top-down or bottom-up approach to the development and implementation of OA policies (i.e. whether they place more emphasis on national rather than regional/institutional policies or place more emphasis on regional/institutional rather than on national policies), this latter limitation reduces the cross-country comparability of this indicator. Furthermore, there is no time series; only 2018 data about the OA status of the 2016 papers supported by the RFOs are presented to complement this indicator. Full results for the coverage of APC at the RFO level are presented in Table 23 and Table 24. Data on the share of their supported papers that are available in OA are presented in Table 25 and Table 26.

Data were available for RFOs in 24 Member States (excluded are Cyprus, Greece, Malta and Romania), as well as in Iceland, Norway and Switzerland. Building on this sample of RFOs, only Denmark could be identified as a Member State where no RFO offered support to researchers for OA publishing costs. It was not possible to determine with certainty whether Bulgaria, Croatia, France, Latvia, Slovakia, and Slovenia had at least one RFO offering OA financial support or not; the status of some RFOs regarding the coverage of APC was set to unknown. The 20 remaining countries all had at least one major RFO with a support mechanism to cover OA costs.

[33] https://www.accesoabierto.net/politicas/

[34] https://roarmap.eprints.org/

Table 23 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 – part 1 of 2

Country	Reaseach Funding Organisations (RFOs)	Science Europe member	MELIBEA	ROARMAP	Main source of national funds	Covers costs of OA publishing	Mechanism
EU-28	European Commission: Horizon 2020		x	x	Yes	Yes	RG
AT	Austrian Science Fund (FWF)	x	x	x	Yes	Yes	SF
BE	Fonds de la Recherche Scientifique (FRS-FNRS)	x	x	x	Yes	Yes *	RG
BE	Research Foundation Flanders (FWO)	x	x	x	Yes	Yes *	RG
BG	Bulgarian Academy of Sciences (BAS)	x			Yes	UN	UN
HR	Croatian Science Foundation (HRZZ)	x			Yes	UN	UN
CZ	Czech Science Foundation (GACR)	x			Yes	Yes	RG
DK	Danish Council for Independent Research (DFF)	x	x	x	Yes	No	
DK	Danish Council for Strategic Research (DCSR)		x	x	Yes	No	
DK	Danish Council for Technology and Innovation (DCTI)		x	x	Yes	No	
DK	Danish National Advanced Technology Foundation (DNATF)		x	x	Yes	No	
DK	Danish National Research Foundation (DG)	x	x	x	Yes	No	
EE	Estonian Research Council (ETAG)	x		x	Yes	Yes	RG
EE	Ministry of Education and Research			x	Yes	Yes	RG
FI	Academy of Finland (AKA)	x	x	x	Yes	Yes	RG
FR	French National Research Agency (ANR)	x	x	x	Yes	No	
FR	French National Institute of Health and Medical Research (INSERM)		x	x	Yes	UN	UN
DE	German Research Foundation (DFG)	x	x	x	Yes	Yes	RG+SF
DE	Helmholtz Association of German Research Centres		x	x	Yes	Yes	PA
DE	Max Planck Society (MPG)	x		x	Yes	Yes	SF
DE	Leibniz Association	x		x	Yes	Yes	SF
HU	Hungarian Academy of Sciences (MTA)	x	x	x	Yes	Yes	SF
HU	Hungarian Scientific Research Fund (OTKA)		x	x	Yes	Yes	SF
IS	Iceland Centre for Research (Rannis)	x	x	x	Yes	Yes	SF
IE	Health Research Board (HRB)	x	x	x	Yes	Yes	RG
IE	Irish Research Council (IRC)	x	x	x	Yes	UN	UN
IE	Higher Education Authority (HEA)		x	x	Yes	UN	UN
IE	Science Foundation Ireland (SFI)	x	x	x	Yes	Yes	RG

Note: RG = Research Grants (charged by direct or indirect costs); SF = Supplemental Funding; PA = Publisher agreement; UN = Unknown. * inconsistent results between sources; results reflect most recent information discovered. † HEFCE was replaced by Research England (under the URKI umbrella) in 2018; UKRI provides the OA block grant referenced here as SF for HEFCE.

Source: Compiled by Science-Metrix using MELIBEA (http://www.accesoabierto.net/politicas/?idioma=en), ROARMAP (https://roarmap.eprints.org/) and ScienceDirect (https://www.scienceeurope.org/wp-content/uploads/2016/10/SE_OpenAccess_SurveyReport.pdf) data.

Put differently, and accounting for Horizon 2020 at the pan-European level, it is 40 out of the 58 RFOs in the table that supported OA publishing by their grantees. OA support mechanisms were uniformly split into two main modalities: 17 RFOs encouraged or required their grantees to use their attributed research grants ('RG') to pay for APC, and 20 offered supplemental funding ("SF") where grants are supplemented with additional funding earmarked specifically to cover APC. The German Research Foundation used both mechanisms. A third support modality was made up of agreements that enable publishers to directly bill RFOs for APC. This modality was used by the Helmholtz Association of German Research Centres and the Italian National Institute for Nuclear Physics.

Table 24 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 – part 2 of 2

Country	Reaseach Funding Organisations (RFOs)	Science Europe member	MELIBEA	ROARMAP	Main source of national funds	Covers costs of OA publishing	Mechanism
IT	Ministero dell'Istruzione dell'Università e della Ricerca (Miur)		x		Yes	UN	UN
IT	National Research Council (CNR)	x			Yes	UN	UN
IT	National Institute for Nuclear Physics (INFN)	x			Yes	Yes	PA
LV	Latvian Science Council (LZP)	x			Yes	UN	UN
LT	Research Council of Lithuania (LMT)	x		x	Yes	Yes	RG
LU	National Research Fund (FNR)	x			Yes	Yes	RG
NL	Netherlands Organisation for Scientific Research (NWO)	x	x	x	Yes	Yes	SF *
NO	Research Council of Norway (RCN)	x	x	x	Yes	Yes	SF *
PL	Foundation for Polish Science (FNP)	x			Yes	UN	UN
PL	National Science Centre (NCN)	x			Yes	Yes	RG
PT	Foundation for Science and Technology (FCT)	x	x	x	Yes	Yes	RG
SK	Slovak Research and Development Agency (APVV)	x			Yes	UN	UN
SI	Slovenian Research Agency (ARRS)	x			Yes	UN	UN
ES	Spanish National Research Council (CSIC)	x			Yes	Yes	SF
SE	Swedish Research Council for Health, Working Life and Welfare (FORTE)	x	x		Yes	Yes	SF
SE	Swedish Research Council for Sustainable Development (FORMAS)	x	x	x	Yes	Yes	RG
SE	Swedish Research Council (VR)	x	x	x	Yes	Yes	RG
CH	Swiss National Science Foundation (SNSF)	x	x	x	Yes	Yes	RG
UK	Research Councils UK (RCUK)	x		x	Yes	Yes	SF
UK	Arts and Humanities Research Council (AHRC)	x	x	x	Yes	Yes	SF
UK	Biotechnology and Biological Sciences Research Council (BBSRC)	x	x	x	Yes	Yes	SF
UK	Engineering and Physical Sciences Research Council (EPSRC)	x	x	x	Yes	Yes	SF *
UK	Economic and Social Research Council (ESRC)	x	x	x	Yes	Yes	SF
UK	Medical Research Council (MRC)	x	x	x	Yes	Yes	SF
UK	Natural Environment Research Council NERC)	x	x	x	Yes	Yes	SF
UK	Science and Technology Facilities Council (STFC)	x	x	x	Yes	Yes	SF
UK	Higher Education Funding Council for England (HEFCE) †		x	x	Yes	Yes	SF
UK	Higher Education Funding Council for Wales (HEFCW)		x		Yes	UN	UN
UK	National Institute for Health Research (NIHR)		x		Yes	Yes	RG
UK	Scottish Funding Council (SFC)		x		Yes	Yes	SF

Note: RG = Research Grants (charged by direct or indirect costs); SF = Supplemental Funding; PA = Publisher agreement; UN = Unknown. * inconsistent results between sources; results reflect most recent information discovered. † HEFCE was replaced by Research England (under the URKI umbrella) in 2018; UKRI provides the OA block grant referenced here as SF for HEFCE.

Source: Compiled by Science-Metrix using MELIBEA (http://www.accesoabierto.net/politicas/?idioma=en), ROARMAP (https://roarmap.eprints.org/) and ScienceDirect (https://www.scienceeurope.org/wp-content/uploads/2016/10/SE_OpenAccess_SurveyReport.pdf) data.

The previous indicator (i.e. RFOs providing funds to cover costs of OA publishing) does not provide a quantitative measure of the extent to which APC are covered in a given country. Accordingly, it cannot be used to monitor progress in this regard. To compensate for these limitations, a complementary quantitative metric has been computed, that is the 'share of a country's main RFOs' publications available in OA.' The papers supported by a given RFO were identified based on the funding acknowledgement data in the Web of Science. Once the papers of an RFO were identified, the indicator was computed in the same way as was done for countries under the Headline indicator for Priority 5b (i.e. Share of a country's publications available in OA).

The share of an RFO's publications available in OA might appear redundant with the Headline indicator for Priority 5b (i.e. Share of publications available in OA). However, figures for the Headline indicator could be very different as they cover a broad variety of publications, including those funded through other sources such as private research foundations, the EU and other transnational funding sources. The portion of EU-funded publications in a given country can be quite large (unpublished work on the UK indicates that EU-funded papers could account for as much as 20 % of its total output). Since EU funding covers APC, this could inflate a country's score relative to one or more of the country's national RFOs.

Table 25 and Table 26 show that RFOs covering APCs had, on average and by a good margin, higher shares of total OA papers (65 %), gold OA papers (40 %) and green OA papers (48 %) relative to

non-APC-covering RFOs (55 %, 30 % and 40 %) and those with an unknown APC status (48 %, 28 % and 31 %). The gaps between RFOs covering APCs and non-APC-covering RFOs were similar across OA types (i.e. roughly 10 percentage points). A similar gap was observed between APC-covering RFOs and RFOs of an unknown APC status for gold OA (12 points), while the gap was notably higher for green OA (18 points).

Table 25 focuses on OA figures for APC-covering RFOs. UK RFOs take up 9 of the top 10 positions, with Italy being the only other country with an RFO (the Italian National Institute for Nuclear Physics) in the top 10. The range of scores retrieved on these metrics for APC-covering RFOs is considerable, with gaps of at least 50 percentage points between bottom and top figures for the share of total (gap of 50 percentage points), gold (54) and green (67) OA. Note that the range across funders is similar across OA types and that the ratio of gold to green OA is below one (0.83); on average green OA surpassed gold OA by about 20 %. For instance, many funders scored much higher in green OA than in gold OA; 17 funders had shares of green OA at least 10 percentage points greater than their shares of gold OA. Among them, the UK Science and Technology Facilities Council (STFU; 87 %), the INFN (79 %), the UK Higher Education Funding Council for England (76 %) and the UK Natural Environment Research Council (71 %) have scores substantially above the 50 % mark for the share of green OA. Nonetheless, the Leibniz Association, the Research Council of Lithuania, the Swedish Research Council for Health (FORTE), the Health Research Board (Ireland) and the UK Medical Research Council scored higher in gold than in green OA by more than 5 percentage points. Horizon 2020, the European Commission's Framework Programme for Research and Technological Development ranks 26th out of the 39 APC-covering RFOs in terms of the share of total OA papers.

Table 26 presents OA shares for RFOs not covering APC or of unknown status in this regard. Generally, figures here are much lower than those observed for the RFOs that do cover APC costs. Whereas 32 out of 39 APC-covering RFOs (82 %) had total OA shares above 50 %, this proportion drops to 3 out of 6 RFOs (50 %) that do not cover APCs and 4 out of 12 RFOs (33 %) with unknown status concerning APC. Among non-APC-covering RFOs and RFOs with an unknown APC status, those running counter to these broader trends are the Danish National Research Foundation, the French Institute of Health and Medical Research and the UK Higher Education Funding Council for Wales.

The Danish RFOs represent a particularly noteworthy case, accounting for 5 out of the 6 RFOs who do not cover APCs. The Danish councils released a joint policy that demands grant holders to make their publications available in OA in whatever form is possible for them, but without providing funding to support this operation. In sum, the Danish councils represent the majority of the RFOs assessed here that do not cover APC costs, and yet they have quite a strong OA policy in other regards. Thus, perhaps unintuitively, it may be that the funders with the least robust commitment to OA are those whose policies towards APC payment are unknown, rather than those funders whose policies are not to pay APCs; recall that the RFOs with an unknown APC status ranked lowest in terms of average share of total/gold/green OA papers.

