ERA PROGRESS REPORT 2016

SCIENCE METRIX STUDY

Data gathering and information for the 2016 ERA monitoring – Technical Report

Written by Science Metrix
September – 2016

Research and Innovation

EUROPEAN COMMISSION

Directorate-General for Research and Innovation
Directorate B — Open Innovation and Open Science
Unit B.2 — Open Science and ERA policy

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EXECUTIVE SUMMARY

This monitoring exercise assesses the current state and recent evolution of the European Research Area (ERA), covering both the ERA as a whole and the individual countries that compose it. Following the 2015 ERA Roadmap, the report examines each of the six priorities for the ERA. The primary lens has been to focus on the Headline and complementary ERA Monitoring Mechanism (EMM) indicators identified by the European Research Area and Innovation Committee (ERAC), with a secondary focus on additional indicators and composite scores to provide more comprehensive and synthetic overviews. This quantitative approach has been bolstered by the collection of substantial qualitative data through document reviews and interviews with key stakeholders across national and sectoral contexts within the ERA. The main findings are as follows.

Priority 1 focuses on driving the excellence and effectiveness of scientific endeavour, primarily through increased support for and competition within the research community. Since the Financial Crisis of 2008, there has been a divergence between the strategy of ramping up support for science in an effort to spur economic growth and the strategy of scaling down such support under the auspices of broader fiscal consolidation. The quantitative and qualitative data reflect this divergence.

The share of GDP dedicated to government budget allocations for research & development (GBARD) has shown a gradual annual decrease since the Financial Crisis in 2008. However, individual governments have adopted divergent strategies since the Crisis, with some cutting back their research budgets in the context of broader fiscal consolidation measures, and others increasing their research budgets in an effort to use research and innovation as the engine to drive their economies forward. In some countries, a shift occurred from direct to indirect fiscal measures to support the R&I sector, the former being taken into account in the GBARD and the latter not, making it difficult to assess the impact of GBARD contraction on overall public funding for R&D. Private-sector investment has also generally decreased, creating additional lines of divergence. These divergences threaten the long-term predictability of research funding systems, which has been identified by stakeholders as a crucial component in effective strategic planning and the performance of research.

Priority 2 focuses on transnational scientific collaboration to address grand challenges — shared topics of relevance to socioeconomic conditions. Overall, transnational collaboration has been increasing as establishment and operation of Joint Programming Initiatives (JPIs) increases, while some European Strategy Forum for Research Infrastructures (ESFRI) Landmarks are already operational, with others proceeding through their developmental phases. However, once again one finds a gap between the leader group in Priority 2 and the other ERA countries. Yet based on GBARD allocated to transnationally coordinated research — one of the two Headline indicators for this priority — the gap is closing for many of the lagging nations. Certain challenges lie at the intersection of the public and private sectors, and other between the various levels of government; these cross-cutting challenges require cooperation and a coordinated approach to be overcome effectively.

Priority 3 focuses on researcher transnational and intersectoral mobility. The EURAXESS job portal is becoming more established as its adoption increases, while on average across ERA countries about 1 in 12 PhD students holds a passport from another EU country. Hiring processes are growing more meritocratic, although the levels of satisfaction with progress on this front vary considerably from country to country. Early career researchers seem to be receiving the greatest benefits of the move towards more merit-based hiring, although it is not clear whether this is a generational shift or whether the group presently in the early career stage will experience a move away from the merit-based approach in later career stages. Furthermore, while intersectoral mobility is a stated focus, monitoring has so far not touched on private-sector hiring processes for researchers.

Priority 4 focuses on gender equality, both in the professional community of researchers and in the content of the research itself. There is considerable diversity in policies and monitoring of gender equality across the various national contexts within the ERA. While parity in the earliest stages of the research career seems at hand, the levels of parity diminish as researchers move up the ladder of career progression stages; furthermore, these decreases at more senior career stages show no signs of substantial change in recent years. Regarding gender dimension in research content, European research takes into account the biological characteristics as well as the social and cultural features of both women and men, and integrates a gender dimension about as often as the global average. Increasing integration of the gender dimension in research in Europe is essentially moving in parallel with increases at the world level, and at a slightly smaller rate. Eastern European and Nordic countries are leading in performance with regard to Priority 4. This pattern is the opposite to that observed in most other priorities. It is therefore not surprising that performance on Priority 4 correlates only weakly, and even negatively, with the two composite indicators reflecting overall performance across priorities (i.e. the Headline composite and Meta-composite).