Table 25 Share of a country's main RFOs' scientific publications available in OA (2016) – part 1 of 2

Country	Research Funding Organisations (RFOs)	Total OA	Gold OA	Green OA
	Funders covering costs of OA publishing	64.7%	40.1%	48.3%
	Funders not covering costs of OA publishing	54.7%	29.8%	38.9%
	Funders unknown status covering costs of OA publishing	47.7%	27.9%	30.8%
Funders covering costs of OA publishing				
UK	Science and Technology Facilities Council (STFC)	90.3%	53.7%	87.4%
UK	Medical Research Council (MRC)	87.9%	74.4%	63.5%
UK	Biotechnology and Biological Sciences Research Council (BBSRC)	85.5%	67.3%	62.6%
UK	Higher Education Funding Council for England (HEFCE) †	85.3%	64.4%	76.4%
UK	Natural Environment Research Council NERC)	83.0%	44.9%	70.7%
UK	Scottish Funding Council (SFC)	80.7%	52.8%	59.2%
IT	National Institute for Nuclear Physics (INFN)	80.4%	27.5%	78.6%
UK	National Institute for Health Research (NIHR)	79.4%	61.7%	58.6%
UK	Economic and Social Research Council (ESRC)	78.8%	47.2%	65.4%
UK	Engineering and Physical Sciences Research Council (EPSRC)	76.9%	33.3%	65.8%
AT	Austrian Science Fund (FWF)	74.1%	48.9%	43.7%
UK	Arts and Humanities Research Council (AHRC)	72.4%	32.4%	57.9%
DE	Max Planck Society (MPG)	71.8%	50.3%	55.0%
HU	Hungarian Academy of Sciences (MTA)	69.1%	31.4%	60.8%
NL	Netherlands Organisation for Scientific Research (NWO)	68.4%	44.7%	49.9%
DE	Leibniz Association	67.9%	59.6%	26.2%
ES	Spanish National Research Council (CSIC)	66.2%	35.6%	57.5%
CH	Swiss National Science Foundation (SNSF)	65.1%	37.6%	50.0%
HU	Hungarian Scientific Research Fund (OTKA)	64.3%	25.5%	55.4%
SE	Swedish Research Council for Health, Working Life and Welfare (FORTE)	63.3%	48.8%	37.8%
BE	Fonds de la Recherche Scientifique (FRS-FNRS)	62.9%	35.4%	48.3%
IE	Health Research Board (HRB)	62.0%	47.5%	38.9%
SE	Swedish Research Council (VR)	61.3%	41.8%	39.2%
DE	Helmholtz Association of German Research Centres	60.8%	31.5%	46.9%
NO	Research Council of Norway (RCN)	60.1%	36.6%	47.6%
EU-28	European Commission: Horizon 2020	59.5%	36.4%	43.1%
FI	Academy of Finland (AKA)	56.9%	33.0%	42.3%
LU	National Research Fund (FNR)	56.7%	29.5%	42.9%
BE	Research Foundation Flanders (FWO)	56.7%	34.1%	40.5%
IE	Science Foundation Ireland (SFI)	56.2%	30.8%	44.2%
DE	German Research Foundation (DFG)	54.4%	35.4%	32.8%
SE	Swedish Research Council for Sustainable Development (FORMAS)	51.4%	36.6%	34.0%
PL	National Science Centre (NCN)	49.7%	32.1%	28.7%
EE	Estonian Research Council (ETAG)	49.5%	32.3%	35.2%
IS	Iceland Centre for Research (Rannis)	48.0%	26.0%	34.5%
PT	Foundation for Science and Technology (FCT)	42.1%	20.4%	31.3%
EE	Ministry of Education and Research	41.8%	28.7%	27.5%
LT	Research Council of Lithuania (LMT)	41.2%	28.4%	20.5%
CZ	Czech Science Foundation (GACR)	40.6%	23.9%	24.1%

Note: Because of recent litigation issues related to the illegal sharing of content on social platforms, and to align with open access definitions at the European Commission regarding unencumbered open access, content from platforms such as ResearchGate and Academia.edu are not accounted for in these statistics. This results in lower open access levels compared to those presented in the previous edition as these platforms were included at the time.
Gold OA may be overestimated, at the expense of green open access, because of recent efforts by 1science to codify sources of gold open access (e.g. publishers' websites), which are easier to identify than green OA sources.
The status of the funders covering cost of OA publishing was evaluated as of August 2018.
(:) = missing data

Source: Prepared by Science-Metrix using data from the Web of Science (Clarivate Analytics) and 1findr (1Science).

Table 26 Share of a country's main RFOs' scientific publications available in OA (2016) – part 2 of 2

Country	Research Funding Organisations (RFOs)	Total OA	Gold OA	Green OA
	Funders covering costs of OA publishing	64.7%	40.1%	48.3%
	Funders not covering costs of OA publishing	54.7%	29.8%	38.9%
	Funders unknown status covering costs of OA publishing	47.7%	27.9%	30.8%
Funders not covering costs of OA publishing				
DK	Danish National Research Foundation (DG)	70.8%	39.2%	56.3%
FR	French National Research Agency (ANR)	59.3%	31.0%	43.4%
DK	Danish Council for Independent Research (DFF)	58.8%	36.4%	39.5%
DK	Danish Council for Strategic Research (DCSR)	48.7%	30.6%	33.3%
DK	Danish Council for Technology and Innovation (DCTI)	47.2%	16.7%	36.1%
DK	Danish National Advanced Technology Foundation (DNATF)	43.3%	24.7%	24.7%
Funders unknown status covering costs of OA publishing				
FR	French National Institute of Health and Medical Research (INSERM)	66.0%	55.8%	30.4%
UK	Higher Education Funding Council for Wales (HEFCW)	65.6%	31.3%	50.0%
HR	Croatian Science Foundation (HRZZ)	58.4%	28.7%	45.0%
PL	Foundation for Polish Science (FNP)	57.8%	33.7%	37.7%
SI	Slovenian Research Agency (ARRS)	49.2%	28.4%	30.7%
IE	Higher Education Authority (HEA)	46.2%	23.6%	36.3%
IE	Irish Research Council (IRC)	45.8%	23.0%	36.4%
IT	Ministero dell'Istruzione dell'Università e della Ricerca (Miur)	44.9%	28.7%	25.9%
SK	Slovak Research and Development Agency (APVV)	42.5%	24.0%	25.4%
IT	National Research Council (CNR)	41.3%	30.2%	22.0%
LV	Latvian Science Council (LZP)	27.4%	12.3%	13.7%
BG	Bulgarian Academy of Sciences (BAS)	27.1%	15.0%	15.9%

Note: Because of recent litigation issues related to the illegal sharing of content on social platforms, and to align with open access definitions at the European Commission regarding unencumbered open access, content from platforms such as ResearchGate and Academia.edu are not accounted for in these statistics. This results in lower open access levels compared to those presented in the previous edition as these platforms were included at the time.
Gold OA may be slightly overestimated, at the expense of green open access, because of recent efforts by 1science to codify sources of gold open access (e.g. publishers' websites), which are easier to identify than green OA sources.
The status of the funders covering cost of OA publishing was evaluated as of August 2018.
(:) = missing data

Source: Prepared by Science-Metrix using data from the Web of Science (Clarivate Analytics) and 1findr (1Science).

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

Unless a survey would have been designed and sent to a large number of RPOs in Europe, it would not have been possible to produce the original EMM indicator of the ERAC committee, namely the share of RPOs making their research data available in OA. To avoid increasing the administrative burden on RPOs, an alternative metric was developed: the share of life sciences papers to which a country contributed and that have at least one open data set in Figshare. Figshare is a research data management and sharing platform integrated in article submission systems from publishers including PloS and others.

Figshare provides almost 90% of OpenAire – a network of OA repositories – content on research data. Since OpenAire was developed to implement the European Commission's and the European Research Council's OA policies, Figshare appears as a key information source for measuring OA to research data. Using Figshare data sets, internationally comparable data can be gathered for all 44 ERA countries for the 2013-2017 period. Indeed, the content of Figshare is at least 90 % complete for 2017. The fact that Figshare is fully integrated with a scientific data's manuscript submission system carries many benefits, the main one being that nearly every data set it contains is linked to a peer-reviewed scientific publication. By matching the linked publications in a bibliographic database such as the WoS, it is then possible to retrieve information on the geographic location of the authors to compute the indicator. This also enables limiting the analysis to 'peer-reviewed' data sets, a key advantage given the prevailing variation in the quality of data sets that are currently uploaded in OA repositories, some of which are simply not related to research.

It should be noted that peer-reviewed OA datasets in Figshare are mostly provided by submissions to PloS One (this source accounts for nearly 90 % of data sets), a general science & technology journal focusing on the life sciences (96 % life sciences papers based on a random sample of 50 papers). Thus, although Figshare is a generalist repository for data sets in any field of science, it

does not equally cover all areas of science and the number of papers with at least one OA data set in Figshare must therefore be normalised by the total number of a country's papers in the life sciences. Over the 2013-2017 period, nearly half of PloS One papers have at least one open data set in Figshare. The very high performance of PloS One in this regard is likely due to its policy requiring researchers to share the data underlying their papers.[35] Thus, before the proposed indicator on OA data sets can be applied more broadly to all fields of science in monitoring progress on Priority 5b of 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 publishers 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 data sets 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.

Within EU-28 Member States, an average of 2.6 % of 2017 life sciences papers had associated data sets deposited in Figshare. While this indicator is new to this edition, average annual growths can be calculated for 2013 to 2017. Growth was found to be at an average annual rate of 2.6 % for the EU-28 countries. Among ERA countries, nearly half (21) moved by more than three positions in the ranking from 2013 to 2017. Those with the strongest increases in ranks included FYR Macedonia (from 40th to 20th), Poland (from 35th to 19th), Norway (from 15th to 2nd) and Albania (from 40th to 28th). Apart from Norway, this is consistent with their average annual growth rates which were among the highest across ERA countries (CAGR near 30 %; note that for Albania, the CAGR is undefined because it started from a score of 0 %). Norway progressed a lot in the ranking because it combined a good score early in 2013 (2.4 %) with a decent growth (CAGR of 12.5 %). Although Serbia experienced the strongest growth on this indicator with 31.3 % average annual increases, it did not move much in the ranking since it started from a very low point in 2013 (0.3 %). The strongest declines in the ranking were observed for Cyprus (from 6th to 23rd), Ukraine (from 25th to 40th), Iceland (from 3rd to 17th) and Latvia (from 26th to 37th). Here again, these changes are consistent with their average annual growth rates which were the lowest among ERA countries all below -10 %.

Distribution of scores is rather narrow on this indicator, but slightly more countries are found below the unweighted ERA average (24 in Clusters 3 and 4) than above (20 in Clusters 1 and 2). That said, most of the combined ERA GDP (for countries with GDP scores in 2017) is found above (78 % mostly in Cluster 2) rather than below (22 %) the ERA average. This is because most of the large economies (i.e. France, Germany, the UK and Spain) are found just above the ERA average along with several medium economies. The most performing country group (Cluster 1) included the Republic of Moldova, Norway, Georgia, Estonia and Luxembourg, most of which are small economies. The group of least performing countries (Cluster 4) showed scores between 1 % and 0 %. The group of countries immediately below the unweighted ERA average (Cluster 3) was large for this indicator with 18 members.

Inequalities were moderate among ERA countries and also appeared to be reducing. The Gini coefficient was equal to 0.360 in 2013 and had steadily decreased to 0.283 in 2017. The group of least performing countries register the largest average annual growth, but measurements were only obtained for half of the six countries it included. Nevertheless, with the most performing group of countries showing the slowest growth, prospects were pointing towards further inclusion.

[35] Lisa M. Federer et al., "Data Sharing in PLOS ONE: An Analysis of Data Availability Statements," *PLOS ONE* 13, no. 5 (May 2, 2018): e0194768, https://doi.org/10.1371/journal.pone.0194768.

Table 27 Share of life sciences papers to which a country contributed and that have at least one open data set in Figshare (2013–2017)

Country	Weight in GDP	Score (2017)	CAGR (2013-17)	Lead/Gap to EU-28 CAGR	Trendline
EU-28		**2.6%**	**2.6%**	**N/A**	
Cluster 1	2.5%	3.9%	1.9%	-0.7	
Cluster 2	75.2%	2.7%	5.3%	2.7	
Cluster 3	17.6%	1.6%	2.6%	0.0	
Cluster 4	4.7%	0.4%	11.3%	8.7	
Cluster 1					
MD	:	4.9%	-6.3%	-8.9	
NO	2.1%	3.8%	12.5%	9.9	
GE	:	3.7%	3.2%	0.7	
EE	0.1%	3.6%	5.6%	3.0	
LU	0.3%	3.5%	-5.7%	-8.3	
Cluster 2					
SE	2.8%	3.1%	-0.5%	-3.0	
CH	3.5%	3.0%	3.7%	1.1	
NL	4.3%	2.9%	3.0%	0.5	
AT	2.2%	2.8%	2.7%	0.1	
FR	13.4%	2.8%	-0.1%	-2.7	
DK	1.7%	2.8%	0.2%	-2.4	
FI	1.3%	2.8%	1.4%	-1.2	
DE	19.1%	2.8%	3.9%	1.3	
UK	13.6%	2.7%	1.1%	-1.4	
ES	6.8%	2.7%	7.4%	4.8	
CZ	1.1%	2.7%	7.6%	5.0	
BE	2.6%	2.3%	-0.1%	-2.6	
IS	0.1%	2.3%	-8.1%	-10.6	
PL	2.7%	2.2%	28.1%	25.5	
MK	0.1%	2.1%	*29.0%*	26.4	
Cluster 3					
IE	1.7%	2.1%	0.5%	-2.1	
IL	:	2.0%	4.3%	1.7	
HU	0.7%	1.9%	-3.1%	-5.6	
SI	0.3%	1.9%	-2.9%	-5.5	
IT	10.0%	1.9%	3.0%	0.4	
CY	0.1%	1.9%	-10.7%	-13.3	
PT	1.1%	1.9%	-4.7%	-7.3	
AL	:	1.7%	:	:	
AM	:	1.7%	-4.7%	-7.3	
SK	0.5%	1.6%	8.3%	5.8	
LT	0.2%	1.5%	26.8%	24.3	
RO	1.1%	1.5%	1.8%	-0.8	
EL	1.0%	1.4%	0.6%	-2.0	
HR	0.3%	1.4%	7.3%	4.7	
BG	0.3%	1.3%	22.4%	19.8	
TN	:	1.3%	4.7%	2.1	
LV	0.2%	1.2%	-9.6%	-12.2	
BA	:	1.1%	0.6%	-2.0	
Cluster 4					
RS	0.2%	1.0%	31.3%	28.7	
UA	:	0.9%	-17.3%	-19.9	
TR	4.4%	0.4%	19.9%	17.3	
MT	0.1%	0.0%	:	:	
ME	:	0.0%	:	:	
FO	:	0.0%	:	:	

Note: Exception to reference period for CAGR: MK (2014-2017)
(:) = missing data
Source: Computed by Science-Metrix using Figshare and WoS (Clarivate Analytics) data.

Comparing Headline to complementary EMM indicators

Given a change in definitions of OA between the last and the current *ERA Progress Report*, the EU-28 share of 2016 publications that are available in any form of OA now stands at 49 %. Larger shares of gold OA papers (43 %) are now registered than green OA publications (26 %), a reversal of the

situation observed in the 2016 Report. Note, however, that the gap between the share of gold and green OA papers is likely overestimated.

Part of this change can be connected to the findings obtained from an analysis of RFO policies and of the publications they support. As noted above, an analysis simply reporting the presence or absence of OA policies in a given context overlooks valuable information such as the scope and extent of those individual policies, such that it cannot offer a meaningful reflection of the effectiveness of the policy mix. Nevertheless, it is worth noting that the share of publications available in OA is slightly larger for RFOs having OA policies and mechanisms that provide financial support to grantees for publishing in gold OA. Publications supported by RFOs with such mechanisms in place were, on average, OA in 65% of cases, compared to 55% of publications supported by RFOs without a mechanism and 48% of publications associated with RFOs with unknown availability of support. The margins between those figures were accentuated for gold OA publications and reduced in the case of green OA publications.

3.5.7 Additional policy highlights 5b

Financial issues and negotiation with publishers: Fast development has been observed in the market to pay for OA via Article Processing Charges and a number of European and national RFOs are supporting it by providing financial resources, block grants and publishing programmes. RPOs across ERA countries have also made resources available to support it. Nonetheless, many ERA countries regard the lack of additional funding for implementation of OA policies as a problem, particularly for curation of data, but also for sustainable funding for established infrastructures. Many ERA countries also share the opinion that in order to get acceptable prices for licences, negotiations with major international scientific publishers need to be moved to the EU level and highlight the importance of transparency of negotiations (EC, 2018c). A very recent development is the launch of Plan S and cOAlition S, an initiative put forward by 11 RFOs[36], with support from the European Commission, with the aim that by 2020 all new scientific publications funded by them will be freely available from the moment of publication (Enserink, 2018).

OA awareness and HR resources: Educational campaigns and awareness-raising events on OA are part of NAPs in several ERA countries. Such events are not only targeted at researchers and RPO staff but also at the general public. For example, in January 2018, a one-day workshop entitled 'Open Access in Practice: Dissemination, Visibility, Usage & Impact of Scholarly Research' was organised by the University of Malta (UM) Library in conjunction with OpenAIRE. The event fostered a discussion and exchange of ideas between key stakeholders (researchers, research administrators, policymakers, project managers, funders, librarians, students, etc.) on the adoption of Open Science practices in Malta. Portugal has also published a Letter of Commitment on Open Access in Portugal and held an awareness-raising campaign towards Open Science, including a 'Conference on Data Management Curation' in 2016.

Repositories and e-infrastructures: Billions of euros continue to be invested annually in OA infrastructures by individual governments, universities, research institutes, research libraries and funders. More ERA countries have projects and initiatives or plan to have, to develop national cloud services and/or interoperability of e-infrastructures (EC, 2018c). Despite investments made by the Commission to establish the European Open Science Cloud (EOSC), LERU (2018b) recently recommended a more inclusive and practical approach when developing the EOSC in order to facilitate engagement and outreach of researchers, support staff and service providers at universities.

OA for data: The literature review indicates that the development of OA for data has been slower than for OA of publications despite the ongoing efforts to develop national, shared services and advocacy for data access in the interest of open scrutiny, integrity and reproducibility. Policies and legal measures are diverse across ERA countries and differences in practices are also found across disciplines/research fields. LERU (2018b) has developed recent recommendations for RPOs on research data management. The main categories of recommendations centre around adopting FAIR principles (findable, accessible, interoperable and reusable), modern reward and recognition systems, provision of suitable infrastructures, awareness-raising and training events and collaboration with local, national and international RPOs, RFOs and relevant stakeholders.

[36] Austrian Science Fund, French National Research Agency, Science Foundation Ireland, National Institute for Nuclear Physics (Italy), National Research Fund (Luxembourg), Netherlands Organisation for Scientific Research, Research Council of Norway, National Science Centre Poland, Slovenian Research Agency, Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning and UK Research and Innovation (for more details see reference cOAlition S, 2018).

Main findings

Sub-priority 5a

1. Knowledge transfer remains diverse across Europe. However, an increase of schemes and initiatives regarding open innovation and knowledge transfer adopted by countries and growth of product or process innovative firms' collaboration with governments, public or private research institutes were observed. Nonetheless, transfer of research results to the market needs to be facilitated and a stronger collaboration between industry and academia remains to be encouraged.
2. A combination of financial incentives and supportive regulatory frameworks are identified as essential factors to strengthen the links between business and academia. A decrease of the overall share of public research financed by the private sector was recently registered in most ERA countries (in roughly 60 % of countries).
3. More initiatives have been implemented aiming to enhance interactions and development of research activities between the public and private sectors. However, collaboration between industry and academia, evaluation and monitoring of related research and innovation policies remain challenges.

Sub-priority 5b

1. With open access (OA) evolving and progressing rapidly one can observe that the majority of ERA countries has adopted policies, and to some extent even legal measures for open access to publications. The degree of enforcement, however, remains uneven among countries. Accordingly, while the shares of gold OA papers are currently similar to those of green OA papers at the aggregate level for ERA countries, there remains substantial variance in the ratio of gold to green OA across individual countries. For instance, 23 % of ERA countries had a share of gold OA papers at least five percentage points greater than their share of green OA papers in 2016, while 32 % of ERA countries had a share of green OA papers at least five points greater than their share of gold OA papers.
2. When it comes to monitoring progress of OA policies and initiatives, only a few ERA countries monitor the development and/or growth of open access publications at national level while the majority of countries do not monitor the development/growth of access to research data nor the impact of OA.
3. Turning from OA of research publications to OA of research data, the progress has been much slower and a great diversity of approaches across national contexts and disciplines can be found. Financial and technical challenges relating to the storage and usable formatting of data made available in OA resulted in low shares of papers for which data sets were made available online. Distribution and circulation of data sets emerge as perhaps the next great challenge for OA policy.

3.6 Priority 6 – International cooperation

3.6.1 Policy context

Promoting international cooperation in research and innovation is recognised as an important component for achieving the European Union's long-term goals. It is an integral part of the Innovation Union flagship initiative. It acknowledges the necessity to cooperate with non-EU countries on the major challenges such as energy, food security, climate change, ageing population, and health among others. The principle of the EU to be open to the world demonstrates a strong dedication to international cooperation. The EU recognises the benefits that it brings, such as scientific excellence, brain circulation and knowledge exchange, ability to tackle global challenges, creating a global pool of highly skilled researchers and science diplomacy.

Additionally, the necessity to encourage international cooperation in order to remain relevant and influential in the field of R&I is recognised. Globalisation of research and innovation and rapid developments in emerging economies determine that a large part of knowledge is produced outside of the European Union. To maintain its global standing as a leader in research and innovation and remain competitive, the EU needs to gain access to this knowledge and tackle the existing challenges that include production of the best scientific outputs, commercialisation of research, solving global challenges and lack of adequate human resources. International cooperation in many ways helps to address these issues, for example by contributing to attracting top talent to ensure access to knowledge and improved knowledge sharing, finding solutions to global challenges and establishing international partnerships.

This is also pertinent to individual ERA countries. Countries with less-developed research systems are more susceptible to these challenges. In most cases, these countries are less connected internationally and experience more difficulties in creating partnerships and attracting international talent (European Commission, 2018). Nevertheless, interviewees from both more and less-developed countries identified that they experience problems related to the internationalisation of their research systems.

The Strategic Forum for International Scientific and Technological Cooperation (SFIC) has been designated as the ERA-related group with responsibility for international R&I cooperation and the ERA Roadmap Priority 6. SFIC is crucial for the development and shaping of the international dimension of ERA as it aims at coordinating the activities of individual Member States and the Commission and plays a major role in shaping EU policymaking in international R&I cooperation. Its objective to facilitate further development, implementation and monitoring of the international dimension of ERA has been reinforced in the SFIC Work Programme 2017-2018.

3.6.2 Headline indicator

Within the European context, one of the main outcomes of strategies and actions designed to promote the internationalisation of science and technology, under Priority 6, is the increased propensity of ERA countries to jointly tackle research projects with third countries (i.e. non-ERA countries). Because scientific publications remain the main channel for disseminating and publicising scientific discoveries in most scientific fields, they offer a useful source of information that captures the outcome of S&T strategies on international cooperation in a simple and straightforward manner. Research partners usually co-author their scientific publications. Therefore, using fractional counting, it is possible to count the number of publications of an ERA country that involve at least one co-author from a non-ERA country.

ERAC selected international co-publications with non-ERA partners per 1 000 researchers in the public sector as the Headline indicator for Priority 6. Using the number of researchers in the public sector as a denominator accounts for size differences across countries. The number of international co-publications with non-ERA partners per 1 000 researchers in the public sector can also convey information on the potential effects of such partnerships on the scientific impact of ERA countries, as measured with citations to scientific publications; it is well known that international co-publications have more impact than those publications produced by a single author or through domestic cooperation (Beaudet et al., 2014). However, a specific indicator measuring the impact of ERA/non-ERA co-publications would be necessary to adequately assess this.

This Headline indicator is prone to a number of shortcomings. First, the volume of papers published by individual researchers, as well as the propensity for international cooperation, varies across fields. Consequently, countries' specialisation patterns will affect this indicator. For example, a country well specialised in mathematics will likely be disadvantaged relative to a country well specialised in biomedical research, because researchers publish fewer papers in the former field than in the latter. Similarly, a country well specialised in particle physics, where international cooperation is widespread, will likely be advantaged relative to a country well specialised in the social sciences, where international cooperation is much less common. An alternative for future monitoring exercises

could be to use the total number of publications by a country as the denominator, which would adequately remove the issue related to output size. To account for both issues, a more complex measure that compensates for differences in the specialisation patterns of countries could be developed in a similar manner to that used for the GDRC indicator (see Section 3.4.2).