Priority 5 focuses on knowledge circulation across sectors, taking a broad conception of knowledge that includes all domains of research, and of circulation implying more of an exchange than a simple one-way transfer towards the private sector. About 1 in 9 innovative firms collaborates with academia, and about 1 in 12 partners with a research institute (in the public or private sector) in the EU-28 and ERA globally. Both of these levels are increasing, although publication output resulting from these collaborations is relatively stable for the EU-28 globally. Many funding instruments are in place across ERA- and national-level contexts to promote such collaboration, and technology & innovation centres often contribute to facilitating connections by playing a mediating role. However, support to help researchers bring developments to market remains underdeveloped from both EU- and national-level governments, a problem that governments and private enterprises worldwide are seeking to solve.

Open access (OA) to scientific publications is increasing worldwide, including across the ERA, while evidence is constantly mounting that demonstrates that publications available in OA have a greater impact within the research community. Many OA policies have been put in place within the ERA, mostly since 2010, although the influence of these policies on OA is not yet clear. Copyright laws and digital infrastructure are important considerations in the continued drive towards full OA, including OA for publications and for data. Among current challenges are privacy considerations for data as well as competitive advantage considerations for data and publications produced in collaboration with the private sector.

Priority 6 focuses on international collaboration with third countries. There is an increasing number of formal partnerships, both between the ERA and third countries and between individual ERA participants and third countries. Globally for the EU-28, the number of PhD students from third countries is growing as a share of doctoral students in the ERA, as are the numbers of co-publications with third-country researchers and the patent and licence revenue from abroad. However, human and financial resources dedicated to supporting third-country partnerships are lacking in many instances, especially relative to the administrative complexity of such arrangements.

When looking **across priorities**, one notes that it is not the same group of countries leading the way within each of the priorities individually. Nonetheless, an overall leader group does emerge and is composed of Belgium, the Netherlands, Sweden, the UK, Norway and Switzerland. Note that no longitudinal analysis was possible across priorities due to missing data, and so one cannot say whether the gap between these leaders and the rest of the ERA is growing larger or smaller globally across all priorities. Nevertheless, progress toward achieving the goals of the ERA is tangible within each of the priorities based on both the quantitative and qualitative analysis, even though the perception of heterogeneity across national contexts persists, showing room for greater convergence towards sharing equally in the benefits of the ERA. Furthermore, an explicit definition of targets, for each priority, would add substance to the notion of 'achieving the ERA', and help to focus the efforts of ERA countries.

Additionally, a harmonious balance needs to be sustained between opposing directions, acknowledging the natural and necessary tensions between top-down and bottom-up approaches, between diversity of national contexts and European unity, and between an internal focus on ERA integration and external focus on openness to increased engagement with external partners.

RÉSUMÉ

Cet exercice de surveillance rend compte de la situation actuelle et des récentes évolutions de l'Espace Européen de la Recherche (EER). Il porte aussi bien sur l'Espace dans son ensemble que sur les différents pays qui le composent. A l'instar de la feuille de route de l'EER 2015 -2020, ce rapport se penche sur les six priorités. L'attention a été portée, en premier lieu, sur les indicateurs principaux et complémentaires du mécanisme de surveillance de l'EER, identifiés par le Comité de l'Espace européen de la recherche et de l'innovation (CEER), puis, dans une moindre mesure, sur des indicateurs secondaires et composites afin de fournir un tableau plus complet et synthétique de la situation. Cette approche quantitative a été complétée par une collecte de données qualitative de grande envergure composée d'une revue de la littérature et d'entretiens avec des parties prenantes de premier plan de l'EER au niveau national et sectoriel. Les principaux résultats sont les suivants :