Second, the Headline indicator can be affected by country size, location and linguistic/historical biases. For example, because large economies (e.g. the US, China, Germany) have access to substantial collaboration opportunities domestically, they are usually less dependent than smaller economies on international partnerships for capacity-building purposes and might therefore not perform as well as smaller countries on this indicator. Additionally, countries at the periphery of ERA or bordering non-ERA countries might have a higher share of non-ERA co-publications. Finally, countries with international languages or countries that have been colonial powers might have a higher share of non-ERA co-publications. Full results for this indicator are provided in Table 28 and shown on a map in Figure 9.

EU-28 Member States have experienced steady increases in non-ERA co-publications since the last monitoring exercise. Average annual growth for EU-28 was found to be 4.4 % in the recent period spanning 2014 to 2016, an intensity similar to that observed over the longer term from 2007 to 2016 (4.2 %).

Country rankings between the 34 states for which data are available (or imputable by a lag of at most one year) both in 2013 and 2016 did not change significantly between the two editions. Only five major movements in ranking (more than 3 positions) can be observed. Bracketing Ireland because of potential shortcomings in this country's data set, the largest increases were observed for Finland (from 13th to 6th), FYR Macedonia (from 33rd to 29th) and Romania (from 27th to 23rd). For FYR Macedonia, this is consistent with its strong short-term average annual growth rate which is the second largest rate among the covered countries (28 % giving it a 23-percentage point lead over EU-28 growth). Finland and Romania had smaller CAGR but started from a higher point in 2014. While Latvia had the largest CAGR (36 %), it did not move up in the ranking as much as the preceding countries because it started from a much lower point in 2014. Montenegro experienced the strongest drop in the ranking (from 22nd to 28th) with one of the largest average annual declines (CAGR of -32 %).

International cooperation as measured by non-ERA co-publications appears to have been very much geographically concentrated. High-GDP countries and smaller western European countries had the strongest performances, such that 84 % of ERA combined GDP was concentrated above the ERA average. The group of countries with the second-best performances (Cluster 2) contained the four largest ERA economies. The most performing group (Cluster 1) contained small economies with strong science and innovation capacities. Clusters 3 and 4 included nearly 60 % of ERA countries while accounting for only 15 % of ERA combined GDP. It contained all the Eastern European and Balkan countries in ERA that were assessed on this indicator.

Scores on this indicator do not show great dispersion, but many are grouped at the lower end of the range. The most performing country group (Cluster 1) comprises Cyprus, Switzerland, Sweden, the Netherlands and Denmark, who led by a wide margin as the only countries with more than 80 co-publications with partners beyond ERA per 1 000 public sector researchers within their own country. Note that Switzerland, home to the European Organization for Nuclear Research (CERN), whose core activities are in particle physics where international cooperation is the norm, is clearly advantaged on this indicator. Furthermore, Switzerland's score is based on only three years of available data (2008, 2010 and 2012) and perhaps does not fully reflect its performance for this indicator. The least performing countries for this indicator, each of whom had fewer than 17 co-publications with non-ERA partners per 1 000 researchers in the public sector, were Montenegro, FYR Macedonia, Serbia, Latvia, Slovakia, Lithuania, Bulgaria, and Bosnia and Herzegovina (with the last using 2014 instead of 2016 as reference year).

Inequalities between countries were moderate on this indicator and had neither reduced nor enlarged since the last ERA monitoring exercise. The Gini coefficient, a common metric used to quantify inequalities in the wealth of nations, was 0.323 in 2016 and 0.325 in 2014. The leading group on this indicator (Cluster 1) had the highest average annual growth in recent years by a good margin (6.7 % CAGR for Cluster 1 compared to 3.9 % for Cluster 3, the next best growth), which might have suggested a trend towards stronger inequalities. Nevertheless, performance and growth for this indicator were not correlated, with strong short-term growth observed among both the leaders and followers. Growth in the group of countries immediately below the unweighted ERA average (Cluster 3) is possibly even stronger than reported when considering that Ireland's negative growth may be associated with a sharp increase in its count of researchers in the public sector.

Long-term average annual growths are only negative for 3 out of 36 countries and are stronger in the least performing countries, indicating good prospects for increased inclusion. Long-term average

annual growths were 6.2 % and 5.1 % for the two groups with the least performing countries (Cluster 3 and 4), slightly above the figures of 3.7 % and 4.9 % found for the two groups of most performing countries (Cluster 1 and 2).

Table 28 Co-publications with non-ERA partners per 1 000 researchers in the public sector (2007-2016)

Country	Weight in GDP	Score (2016)	CAGR			
			Short-term (2014-16)	Lead/Gap to EU-28 CAGR	Long-term (2007-16)	Trendline
EU-28		**54.4**	**4.4%**	**N/A**	**4.2%**	
Cluster 1	12.4%	92.9	6.7%	2.3	3.7%	
Cluster 2	71.3%	59.2	3.5%	-0.9	4.9%	
Cluster 3	14.8%	31.5	3.9%	-0.5	6.2%	
Cluster 4	1.5%	13.3	1.9%	-2.5	5.1%	
Cluster 1						
CY	0.1%	102.2	9.8%	5.4	7.4%	
CH	3.6%	*96.2*	:	:	*0.5%*	
SE	2.8%	94.0	4.9%	0.5	2.6%	
NL	4.3%	91.5	3.8%	-0.6	4.7%	
DK	1.7%	80.5	8.5%	4.1	3.3%	
Cluster 2						
UK	14.5%	69.5	6.6%	2.2	5.5%	
FI	1.3%	63.0	11.0%	6.6	9.2%	
BE	2.5%	62.6	0.7%	-3.7	2.9%	
IS	0.1%	62.6	*1.2%*	-3.2	7.8%	
AT	2.1%	62.0	5.0%	0.6	3.2%	
NO	2.0%	56.3	0.5%	-3.9	4.1%	
FR	13.3%	*55.4*	*-0.3%*	-4.7	*3.1%*	
IT	10.1%	55.0	3.4%	-1.0	3.3%	
ES	6.7%	54.3	5.9%	1.6	9.1%	
DE	18.9%	51.4	1.2%	-3.1	0.6%	
Cluster 3						
SI	0.2%	43.6	8.1%	3.8	7.2%	
IE	1.7%	42.9	-13.2%	-17.6	-3.1%	
LU	0.3%	39.0	-3.8%	-8.1	14.8%	
CZ	1.1%	37.3	5.6%	1.2	7.1%	
MT	0.1%	37.1	15.5%	11.1	14.2%	
PT	1.1%	35.8	4.3%	-0.1	9.8%	
HU	0.7%	35.7	3.8%	-0.6	2.5%	
EE	0.1%	27.7	6.3%	1.9	9.3%	
RO	1.0%	24.4	8.4%	4.0	6.3%	
EL	1.0%	24.3	6.9%	2.5	-1.5%	
TR	4.7%	*23.4*	*6.4%*	2.1	*4.6%*	
HR	0.3%	20.6	-0.7%	-5.0	5.6%	
PL	2.5%	*17.7*	*2.4%*	-2.0	*3.9%*	
Cluster 4						
ME	0.0%	*17.0*	*-31.9%*	-36.3	*-6.4%*	
MK	0.1%	15.6	27.8%	23.4	10.4%	
RS	0.2%	15.6	-1.0%	-5.3	*3.3%*	
LV	0.2%	14.2	35.5%	31.1	14.8%	
SK	0.5%	12.4	9.0%	4.6	3.2%	
LT	0.2%	12.3	7.5%	3.1	8.3%	
BG	0.3%	11.0	2.8%	-1.5	2.1%	
BA	0.1%	*8.5*	*-34.5%*	-38.9	:	

Note: Break in time series: HR (2016); 2007 (DK, NO); 2011 (FI, RO, SI); FR (2010); DE (2014, 2016); EL (2011); NL (2012); PT (2008, 2013); SE (2007, 2011, 2013); IS (2011, 2013). Definition differs: HR (2012-2015); 2007-2009 (FR, NO); DE (2015-2016); NL (2007-2015); SK (2007-2014); SE (2007); CH (2008, 2010, 2012, 2014, 2015). Estimated: EU28 (2008-2010); AT (2008, 2010, 2012, 2014); DK (2016); 2007 (EL, LU); IE (2007, 2011, 2013); IT (2015); LU (2007); SE (2007-2015); UK (2007, 2008). Provisional: 2016 (EU-28, AT, CY, CZ, IT, LU, MT, NL, PT, SI, SE, UK); 2015 (DK, FR). Potential outlier: PT (2007). Exception to reference year: 2015 (FR, PL, ME, TR); BA (2014); CH (2012). Exception to reference period for short-term CAGR: 2013-2015 (FR, PL, ME, TR); IS (2013-2016); BA (2012-2014). Exception to reference period for long-term CAGR: 2007-2015 (FR, PL, TR); RS (2008-2016); CH (2008-2012); ME (2011-2015). Data unavailable: AL, AM, FO, GE, IL, MD, TN, UA
(:) = missing data

Source: Computed by Science-Metrix using WoS data (Clarivate Analytics) and Eurostat data (online data code: rd_p_persocc).

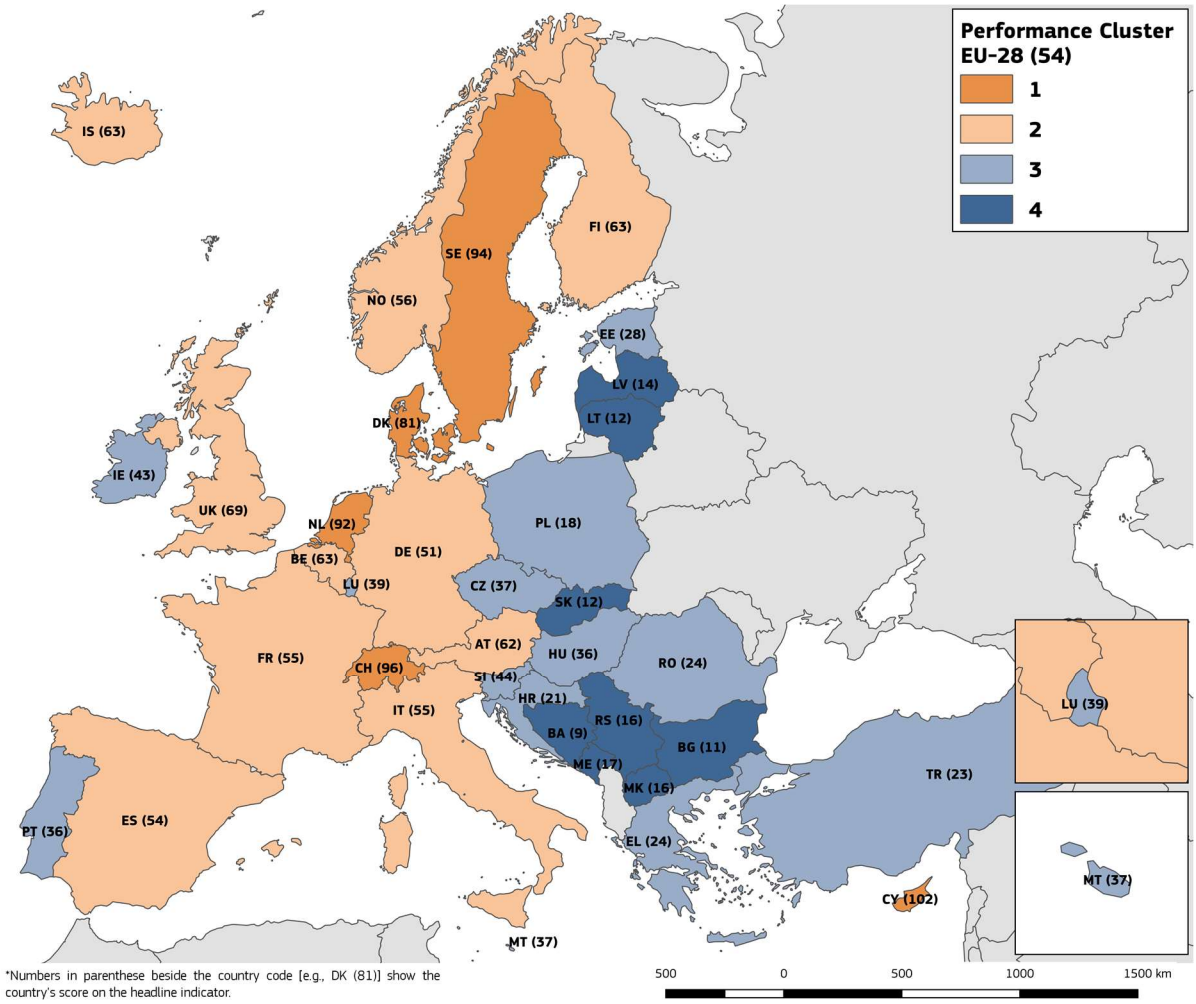

Figure 9 Map pf co-publications with non-ERA partners per 1 000 researchers in the public sector (2016)

Note: As per Table 28.
Source: Computed by Science-Metrix using WoS data (Clarivate Analytics) and Eurostat data (online data code: rd_p_persocc).

3.6.3 Complementary EMM indicators

The three complementary EMM indicators identified by ERAC to track progress towards achieving ERA on Priority 6 are the number of foreign doctorate students as a share of all doctorate students, the knowledge-intensive services exports as percentage of total services exports and the exports of medium and high technology products as a share of total product exports. Note that the last two replace the indicator *Licence and patent revenues from abroad as a share of GDP* originally selected by ERAC. The data source for this indicator is now discontinued and the indicator had to be replaced. Refer to the 2018 ERA Monitoring Handbook for details on their policy relevance and the rationale behind the change.

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

By attracting outstanding researchers from abroad, ERA will improve its capacity to address grand challenges and increase its competitiveness. Enrolling international students represents the first step towards this goal. It is therefore relevant to monitor the openness and attractiveness of each country's education system and research institutions to foreign students. Accordingly, the first complementary EMM indicator selected by ERAC for Priority 6 shows the percentage of a country's doctoral students who come from a country outside the EU. As was the case with the Headline indicator for this priority, this indicator is affected by country size, location and historical biases. Full results are shown in Table 29.

Shares of non-EU doctoral students were increasing moderately in recent years (from 2013 to 2016) at the EU-28 level, while some countries experienced strong surges on this indicator. For EU-28 Member States altogether, 14% of doctorate students held non-EU nationalities. From 2013 to 2016, annual average growth within EU-28 Member States has been measured at 3.8 %. Countries with noteworthy growth rates include FYR Macedonia, whose annual average growth is 103 %, Lithuania

(49 %) and Cyprus (41 %). FYR Macedonia's growth rate was such that it moved up from 22nd place in 2013 to 1st place in 2016, the only movement greater than 6 positions in the ranking. Malta has seen its share of non-EU doctoral students reduce, at an average annual rate of -15 %, but this case represented the only notable decrease (by more than -6 %) among ERA countries. Malta lost 6 places in the ranking from 2013 to 2016 moving from 27th to 33rd.

The economic weight of ERA countries was mostly split between Cluster 1 (38 % of combined ERA GDP including France and the UK) and Cluster 3 (47 % of combined ERA GDP including Italy, Germany and Spain) on this indicator. Accordingly, there was no clear relationship between economic performances and scores on this indicator.

Strong performers in terms of shares of non-EU doctoral students included some large economies, smaller countries with advanced research and innovation systems, and FYR Macedonia. This latter country was the strongest performer. It was followed by France, Belgium, the UK, Luxembourg, Sweden and the Netherlands. Shares in non-EU doctoral students for the group of least performing countries (Cluster 4; i.e. Croatia, Slovakia, Poland, Malta and Greece) were equal to or below 2.5 %.

Scores for this indicator, although limited to a small range from 0 % to 34 %, were rather skewed leading to the ERA average (13 %) being closer to the lower than the upper limit of this range. Accordingly, moderate-to-high inequalities are to be found among ERA countries on this indicator. Recent growth rates were not indicative of any pattern towards greater inclusion. Performance and growth showed no meaningful correlation for this indicator, as stronger and weaker performers were similarly likely to experience growth. That said, the group of least performing countries (Cluster 4) had the smallest average CAGR of the 4 groups (3.5 % compared to figures between 9.4 % and 18.3 % for the other groups of countries). Despite this, the Gini coefficient for scores on this indicator went down from 0.474 in 2013 to 0.427 by 2016, thereby indicating that inequalities actually decreased over that period.

Table 29 Non-EU doctorate students as a share of all doctorate students (2013-2016)

Country	Weight in GDP	Score (2016)	CAGR (2013-16)	Lead/Gap to EU-28 CAGR	Trendline
EU-28		**13.9%**	**3.8%**	**N/A**	
Cluster 1	37.7%	29.2%	18.3%	14.4	
Cluster 2	11.4%	16.8%	9.4%	5.6	
Cluster 3	46.5%	6.5%	16.3%	12.4	
Cluster 4	4.4%	1.7%	3.5%	-0.3	
Cluster 1					
MK	0.1%	33.4%	103.2%	99.4	
FR	13.3%	31.8%	-1.6%	-5.4	
BE	2.5%	31.4%	8.0%	4.2	
UK	14.4%	29.7%	1.5%	-2.3	
LU	0.3%	29.1%	*9.7%*	5.9	
SE	2.8%	24.3%	1.6%	-2.2	
NL	4.2%	24.3%	5.4%	1.5	
Cluster 2					
PT	1.1%	22.6%	26.4%	22.6	
CH	3.6%	17.8%	-1.5%	-5.3	
IE	1.6%	17.4%	9.9%	6.1	
DK	1.7%	16.6%	3.4%	-0.4	
IS	0.1%	15.1%	19.9%	16.1	
FI	1.3%	14.9%	9.9%	6.1	
NO	2.0%	13.3%	-1.9%	-5.8	
Cluster 3					
ES	6.7%	11.6%	-1.8%	-5.6	
IT	10.1%	10.8%	2.5%	-1.4	
AT	2.1%	10.6%	-1.2%	-5.0	
EE	0.1%	8.1%	23.1%	19.3	
TR	4.7%	7.0%	*22.6%*	18.7	
HU	0.7%	6.9%	27.7%	23.8	
CZ	1.1%	6.3%	11.6%	7.8	
RS	0.2%	*6.1%*	*14.2%*	10.4	
SI	0.2%	*5.4%*	*11.8%*	8.0	
LV	0.1%	5.2%	20.6%	16.8	
LT	0.2%	4.3%	48.5%	44.7	
DE	18.8%	4.1%	7.3%	3.5	
BG	0.3%	4.0%	9.4%	5.6	
CY	0.1%	3.7%	40.7%	36.9	
RO	1.0%	2.9%	7.1%	3.3	
Cluster 4					
HR	0.3%	2.5%	15.0%	11.2	
SK	0.5%	2.1%	5.4%	1.5	
PL	2.6%	1.7%	8.3%	4.5	
MT	0.1%	1.6%	-14.5%	-18.4	
EL	1.0%	0.8%	:	:	

Note: Definition differs: EU-28 (2014-2016); DE (2016); EL (2015, 2016); PL (2014)
Estimated: LU (2014)
Break in series: Science-Metrix detected a strong gap from 2014 to 2015 for MK. According to Eurostat's flags, there is no issue with the data.
Eurostat country flags have been retained in the EU-28 aggregate
Imputed data in EU-28 aggregate for: EL (2013-2014); LU (2013); SI (2016); ES (2014-2015)
Exception to reference year: 2015 (SI, RS)
Exception to reference period: 2014-2016 (LU, TR); 2013-2015 (SI, RS)
Data unavailable: AL, AM, BA, FO, GE, IL, MD, ME, TN, UA
(:) = missing data

Source: Computed by Science-Metrix using Eurostat data (online data codes: educ_uoe_mobs02, educ_uoe_enrt01).

Knowledge-intensive services exports as percentage of total services exports

Knowledge-intensive services industries rely heavily on state-of-the-art technology and on a highly educated and skilled workforce. Not only is housing active knowledge-intensive services industries indicative of a high level of innovation and professional expertise, exporting such services to other

countries represents important revenues for the exporting country and an appealing feature to attract foreign scientists and engineers. The share of knowledge-intensive services exports to the total services exports is presented in Table 30.

Indicator 6.3a is new to the 2018 edition of the ERA Progress Report. The data set used extends from 2010 to 2016, and the growth of countries is analysed both in a recent period (2014-2016) and a long-term period (2010-2016).

Average annual growth rates in knowledge-intensive services exports for the EU-28 highlighted stability over both the short (0.6 %) and long term (0.6 %). On average, 69 % of EU-28 Member States' services exports were knowledge intensive.

Across the ERA countries covered, there were few notable changes in ranking from 2014 to 2016. In fact, only a few growth figures stand out on this indicator — 24 out of 34 short-term growth rates were contained between the 3 % and -3 % marks. This resulted in only 7 countries moving by more than 3 places. The strongest changes were declines by 14 places for Malta (from 16th in 2014 to 30th in 2016) as well as by 8 ranks for Greece (from 17th to 25th). This is consistent with Greece's decrease in percentage of knowledge-intensive services exports which was the lowest observed with a 10-percentage points gap to the EU-28 growth rate. For Malta, the drop is not coherent with its growth rate due to an exception to the reference period. Its drop in the ranking is due to its 2014 data point being much higher than most other points in its time series. While Lithuania had by far the highest average annual growth from 2014 to 2016, placing it 11 percentage points ahead of the EU-28, it did not move in the ranking. This is because its score started from a low point. The countries with the largest progression in the ranking are Latvia (from 21st to 16th) and Finland (from 14th to 9th) with CAGR from 2014 to 2016 of, respectively, 5.5 % and 6.7 %.

The strength of ERA countries in knowledge-intensive services exports appear to have been comparatively spread across small, medium and large economies. The most performing groups of countries (Cluster 1 and Cluster 2) involved 15 out of 36 countries, and together they accounted for 67 % of ERA combined GDP. While this figure is significant, it indicates less concentration than for many other indicators in this report. The least performing country groups included large economies, such as Italy (Cluster 3) and Spain (Cluster 4) and accounted for 33 % of ERA combined GDP with 21 countries.

Ireland and Luxembourg, in the most performing cluster, clearly stood out with over 90 % of their services exports found to be knowledge intensive. The share was above 65 % for all but one of the 14 remaining countries in Clusters 1 and 2. For countries in the least performing group (Cluster 4, a third or less of services exports were knowledge intensive.)

While more countries were found in the least performing country groupings (21 countries in Clusters 3 and 4) than in the most performing groupings (15 countries in Clusters 1 and 2), the ERA average (54 %) was located near the middle of the wide range of observed scores (94 % to 19 %), which is indicative of small inequalities across countries. Findings for the Gini coefficient (at 0.199 for 2016) confirm high inclusion between countries on this indicator. On average, short-term annual growth rates were stronger for the country group immediately above the unweighted ERA average (Cluster 2) and for the least performing countries (Cluster 4). Therefore, recent trends should not have greatly impacted the extent of inequalities between countries as suggested by the Gini coefficient which remained roughly unchanged between 2014 (0.203) and 2016 (0.199).

Long-term average annual growth rates at country levels were close to their short-term counterparts. Finland (Cluster 2) displayed notably high average growth rates over both the long-term and short-term periods, whereas Greece's (Cluster 3) gap widened. Malta was an exception to this observed continuity between short-term and long-term growth rates, as it recently reduced its annual average decline to -1 % after a long-term trend measured at -12 %. Considering country groups, long-term average annual growths were slightly positive for those clusters immediately below and above the ERA unweighted average (Cluster 2 and 3), insignificant for the most performing country group (Cluster 1), and slightly negative for the least performing one (Cluster 4).