La **priorité 1** porte sur le développement de l'excellence et de l'efficience de la production scientifique, principalement par le biais d'un accroissement du support apporté à la recherche et de la compétition au sein de la communauté scientifique. Depuis la crise financière de 2008, deux stratégies divergentes ont émergé : une montée en puissance du support financier à la science, afin de contrer les effets de la crise, dans certains pays, ou une réduction de ce support, dans la lignée de la rigueur budgétaire générale, dans d'autres. Les données quantitatives et qualitatives rendent comptes de ces divergences ainsi que d'un accroissement de l'écart entre les pays de tête et les autres pays de l'EER, en ce qui concerne la priorité 1.

La part du PIB dédiée aux crédits budgétaires publics de R&D (CBPRD) s'est réduite progressivement d'année en année depuis la crise financière de 2008. Cependant, les différents gouvernements ont adopté des stratégies divergentes depuis la crise. Certains ont réduit le budget alloué à la recherche dans le cadre de mesures de consolidation fiscales plus larges, tandis que d'autres ont accrus leurs budgets de recherche afin d'actionner la recherche et innovation comme levier pour soutenir l'économie. Dans certains pays ayant connu une baisse du financement direct de la R&I, une compensation provenant de mesures fiscales indirectes (les premières étant prises en compte dans le CBPRD mais pas les secondes) est survenue rendant difficile l'évaluation de la situation sur la seule base du CBPRD. L'investissement du secteur privé s'est généralement réduit, accentuant encore les divergences. Ces dernières nuisent à une vision de long-terme du système de financement de la recherche qui est pourtant une composante cruciale pour une planification stratégique efficace et une recherche performante selon les parties prenantes.

La **priorité 2** porte sur la collaboration scientifique transnationale ayant pour but de relever des défis majeurs aux sujets de préoccupations communes et relatifs au bien-être socioéconomique. La collaboration transnationale s'est globalement améliorée, étant donné que les initiatives de programmation conjointes (JPIs) ont pris leur envol, et que certaines infrastructures issues du forum ESFRI (European Scientific Forum for Research Infrastructures) sont déjà opérationnelles ou en phase de développement. Pour la priorité 2, un écart entre les pays les plus avancés et le reste des pays de l'EER existe également. Cependant, ces écarts se sont amoindris pour certains des pays les moins avancés en ce qui a trait à la part des crédits budgétaires publics de RD qui est allouée à la coordination transnationale de la recherche scientifique — un des deux indicateurs principaux pour la priorité 2. Certains défis se situent à la conjonction entre le secteur public et privé et d'autres entre les différents niveaux de gouvernement. Une approche combinant coopération et coordination est nécessaire pour relever efficacement ces défis transversaux.

La **priorité 3** porte sur la mobilité intersectorielle et transnationale des chercheurs au sein de l'EER. Le site d'offre d'emplois EURAXESS connaît un taux d'utilisation en croissance et, en moyenne à travers les pays de l'EER, un doctorant sur douze poursuit ses activités de recherche dans un autre pays que le sien. Les processus de recrutement sont de plus en plus souvent basés sur des principes méritocratiques. Cependant, la satisfaction des chercheurs, concernant l'application de ces principes, varie de façon substantielle d'un pays à l'autre. Les chercheurs en

début de carrière semblent bénéficier le plus de cette évolution vers les principes de recrutement basés sur le mérite. Les données ne permettent cependant pas de déterminer s'il s'agit d'un changement générationnel ou si ces principes s'étiolent au cours de la carrière. Bien que la mobilité intersectorielle soit une priorité affichée, la surveillance ne porte pas sur les processus de recrutement des chercheurs dans le secteur privé, pour l'instant.