Table 30 Knowledge-intensive services exports as percentage of total services exports (2010-2016)

Country	Weight in GDP	Score (2016)	CAGR			
			Short-term (2014-16)	Lead/Gap to EU-28 CAGR	Long-term (2010-16)	Trendline
EU-28		**69%**	**0.6%**	**N/A**	**0.6%**	
Cluster 1	29.8%	82%	0.4%	-0.2	0.2%	
Cluster 2	37.0%	68%	1.2%	0.6	1.4%	
Cluster 3	20.6%	45%	0.5%	-0.1	0.9%	
Cluster 4	12.5%	28%	1.6%	1.0	-1.2%	
Cluster 1						
IE	1.6%	94%	0.2%	-0.4	*0.2%*	
LU	0.3%	93%	1.5%	0.9	0.6%	
NO	2.0%	*78%*	:	:	*0.6%*	
NL	4.2%	78%	1.0%	0.4	:	
DE	18.8%	75%	0.7%	0.0	-0.4%	
SE	2.8%	73%	-1.3%	-2.0	0.2%	
Cluster 2						
DK	1.7%	72%	-3.9%	-4.5	-1.4%	
UK	14.4%	*72%*	*0.4%*	-0.2	*-0.4%*	
FI	1.3%	70%	6.7%	6.0	7.6%	
CY	0.1%	70%	3.5%	2.9	0.2%	
BE	2.5%	69%	1.3%	0.7	*1.0%*	
CH	3.6%	*68%*	*1.5%*	0.9	*0.7%*	
FR	13.3%	68%	2.2%	1.6	1.2%	
IL	:	*66%*	*1.1%*	0.5	*2.4%*	
IS	0.1%	*57%*	*-1.9%*	-2.5	:	
Cluster 3						
LV	0.1%	52%	5.5%	4.8	-0.5%	
IT	10.1%	51%	-0.1%	-0.7	-0.1%	
UA	:	49%	-0.7%	-1.3	1.4%	
HU	0.7%	49%	0.6%	-0.1	0.1%	
EE	0.1%	49%	3.5%	2.9	0.0%	
RS	0.2%	*48%*	*3.6%*	2.9	*1.8%*	
RO	1.0%	46%	1.2%	0.5	1.7%	
CZ	1.1%	44%	1.3%	0.6	2.4%	
AT	2.1%	43%	-1.6%	-2.2	4.1%	
EL	1.0%	42%	-9.4%	-10.0	-6.0%	
PT	1.1%	41%	-3.1%	-3.7	0.0%	
PL	2.5%	40%	2.7%	2.1	0.1%	
BG	0.3%	39%	2.4%	1.8	6.4%	
SI	0.2%	36%	1.9%	1.3	1.3%	
Cluster 4						
MT	0.1%	*34%*	*-1.0%*	-1.6	*-12.3%*	
SK	0.5%	33%	-3.0%	-3.6	*-1.6%*	
ES	6.7%	*33%*	*3.7%*	3.0	:	
TR	4.7%	*32%*	*2.6%*	2.0	*4.2%*	
MK	0.1%	*26%*	*-2.3%*	-2.9	*-0.3%*	
LT	0.2%	*22%*	*11.4%*	10.8	*4.3%*	
HR	0.3%	19%	0.0%	-0.6	*-1.2%*	

Note: Potential outlier: MK (2010)
Exception to reference year: 2015 (ES, LT, MT, UK, IS, NO, CH, MK, RS, TR, IL)
Exception to reference period for short-term CAGR: 2013-2015 (ES, LT, MT, UK, IS, CH, MK, RS, TR, IL)
Exception to reference period for long-term CAGR: 2010-2015 (LT, MT, UK, NO, CH, RS, TR, IL); 2011-2015 (MK); 2011-2016 (BE, IE, HR); 2012-2016 (SK)
Data unavailable: AL, AM, BA, FO, GE, MD, ME, TN
(:) = missing data

Source: Compiled by Science-Metrix with using data from the European Innovation Scoreboard (EIS) 2018 (https://ec.europa.eu/docsroom/documents/30282/attachments/1/translations/en/renditions/native).

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

The rationale for exports of medium and high technology products as a share of total product exports is similar to the previous indicator; the level of exports of cutting-edge technology products is indicative of innovation and a skilled workforce, and most likely contributes to an attractive environment for foreign scientists and engineers while also contributing to the international

competitiveness of a country (it represents important revenues from abroad). The share of medium and high technology product exports to the total product exports are shown in Table 31. This indicator is once again a new addition to the ERA Progress Report.

As for the indicator on knowledge-intensive services exports, scores for this indicator were rather stable over time, showing minimal growth at the EU-28 level both in the short (CAGR of 0.4 %) and longer term (0.5 %). On average, 57 % of EU-28 Member States' product exports were for medium and high technology products in 2017.

A small number of pronounced changes in recent growth at the country level can nonetheless be observed. For Cyprus, an 11-percentage point gap to the EU-28 reference in the short-term period led to a drop of 12 places in the ranking (from 2nd in 2015 to 14th in 2017). This reversed a long-term trend towards higher values from 2010 to 2014. Together with Luxembourg which went from 16th to 23rd (CAGR of -7.4 %), the recent change for Cyprus is the only notable drop in the ranking for this indicator. Switzerland had the strongest short-term average annual growth rate (9.5 %) giving it a 9-point lead relative to EU-28. Note that this growth followed a period of decline from 2010 to 2014.

Interestingly, most countries fell above the ERA average for this indicator with close to 60 % of countries in Clusters 1 and 2. Together, these two groups were economically diverse and accounted for 81 % of combined ERA GDP. The largest group of countries (Cluster 2) included large economies (Italy, France and the UK), as well as medium and small economies, for a combined 60 % of ERA GDP. Germany accounted for almost all of the first group (Cluster 1) of countries' combined GDP. The 40 % of countries below the ERA average only accounted for 19 % of combined ERA GDP.

The composition of country groups for medium and high technology products exports is strikingly different from the one obtained on the previous indicator, the share of knowledge services exports. Ireland and Luxembourg, who stood out as the top-performing countries in terms of knowledge-intensive services exports, positioned themselves in Clusters 2 and 3, respectively, in terms of medium and high technology product exports. In contrast, Slovakia stood in Cluster 4 for the previous indicator but in Cluster 1 for this one. Germany is the only country that positioned itself in the most performing country group (Cluster 1) for both indicators. The share of medium and high technology product exports of all countries in the most performing country group (Cluster 1 with Hungary, Germany, Slovakia, the Czech Republic and Malta) was above 60 %, but none of the individual countries clearly stood above the others. Medium and high technology products represented less than 34 % of exports for countries in the group of least performing countries (Cluster 4, i.e. Bulgaria, Ukraine, Greece, Norway and Iceland).

Inequalities between ERA countries were very low on this indicator with a Gini coefficient at 0.152 in 2017. The recent growth pattern at the level of country groups did not reveal a clear tendency towards increasing or reducing inequalities which is reflected in the Gini coefficient which remained roughly stable (0.156 in 2015 and 0.152 in 2017).

Table 31 Exports of medium and high technology products as a share of total product exports (2010-2017)

Country	Weight in GDP	Score (2017)	CAGR			Trendline
			Short-term (2015-17)	Lead/Gap to EU-28 CAGR	Long-term (2010-17)	
EU-28		**57%**	**0.4%**	**N/A**	**0.5%**	
Cluster 1	21.5%	66%	0.8%	0.4	0.6%	
Cluster 2	60.0%	54%	0.7%	0.3	1.1%	
Cluster 3	15.0%	42%	0.2%	-0.2	1.1%	
Cluster 4	3.5%	22%	-0.5%	-1.0	-2.4%	
Cluster 1						
HU	0.7%	68%	-0.8%	-1.2	-0.6%	
DE	19.1%	68%	0.4%	0.0	0.5%	
SK	0.5%	66%	-0.1%	-0.5	1.0%	
CZ	1.1%	66%	1.3%	0.8	0.5%	
MT	0.1%	62%	3.4%	3.0	1.7%	
Cluster 2						
MK	0.1%	60%	0.5%	0.1	7.9%	
FR	13.4%	58%	-0.2%	-0.6	0.2%	
AT	2.2%	58%	0.4%	0.0	1.0%	
UK	13.6%	57%	2.2%	1.7	0.8%	
SI	0.3%	57%	0.9%	0.5	0.3%	
IE	1.7%	56%	3.2%	2.8	1.6%	
RO	1.1%	56%	2.8%	2.4	1.3%	
IL	:	*55%*	*1.8%*	1.4	*0.6%*	
SE	2.8%	54%	-0.2%	-0.7	0.2%	
CY	0.1%	54%	-10.5%	-10.9	4.2%	
IT	10.0%	52%	0.3%	-0.1	0.5%	
NL	4.3%	50%	1.1%	0.7	1.8%	
CH	3.5%	*50%*	*9.5%*	9.1	*-3.9%*	
PL	2.7%	49%	-0.5%	-0.9	-0.6%	
BE	2.6%	48%	-0.4%	-0.8	-0.2%	
DK	1.7%	48%	0.2%	-0.3	2.0%	
Cluster 3						
ES	6.8%	47%	-0.6%	-1.0	-0.2%	
LU	0.3%	45%	-7.0%	-7.4	-2.0%	
RS	0.2%	*45%*	*0.1%*	-0.4	*6.3%*	
FI	1.3%	45%	0.1%	-0.3	-0.1%	
TR	4.4%	43%	2.9%	2.5	2.0%	
EE	0.1%	41%	-1.7%	-2.2	1.8%	
HR	0.3%	40%	2.5%	2.1	-1.7%	
PT	1.1%	38%	2.2%	1.8	0.8%	
LT	0.2%	37%	3.5%	3.1	2.0%	
LV	0.2%	35%	0.1%	-0.4	1.8%	
Cluster 4						
BG	0.3%	34%	4.3%	3.9	3.8%	
UA	:	*29%*	:	:	*-5.1%*	
EL	1.0%	21%	-3.3%	-3.7	-1.8%	
NO	2.1%	14%	2.7%	2.3	-2.2%	
IS	0.1%	10%	-5.9%	-6.3	-6.8%	

Note: Exception to reference year: 2016 (CH, RS, IL); UA (2015)
Exception to reference period for the short-term CAGR: 2014-2016 (CH, RS, IL)
Exception to reference period for the long-term CAGR: 2010-2016 (CH, RS, IL), 2010-2014 (UA)
Data unavailable: AL, AM, BA, FO, GE, MD, ME, TN
(:) = missing data

Source: Source: Compiled by Science-Metrix with using data from the European Innovation Scoreboard (EIS) 2018. (https://ec.europa.eu/docsroom/documents/30282/attachments/1/translations/en/renditions/native)S)

Comparing Headline to complementary EMM indicators

The Headline indicator shows a positive and moderate correlation with two of the three complementary EMM indicators for Priority 6. The number of non-ERA co-publications per 1 000 researchers correlates positively but moderately with the share of non-EU doctorate students (Pearson *r* of 0.43). Next, the Headline indicator also shows a positive moderate correlation with the complementary indicator knowledge-intensive services exports as a percentage of total services exports (Pearson *r* of 0.63). The third complementary indicator, exports of medium and high

technology products as a share of total product exports, however, does not seem to be related to the Headline indicator as shown by their very weak correlation (Pearson *r* of 0.10).

The moderate strength of the correlations indicates that the various facets represented by the different complementary indicators are not all accounted for in the Headline indicators. Moreover, there is a risk of omitting important variation on a country-by-country basis that could reveal itself to be crucial in understanding the functioning and explaining the relative performance of individual R&I systems.

3.6.4 Additional policy highlights

International cooperation landscape: The context for international research collaboration has been strengthened by the following developments, among others:

(1) The Commission is continuously holding S&T cooperation dialogues with its main international partners as well as initiating policy dialogues with different regions around the world. Such initiatives help to identify strategic cooperation opportunities and to set priorities (European Commission, 2017).

(2) The Commission is also regularly preparing multi-annual roadmaps for its key partners around the world. During this process, Member States are involved through SFIC.

(3) 'A strategic approach has been developed on how to strengthen and streamline the external dimension of ERA in line with the ERA Roadmap. In this context, SFIC will continue monitoring, mapping out and benchmarking national roadmaps for the implementation of Priority 6 of the ERA Roadmap and discuss experiences in implementing them (SFIC, 2017).'

Agreements between the EU and third countries: The European Union has developed privileged international relationships by signing international agreements on science and technology with the following countries: Australia (1994), Canada (1996), South Africa (1997), the United States (1998), China (1999), Russia (2001), Argentina (2001), India (2002), Ukraine (2003), Tunisia (2004), Mexico (2005), Morocco (2005), Brazil (2007), Chile (2007), South Korea (2007), Egypt (2008), New Zealand (2009), Japan, (2011), Jordan (2011), and Algeria (2013). These agreements allow the identification of common interests and priorities, the necessary tools for cooperation and facilitate policy dialogue. However, no new Science and Technology agreements were signed in recent years. The European Research Council also developed a route for young researchers to temporarily join ERC teams in Europe through Implementing Arrangements with a number of third countries' funding bodies and ministries. Since the last ERA Progress Report was published, new agreements with Brazil (2016), Canada (2016) and India (2017) were signed. Other countries with these arrangements are: the United States (2012), South Korea (2013), Argentina (2015), Japan (2015), China (2015), South Africa (2015) and Mexico (2015). It is expected that this process will be further developed and arrangements with more countries will be signed.

International cooperation activities between ERA countries and third countries: Bilateral agreements between ERA countries and third countries are a common practice to establish long-term and sustainable international partnerships. Interview data and literature reveal that ERA countries cooperate with a wide range of third countries with the strongest concentration of the bilateral agreements being with the US, China, Brazil, India, Russia, Japan, South Korea and increasingly South Africa. It was also indicated that signing agreements does not necessarily result in long-term effective collaborations. Their success is a result of a genuine planning where mutual interest in research fields and topics is identified and matching funds are guaranteed. Additionally, several interviewees, especially from smaller countries and countries with less-developed national research systems, emphasised that developing and maintaining cooperation activities with third countries is often more effective using European instruments. The interview data also showed that bilateral and multilateral cooperation activities between RPOs in ERA countries and third countries is continuously growing. The cooperation between RFOs is also slowly increasing in some countries. It is more common in countries with more-developed national research systems and where organisations enjoy a higher level of autonomy.

Additionally, countries and organisations employ other tools to encourage international cooperation activities with third countries including national and institutional strategies for internationalisation, creation of innovation and research centres, and delegation of representatives for research and innovation. There are countries that introduced separate internationalisation strategies (e.g. Germany, Italy and Austria) while others prioritised the topic in their national strategies (e.g. Estonia, Spain and Ireland). Even if an exhaustive presentation of the institutional strategies on international cooperation is not possible, they exist is most countries. However, the prevalence of these strategies is heterogenous among and within countries. Some countries such as Germany and Denmark have established innovation and research centres in third countries while others like Belgium appointed representatives for research and innovation in their embassies and consulates. These actions allow

for a more coherent and sustainable R&I cooperation by providing consultative support and helping RPOs and businesses in a home country to connect with counterparts abroad.

Researcher mobility: Research mobility is an important topic both on the EU and national levels. As a result, a number of European and national initiatives are being applied to encourage mobility within and outside Europe. Societal challenges are not exceptional to Europe. They are complex and wide-reaching. Thus, the effective way to address them depends on international cooperation and the involvement of the best skilled research and innovation staff from all over the world. Knowledge must be shared across borders, sectors and disciplines. The EU promotes this through Marie Skłodowska-Curie actions. This is a well-established and prestigious programme, offering attractive working conditions for researchers at all levels. At the same time, most countries have introduced incentives directed to incoming, outgoing and returning researchers. The need for incentivising incoming and returning mobility schemes is explained by the increasing loss of human resources across ERA countries. It is important to note, that qualitative data suggest that countries with less-developed research systems experience the largest brain drain. As a result, they concentrate their internationalisation efforts on attracting foreign and returning researchers. At the same time, the weak attractiveness of their system often hinders the success of their mobility schemes. In contrast, countries with more-developed research systems promote brain circulation and experience higher flows of inward and outward mobility. This is related to the attractiveness of their research systems where researchers gain access to more attractive funding and career development opportunities and ability to work with top talent in leading organisations.

Major challenges for international cooperation: Even though international cooperation is continuously growing and being recognised as a key priority at national and EU levels, there are still some factors that hinder the process. As indicated in the last ERA Progress Report, there is a lack of financial and human resources in some countries, which remains a persistent problem. There are also difficulties related to heavy bureaucratic burden and stringent immigration rules. As a result, research performing organisations experience obstacles in bringing researchers from third countries and this often prevents RPOs from fully exploring the benefits of it. It is particularly challenging for RPOs that are small in size and lack relevant experience in international cooperation. Another important insight from interviewees is that despite many benefits of international cooperation, the major effort is being concentrated on European cooperation activities.

Main findings

1. The extent of international cooperation activities between ERA countries and third countries seems to be on the increase. However, countries with more-developed research systems have more attractive collaboration opportunities. They are also better equipped to sustain and initiate new partnerships.

2. International mobility of researchers is actively promoted both at EU and national levels. At the EU level it was addressed through EURAXESS as well as promoted via the Marie Skłodowska-Curie Actions programme. At the national level, international cooperation is embedded in internationalisation strategies or national R&I strategies as well as ERA roadmaps. Qualitative data suggests that ERA countries, especially those with less-developed research systems, are more actively promoting incoming mobility due to the lack of human resources. There is a need to facilitate more active brain circulation, which involves both incoming and outgoing mobility of researchers on national levels through more diverse incentives. At the same time, ERA countries need to do further work on increasing the attractiveness of their research systems in order to attract the best talent to overcome labour shortages, strengthen research capabilities, boost innovation and deal with grand challenges.

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

This is the first ERA Progress Report, which aims to assess the progress made by ERA countries in terms of implementation of their National Action Plans. This assessment includes 28 ERA countries, for which the National Action Plans were available. Please refer to Table 32 for a full list of countries.

As discussed in t Section 2 of this report describing our methodology, the main goal of this task was to assess whether ERA countries have been delivering on objectives set for themselves in their respective National Action Plans. It must be noted that the respective country NAPs (and not ERA Priorities as established in the ERA Communication and ERA Roadmap) were used as an assessment framework. This is to say that this task has analysed whether and how countries were implementing what they have announced in their own NAPs and not their compliance in relation to EU documents. Importantly, the analysis of NAPs provided in this report has only assessed elements established directly by the NAPs (such as objectives, baselines, targets, timelines and milestones).

Our analysis had two main steps. First, we have implemented detailed analysis of individual NAPs to identify tangible policy objectives, baselines and timelines. Second, we have carried out 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. For further discussion about the methodology, please refer to Section 2.

As a result of this assessment, we have classified countries into the following categories in terms of progress with implementation of their respective NAPs:

- ++ means that the country has achieved **substantial progress** with implementation of its NAP. This means that the majority of objectives indicated in the NAP were either fully accomplished or the implementation is well under way.
- + means that the country has achieved **medium progress** with implementation of its NAP. This means that we were able to find information that the country has either accomplished or has already started implementing at least half of its objectives/commitments.
- +/- means that the country has achieved **very small/mixed progress** with implementation of its NAP. This means that only a few of the reforms indicated by the country in its respective NAP were accomplished or ongoing.
- n/a means one of two things: either (1) **data were not available/sufficient** to assess the progress or (2) objectives of the NAP were too vague to be assessed.

Table 32 classifies countries into four groups according to progress with implementation of their NAPs. The analysis provides the following insights:

- Assessment of the NAPs revealed that **the majority of NAPs included tangible policy objectives that were possible to assess qualitatively (mainly) or quantitatively** (i.e. we could establish whether the country has accomplished a certain objective/reform, or its implementation is ongoing).
- The majority of analysed NAPs have included a description of the baseline situation. However, this was done mainly qualitatively by describing where the country stands at the moment and not by providing baseline values of the indicators.
- The majority of analysed NAPs have set timelines for implementation of their objectives, although these timelines were usually not very detailed. This means that countries have usually indicated the year by which certain specific objectives were expected to be achieved, but they have not indicated intermediate milestones.
- The three points made above do not hold for three countries falling into the n/a group, as shown in the table below. Only Cyprus falls into this group mainly due to the fact that their NAP was only drafted in 2017 and therefore it is too early to assess it. Lithuania and Bulgaria fall into the n/a group due to the fact that their objectives are too intangible to be assessed. For example, the Lithuanian NAP provides very wide objectives (e.g. 'to develop a favourable environment for capable and motivated individuals to become highly qualified professionals and to realise themselves in conformity with the expectations of the state and society') without any tangible actions on how this may be achieved. Such objectives are complemented by very high-level indicators (e.g. 'the number of applications submitted for European and international patents by Lithuanian entities'), which are not fit-for-purpose to assess the progress with the respective objectives. The same can be said about the Bulgarian NAP, while additionally it does not provide any indicators. This was also the case with parts of the NAPs of other countries, however only to a minor extent.
- We 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. The main reason for this was the establishment of very tangible objectives, which can be measured and followed up.
- The only somewhat concerning finding about the countries above was that some of their objectives seemed to be a bit tautological, i.e. they were set at the time, when they were already being implemented. This means that some of the countries falling into the group with most progress, had already started implementing a large share of their plans at the time when they were written.
- 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 possibly due to the lower status of the NAP as a strategic document in these countries.

- We also found that Croatia, Montenegro and Serbia have implemented only a few of their planned reforms and, therefore, they fell into the group of countries with mixed or little progress (+/-).
- 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.

Table 32 General assessment of implementation progress on the basis of the National Action Plans

No.	Country	General assessment of progress	NAP structured according to ERA priorities?
1	Austria	++	Yes
2	Belgium	++	Yes
3	Finland	++	Yes
4	France	++	Yes
5	Ireland	++	Yes
6	Netherlands	++	Yes
7	Norway	++	Yes
8	Switzerland	++	Yes
9	United Kingdom	++	Yes
10	Czech Republic	+	Yes
11	Denmark	+	Yes
12	Estonia	+	No
13	Germany	+	Yes
14	Greece	+	Yes
15	Italy	+	Yes
16	Latvia	+	Yes
17	Luxembourg	+	Yes
18	Malta	+	Yes
19	Portugal	+	Yes
20	Romania	+	Yes
21	Slovenia	+	Yes
22	Spain	+	Yes
23	Croatia	+/-	Yes
24	Montenegro	+/-	Yes
25	Serbia	+/-	No
26	Bulgaria	n/a	No
27	Cyprus	n/a	Yes
28	Lithuania	n/a	Yes

Source: Compiled by PPMI Group as a result of in-depth analysis of the National Action Plans.

While this section has provided a general assessment of the progress with implementation of the NAPs across all ERA countries, the study team has also developed detailed narratives on the implementation of the NAPs for each specific country. These narratives are provided as part of the

ERA Country Profiles 2018. There we provide a more in-depth analysis of the strengths, challenges and other specific characteristics of each country.

5 CONCLUSIONS

Priority 1

The first priority seeks to establish more effective national research systems by providing consistent and predictable funding for research as well as by making the allocation processes more competitive and transparent. It is expected that enhanced competition will increase the quality of research and ensure an effective use of R&I funds.

R&I systems across ERA countries have been negatively affected by the financial crisis of 2008. As a result, austerity measures were introduced, and on average budgets allocated to R&I were reduced. The EU is committed to mitigating the effects of the financial crisis on R&I funding and effectiveness. At the same time, some ERA countries are decreasing their public funding for R&I while others are increasing it slowly. Having said that, these increases are usually insufficient to make a substantial impact. Countries with less-developed research systems often had the sharpest decline in GBARD. As a result, they are often reliant on funding from EU structural funds. However, decreasing public funding is not specific to countries with less-developed research systems. It is also visible in some countries with more-developed research systems. Currently, these cuts do not have a major negative effect on these countries, and they maintain leading positions across different indicators. Nevertheless, the lack of justification for these cuts can negatively affect the future performance of these countries. As a result of decreasing public funding for R&I, a number of ERA countries use indirect fiscal measures to strengthen the private R&I base.

The financial crisis of 2008 has also encouraged countries to review their funding practices and introduce some kind of competitive funding with the goal to increase productivity and encourage effective use of funds. Some kind of competitive funding was introduced by many ERA countries. Despite the growing use of competitive funding practices, negative effects were identified, suggesting that the competitive process should be increased but not without a limit. There was also a concern that competitive funding has to be introduced and increased with caution by considering numerous differences that exist across national research systems.

General country rankings across Priority 1 indicators remain roughly unchanged compared to the last ERA monitoring exercise. Quantitative data also suggests that inequalities across countries increased only slightly or not at all depending on the indicator. This means that the least performing countries need to step up their efforts in order to make substantial progress and catch up to the performance leaders.

Sub-priority 2a

As in the previous report, Priority 2 – Optimal transnational cooperation and competition was divided into two components: sub-priority 2a, which focuses on ERA countries' efforts to jointly address grand challenges, and sub-priority 2b, which focuses on the Member States efforts to make optimal use of public investments in research infrastructures (RI). Three indicators were used to measure the progress under sub-priority 2a, each focusing on three different facets, including the transnational cooperation, participation in Public-to-Public collaborations and co-publications with other ERA countries.

GBARD allocated to transnationally coordinated research (Europe-wide, transnational public R&I programmes and bilateral or multilateral public R&I programmes) expressed in euros per FTE researcher in the public sector was chosen as the Headline indicator for sub-priority 2a. The study found that although there was still an increase in international cooperation in EU-28 countries over the recent period from 2014 to 2016, EU-28 Member States (France excluded) have seen a slowdown in growth on GBARD allocated to transnationally coordinated research since the previous monitoring exercise. While average annual growth stood at 7.2 % for EU-28 from 2012 to 2014, this figure decreased to 3.9 % during the period 2014 to 2016. Similarly, although there has been overall progress over the longer period of 2012 to 2016, reduction in growth since the previous ERA Progress Report was still found with a figure of 5.6 % annual average growth. Several countries contributed to these decreases in scores, including Croatia (which displays a 27-point gap in growth to the EU-28 annual average), Greece (25-point gap), Bulgaria (23-point gap) and Ireland (21-point gap).

Member States' participation (EUR) in Public-to-Public collaborations per FTE researcher in the public sector (2012–2016) was selected as the second and complementary indicator for sub-priority 2a. The study found that an average of EUR 558 per FTE researcher was invested in these collaborations in 2016 in the EU-28. Balancing out of a large number of pronounced increases and decreases in growth rates at the individual country level showed that overall for the EU-28 there was an average annual growth score of 0.7 % over the period 2014 to 2016. It is important to note, however, that

scores collected on this indicator dispersed along a very broad range of highly skewed across countries pointing to moderate-to-high inequalities.

Since the last monitoring exercise, EU-28 Member States progressed slowly based on this indicator with an average annual increase of 3.3 % for the 2014-2016 period; this figure is broadly aligned with the EU-28 longer-term average annual growth (2007-2016) of 3.2 %. The ordering of country scores in 2016 has generally remained close to that of 2014. Notable gains in ranking were made by Malta (ascending from 9th to 2nd position).