La **priorité 4** porte sur l'égalité entre les femmes et les hommes, aussi bien en ce qui concerne les ressources humaines que dans le contenu de la recherche. Les politiques et mécanismes de surveillance relatifs à l'égalité entre les femmes et les hommes, en matière de genre, sont très hétérogènes entre les pays de l'EER. Bien que la parité semble acquise en tout début de carrière, le déséquilibre s'accentue au cours des étapes de la carrière académique. De plus, aucune évolution notable n'a été observée ces dernières années en ce qui concerne les plus hauts échelons. En ce qui concerne la dimension de genre, la recherche Européenne prend en compte les caractéristiques biologiques ainsi que les aspects sociaux et culturels des femmes et des hommes, à un niveau similaire au niveau mondial et connaît la même progression. Globalement, les pays du Nord et de l'Est de l'Europe ont les meilleures performances en ce qui a trait à la priorité 4. Ce patron est diamétralement opposé à celui observé dans la plupart des autres priorités. Il n'est donc pas surprenant que la performance des pays sur la priorité 4 corrèle faiblement, et même négativement (pour le composite basé sur les indicateurs principaux), avec les deux indicateurs composites de la performance globale à travers l'ensemble des priorités.

La **priorité 5** porte sur l'échange des connaissances dans un sens large dans la mesure où il ne se restreint pas à certaines disciplines et se veut multidirectionnel entre le secteur public et privé. Environ une entreprise sur neuf collabore avec des partenaires de recherche académiques et environ une sur douze avec un institut de recherche (public ou privé) au sein de UE et de l'EER globalement. Ces deux types de partenariats sont en progression. Cependant, le volume de publications en résultant reste relativement stable au sein de l'UE. Plusieurs instruments de financement sont en place à travers l'EER et aux niveaux nationaux pour promouvoir de telles collaborations. Les centres de technologie et d'innovation contribuent à la mise en place de ces liens. Cependant, le soutien aux chercheurs dans le processus de commercialisation reste marginal aussi bien au niveau Européen qu'aux niveaux nationaux. Ce problème est une préoccupation à l'échelle mondiale aussi bien au niveau des gouvernements que du secteur privé.

Le volume de publications scientifiques en libre accès (Open Access) est en croissance au niveau mondial ainsi que dans l'EER. De plus, les publications en libre accès tendent à avoir un impact plus important, au sein de la communauté scientifique, que celles qui ne le sont pas. Plusieurs politiques de libre accès sont mises en place à travers l'EER, principalement depuis 2010. Cependant, leur influence reste à démontrer. Les lois sur les droits d'auteur et les infrastructures digitales sont des éléments importants à prendre en compte pour continuer les avancées vers un libre accès généralisé des publications et des données. Les questions relatives à la confidentialité des données et aux avantages compétitifs que représentent les données et publications issues de collaborations avec le secteur privé constituent des défis actuels importants.

La **priorité 6** porte sur la collaboration internationale avec les pays tiers (hors de l'EER). Le volume de partenariat avec les pays tiers est en croissance aussi bien au niveau de l'EER que des pays qui le constituent. La part des doctorants de l'EER ne provenant pas d'États membres est en croissance de même que le nombre de co-publications avec des chercheurs de pays tiers et les revenus provenant de l'étranger issus des brevets et licences. Cependant, les ressources humaines et financières dédiées au soutien des partenariats avec les pays tiers sont souvent limitées, en particulier compte tenu de la complexité administrative à les mettre en place.

Les pays de tête varient selon les **différentes priorités**. Cependant, un groupe de pays se détache dans l'ensemble. Il s'agit de la Belgique, des Pays-Bas, de la Suède, du Royaume-Uni, de la Norvège, et de la Suisse. Il n'est toutefois pas possible de déterminer si l'écart avec les autres pays s'accroit où se resserre, faute de données longitudinales agrégées pour l'ensemble des priorités. Des progrès significatifs vers l'atteinte des objectifs de l'EER sont néanmoins observés pour chacune des priorités prise individuellement, bien que les réalités nationales soient encore perçues comme très hétérogènes et appellent à une plus grande convergence afin de mieux redistribuer les bénéfices de l'EER. De plus, une définition explicite de cibles, pour chaque priorité, permettrait de mieux incarner la notion de 'd'atteinte de l'EER', et aiderait à canaliser les efforts des pays de l'EER.

De plus, un équilibre harmonieux des forces en présence doit être mis en place de façon durable. Il passe par la reconnaissance des tensions naturelles et nécessaires entre les approches descendantes et ascendantes, entre la diversité des contextes nationaux et l'unité européenne et entre les préoccupations internes relatives à l'intégration de l'EER et les préoccupations externes relatives à l'accroissement de l'engagement envers les partenaires tiers.

1 INTRODUCTION

According to the European Commission's 2012 Communication 'A Reinforced European Research Area Partnership for Excellence and Growth', COM(2012) 392, 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 (p.3).

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 Commission, the Member States, and research funding organisations (RFOs)/research performing organisations (RPOs) (European Commission, 2012).

While significant progress has been achieved in setting up the conditions necessary for the completion of the ERA, the 2014 monitoring exercise highlighted the unevenness of progress made across relevant actors pointing to the need for speeding up the pace of implementation of the ERA (European Commission & Directorate General for Research and Innovation, 2015a). For example, this 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 this context, efforts are ongoing to refine the key implementation priorities that are likely to have the biggest impact on Europe's science, research and innovation systems. In the 2012 Communication, the European Commission defined five key ERA implementation priorities. In addition to these five ERA priorities, the reforms and actions to be implemented alongside them were defined, and the international dimension outside the ERA was identified as a cross-cutting theme (European Commission, 2012). Subsequently, in 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 (ERAC Secretariat, 2015b). 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 Communication recognised open, national-level 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 performance. In addition, institutional funding decisions were expected to build on performance assessments of organisations and teams and the quality of their outputs (European Commission, 2012). As the ERA process evolves, 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' (ERAC Secretariat, 2015b) 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 in 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 asserts 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' (p.7). Horizon 2020 is expected to play prominent roles in underpinning the R&I agenda. 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 the strong connection between excellent research and the availability of access to world-class facilities and research infrastructures (RIs), including ICT-based e-infrastructures (eRIs). 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 on 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 is maintained in the 2015 ERA Roadmap. RIs are placed not only at the base 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' (p.9), 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' (p.9).

Priority 3 – An open labour market for researchers: The ERA process asserts that researcher mobility contributes to excellence. However, the lack of transparent, open and merit-based recruitment remains a factor that reduces the attractiveness of research careers and hinders mobility, gender equality and research performance. Member States were 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' in order to remove barriers and enhance the portability of national grants while protecting the interests of all parties. Additional barriers identified included human resources policies that hinder career prospects for young researchers, as well as 'inadequate gender equality practices, social security obstacles and insufficient academia-business mobility' (p.10). The 2015 ERA Roadmap has renewed this commitment, 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 (p.11).

Priority 4 – Gender equality and gender mainstreaming in research: The 2012 Communication highlighted that notwithstanding 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 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 to foster scientific excellence and gender equality by Member States. 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' (p.13). At the same time, the Roadmap seeks 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 different 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 the 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. 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 makes 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' (p.4) 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' (p.19). 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 present study

The ongoing ERA Monitoring Mechanism (i.e. the 2016 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 2016 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 various Council Conclusions and ERAC opinions on the monitoring of the ERA and the approach specified in the ICF report (ICF, 2015) — and using multiple lines of evidence to triangulate the findings — the study team gathered, systematised 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 (2005-2015). Data from all 28 EU MS, 12 AC and Switzerland (currently under hybrid status) were used to examine progress at the European, regional, country and organisational levels. The set of 41 countries described above will be referred to as 'ERA countries' throughout this report. The evidence base presented in this report is expected to support ongoing policy development and efforts towards the improved implementation of the ERA. The findings provide a strong basis for the production of the *2016 ERA Facts and Figures* report, which is a central tool in the 2016 EMM.

2 METHODOLOGY

Three lines of evidence have been used in achieving this study's goal: desk research and document review (Section 2.1), interviews (Section 2.2), and the compilation of quantitative data (Section 2.3). Altogether, these tools enabled the collection, organisation, assessment, and synthetisation of qualitative and quantitative information at the European, regional, MS/AC 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.