Qualitative analysis showed that pooling of resources and research capacities to more effectively address common challenges remains the main perceived and actual added value of EU-level transnational cooperation instruments, such as JPIs, ERA-NET and other P2P instruments. Active participation in JPIs, ERA-NETs and similar instruments was one of the most frequently emphasised strategic goals in the newest national ERA roadmaps among a number of Member States. In addition, evaluation, monitoring and impact assessment of the instruments for transnational cooperation in research is increasingly recognised as a catalyst for success of these instruments by EU Member States. In terms of the key areas for potential improvement, a lack of systemic coordination both between different EU transnational research cooperation instruments and between these instruments and national research agendas and programmes, together with the lack of funding in some Member States, remain the main hindrances for successful coordination of national R&I policies and participation in P2P actions by Member States.

Sub-priority 2b

Two indicators were used in assessing the progress under sub-priority 2b ('Making optimal use of public investments in research infrastructures'): the availability of national roadmaps with identified ESFRI projects and corresponding investment needs (the Headline indicator); and the country's participation in ESFRI developing projects (i.e. early development phase projects aiming to establish RIs) and operational landmarks (implementation phase RIs requiring continued financial support for operation), expressed in terms of the share of developing ESFRI Projects and operational ESFRI Landmarks in which a Member State/Associate Country is a partner (2018) (complementary indicator).

As of 2018, there were 16 countries that had roadmaps in place with both ESFRI projects and funding needs identified. These countries were — ordered according to the year in which the national roadmap came into effect — Germany, Croatia, Estonia, Finland, Sweden, Denmark, Montenegro, Switzerland, France, Slovenia, Israel, Bulgaria, Greece, Italy, Romania and Hungary. Additionally, six countries had roadmaps identifying ESFRI projects but no funding requirements (Austria, Poland, Portugal, Czech Republic, Lithuania and the Netherlands). Norway had a roadmap with funding requirements identified but no ESFRI projects identified. Ireland, the UK and Spain all had a roadmap in place but identified neither ESFRI projects nor the funding needs associated therewith. The remaining 18 countries had no national roadmap in place.

In terms of the complementary indicator for sub-priority 2b, since the last ERA Progress Report, growth in ESFRI participation (i.e. share of ESFRI Projects and/or Landmarks in which a Member State/Associate Country is a partner) has shown clear increases. Firstly, ESFRI Projects and Landmarks, on average, included more countries in 2018 than they did in 2016. Projects involved an average of 6.6 countries in 2016 and 9.1 in 2018. For Landmarks, that figure is 11.7 in 2018, up from 9.9 in 2016. In 2016, EU-28 Member States had an average participation of 21 % in developing projects and of 30 % in operational Landmarks. These EU-28 averages increased to 29 % (38 % increase from 2016) and 37 % (23 % increase from 2016), respectively, in 2018. The growth figure being higher for developing projects than for operational Landmarks is indicative of a continued expansion potential for ESFRI initiatives and services, as well as of increased inclusion among ERA countries.

In addition, quantitative analysis showed that countries that have a National Roadmap policy in place are more likely to be participating in a greater share of ESFRI projects in the preparatory phase and operational landmarks. Moreover, the presence of a roadmap that includes explicit details about the specific ESFRI projects targeted and about the funding requirements needed for this participation coincides with higher levels of participation in ESFRI developing projects and operational landmarks.

Qualitative analysis showed that there remains the need for more cooperation and synchronisation of national research infrastructures in terms their inclusion into a harmonious pan-European landscape of RI. Instruments that could serve for this purpose include improvement of communication strategies and networking events, increasing numbers of international outreach events and more dedicated funding/support to ESFRI and ERIC.

Priority 3

Priority 3 focuses on the progress of ERA countries in terms of ensuring an open labour market for researchers and improvement of researchers' career development opportunities. One of the key initiatives in this area includes EURAXESS, which is a unique web portal providing access to a complete range of information and support services for European and non-European researchers, wishing to pursue research careers in Europe. In this way EURAXESS functions as the direct proxy and platform for an open labour market of researchers in Europe. Other key initiatives in this area include removing legal and other barriers to the application of open, transparent and merit-based recruitment of researchers, implementation of the HR Strategy for Researchers incorporating the Charter & Code, as well as supporting the setting up and running of structured innovative doctoral training programmes applying the Principles for Innovative Doctoral Training. Overall, three indicators were used to assess ERA progress under priority 3. The Headline indicator for priority 3 was the number of researcher job postings from a given country that are advertised through the EURAXESS job portal per 1 000 researchers in the public sector. Two complementary indicators include the share of doctoral candidates with a citizenship of another EU Member State (2013-2016); and the share of researchers expressing satisfaction that the hiring procedures in their institution are Open, Transparent and Merit-based (2012-2017).

In terms of the number of researcher job postings from a given country that are advertised through the EURAXESS job portal per 1 000 researchers in the public sector, the EU-28 Member States appeared to be positioned in a downward trajectory with annual average declines of 5 % for the whole country group since 2014. This average annual decline reversed a previous course of positive growth over the 2012 to 2014 period (CAGR of 7.3 %). Results at the aggregate level contrasted sharply with a few very strong growth rates that stood out from the portrait of individual countries (i.e. Finland, Germany, Latvia, Turkey and Luxembourg), whereas decreases were driven by Bulgaria (61 % average annual decrease), Greece (45 % decrease) and Sweden (44 % decrease).

In terms of the share of doctoral candidates with citizenship of another EU Member State, the data for 2013-2016 show that the EU-28 average score has moderately increased since 2013, from 6.4 % to 7.1 % in 2016. In addition, there has been a moderate number of changes in ranks on this indicator since the last Report. Cyprus gained 12 ranks, moving from 21st position up to the 9th. Latvia and Iceland respectively moved up six and five ranks, while Portugal moved down by six positions and Lithuania by five places.

In terms of the third indicator (share of researchers expressing satisfaction that the hiring procedures in their institution are open, transparent and merit-based), the last ERA Progress Report, based on MORE survey results for 2012, found that 49 % of respondents in EU-28 Member States were satisfied with the hiring procedures in their institution. The present study found that this score increased to 65 % in the 2016 edition of the survey. Average annual growth in between two timepoints, assuming exponential growth, is estimated to be 7.5 % at the EU-28 level. Growth in scores could be seen across all ERA countries, with the exception of Spain, which saw a slight decrease. Country rankings have been fully reshuffled on this indicator since the last report, with 14 out of 31 ERA countries associated with movements of more than three positions (some countries are excluded since they do not have scores in 2016). As many as 8 countries experienced changes of 10 or more positions in ranking. To take just a few examples, Romania moved up from 20th to 3rd position, while Spain, Norway and Ireland dropped by 13 places.

Qualitative analysis confirmed that a large gap still exists between the EU countries in terms of the open labour market and career development opportunities provided to researchers measured by availability of opportunities for learning, research funding opportunities, financial security, salaries and shares of fixed-term contracts. This heterogeneity reflects different higher education and research systems, as well as economic developments influencing public budgets for research and hence research funding and salaries of researchers. In addition, the different employment status of researchers across different European countries and the resulting limited portability of social security and pension schemes across borders is one of the key barriers for international mobility of researchers.

Priority 4

The fourth priority relates to emphasising gender equality and gender mainstreaming in research, including addressing gender inequalities in research institutions and in decision-making bodies, and promoting the integration of the gender dimension in research content, R&I policies and programmes.

Policies and initiatives at EU, country and institutional level have been adopted to tackle inequality issues and positive results have been identified as a consequence of such initiatives and programmes. Regarding gender balance in research positions, the aggregate score for EU-28 Member States remained mostly unchanged for the share of women in Grade A positions in the higher education

sector and for the share of female PhD graduates since the last ERA monitoring exercise. The study results also showed that while gender parity was nearly reached by all ERA countries at the entry stage of an academic career, women remain largely under-represented in higher academic echelons.

A number of gender equality plans and related policies were implemented in research organisations across ERA countries, to tackle unconscious gender biases, to include a gender dimension in research programmes and training, and to promote programmes and resources for equal opportunities in career progression with various degrees of progress.

Despite some progress towards gender equality in research and innovation, gender inequality in research and academia is still evident. Efforts towards increasing the enrolment and retention of women in science, implementation of work-life balance policies, reducing gender pay gap and removing obstacles to women's career progression are still needed in order to achieve gender equality and gender mainstreaming in ERA.

Sub-priority 5a

In the ERA Roadmap, priority 5 was divided into two sub-categories of knowledge circulation and open access. Sub-priority 5a aims to encourage effective knowledge transfer and open innovation between sectors across all ERA countries in order to maximise the exploitation of scientific results for the benefits of research institutions, individual researchers, business, and society as a whole.

Knowledge transfer remains diverse across Europe and stronger facilitation of transfer of research results to the market needs to be facilitated and closer collaboration between industry and academia needs to be encouraged across ERA countries. More initiatives, schemes and supportive regulatory frameworks have been adopted aiming to enhance interactions and development of research activities between the public and private sectors. Challenges remain regarding the implementation of effective policies for evaluation and monitoring of research and innovation.

The study found that around 15 % of firms that innovate in products or processes collaborate with university, government, public or private research institute partners at the EU-28 level. The EU-28 share of collaboration with universities remained roughly stable between 2012 and 2014 while the EU-28 share of enterprises collaborating with government, public or private research institutes has experienced an average annual increase of 4 % in the same period (in this latter case, many Member States had missing data and were thus omitted from the aggregate). A slight decline in the number of public–private co-publications produced per million population was also registered.

Sub-priority 5b

Sub-priority 5b aims to increase accessibility of research data and publications in order to promote the circulation of scientific ideas that benefit the research community and society as a whole. Open access (OA) evolved and progressed rapidly over the last few years and it is possible to observe that the majority of ERA countries have adopted policies and to some extent legal measures for open access to publications and open data practices. However, even in countries where legal measures have been adopted, its enforcement varies greatly. The EU-28 share of 2016 publications that are available in any form of OA now stands at 49 %; with similar shares of gold and green OA papers. Nevertheless, there remains substantial variance in the ratio of gold to green OA across individual countries with some of them scoring much higher in gold OA while others do so in green OA.

Turning from OA to research publications towards OA to research data, the progress has been much slower and a great diversity of approaches across national contexts and disciplines can be found. Financial and technical challenges relating to the storage and usable formatting of data made available in OA resulted in low shares of papers for which datasets were made available online. Distribution and circulation of data sets emerge as perhaps the next great challenge for OA policy.

Priority 6

Priority 6 focuses on international cooperation. One of the EU's principles is to be open to the world in order to tackle global challenges, ensure brain circulation, and create a global pool of highly skilled researchers. At the same time the EU needs to remain a relevant global R&I player. To ensure genuine and effective cooperation activities, the EU established privileged international relationships with third countries by signing international S&T agreements. It continues to maintain and improve these partnerships by holding S&T cooperation dialogues as well as policy dialogues with new countries and regions. The internationalisation of ERA is also strongly supported by the Strategic Forum for International S&T Cooperation (SFIC), which developed a strategic approach on how to strengthen and streamline priority 6.

The promotion of international cooperation is also pertinent to individual ERA countries. They employ different tools to encourage international cooperation that include bilateral agreements, establishment of research and innovation centres, delegations of R&I advisers and specialists to their consulates and embassies worldwide. At the same time, a number of ERA countries prepared national internationalisation strategies or emphasised it in their national R&I documents. Additionally, both RPOs and RFOs are increasingly pursuing bilateral or multilateral cooperation opportunities with organisations based in third countries. The qualitative data suggest that cooperation activities on the organisational level are continuously growing in a number of ERA countries.

Despite many positive developments, individual countries have progressed unevenly. Even though countries with less-developed research systems are usually more susceptible to the lower level of science and technology internationalisation, interview data suggests that challenges remain across all ERA. The greatest challenge to most ERA countries is a lack of financial and human resources dedicated to the establishment and managing of international partnerships. Lower levels of internationalisation in countries with less-developed research systems is also a result of lower attractiveness and visibility of their research systems compared to performance leaders.

Implementation progress of the National Action Plans

For the first time, this ERA Progress Report 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. *Inter alia*, this was also due to establishing very tangible objectives, which were possible to be measured and followed 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 the 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 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.

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KI-01-19-101-EN-N

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 study is to assist the European Commission in implementing the 2018 ERA Monitoring Mechanism to assess the recent progress made towards achieving six ERA priorities.

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.

Research & Innovation policy

Publications Office

ISBN 978-92-79-99760-0
doi:10.2777/103628