2.1 Desk research and document reviews

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. The work included the analysis of documents at the level of stakeholder bodies representing several or more organisations and individual RPOs and RFOs, as well as at the level of regions and individual MS/AC. Efforts were made to identify and document examples of good practice, in particular for assessing institutional change at the organisational level, as required for the completion of the ERA. Specifically, the study team conducted an initial review of documentation provided by the Commission, with the intention of identifying preliminary evidence on progress towards the completion of the ERA. Additional information from sources other than the Commission were also considered. 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).

Table 1 Main sources used in the desk research and document review

Category	Number of documents
National Level	
ERAWATCH Country Reports	5
National Action Plans	27
OECD Policy reviews	1
Research and Innovation Observatory (RIO) Country Reports	18 (2014) 28 (2015)
Researchers' Report 2014: Country profiles	5
Organisation level	
Conference of European Schools for Advanced Engineering	7
ERAC documents	2
European Association of Research and Technological Organisations	2
European Commission – DG-RI	12
European Commission reports	3
European University Association	9
League of European Research Universities	7
Science Europe	6
Other sources (Reports from research organisations, academic / opinion papers)	2

Source: Compiled by Science-Metrix

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

2.2 Interviews

In total, 87 telephone interviews were conducted between the end of April and the end of June 2016. The interviews involved 92 key members of stakeholder research funding organisations (RFOs) and research performing organisations (RPOs) from countries across the ERA, the chairs of the ERA-related groups, and representatives of the ERA stakeholders' organisations and candidate organisations. Contact details were provided by the European Commission in consultation with Member States and Associated Countries, while Science-Metrix was able to identify additional interviewees based on a 'snowball approach'. The European Commission had the opportunity to comment and approve the interview instrument before the roll-out of interviews. 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 for the literature review part of this monitoring. The discussion in this report uses the term 'qualitative data' to denote situations where there was convergence between interview data and the literature review.

2.3 Compilation of quantitative data

Finally, extensive quantitative data was 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). Refer to Table 2 for a list of Headline and EMM indicators. Additional indicators included in the 2016 EMM include indicators used in the *2014 ERA Facts and Figures* report and its companion country fiches (European Commission & Directorate General for Research and Innovation, 2015a), as well as indicators identified in discussion between Science-Metrix and the European Commission to further round out the quantitative assessment. Additionally, Science-Metrix computed composite indicators to facilitate integrated assessments, including assessments across indicators within a given priority, as well as assessments across priorities. Refer to Annex 2 for a complete list of the indicators covered in this report, sorted by priority, type (Headline, EMM, etc.) and alphabetical order ([1]).

[1] The 2016 ERA Monitoring Handbook provides full methodological details on the policy relevance, limitations and technical 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 (SII) (source: EIS)
Sub-priority 2a: Optimal transnational cooperation	Participation in public-to-public partnerships per researcher in the public sector (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 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 (CWTS and Eurostat)
Sub-priority 5b: Open Access	Share of RFOs that provide funds to cover the costs of making publications available in OA and share of RPOs making their research data available in OA (data unavailable)	Share of publications available in open access (green and gold) (1science, WoS)	Presence or absence of national OA policies in RIO policy repositories (JRC Research and Innovation Observatory (RIO) policy repositories)
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 (EIS)	Licence and patent revenues from abroad as a share of GDP (Eurostat)

Note: The cells in light green represent Headline indicators while the cells in light grey hold EMM complementary indicators. For a discussion of the biases affecting the Headline and EMM complementary indicators, refer to Table 4 of the 2016 ERA Monitoring Handbook (Section 4, page 49).

Source: Assembled by Science-Metrix from ERAC documentation

2.3.1 General approach to the analysis and presentation of quantitative indicators

The general time frame to be assessed was the 2005-2015 period, with each results table providing an assessment of static performance in the most recent year for which high-quality data was available across countries, as well as a longitudinal assessment of evolving performance, where the length of this assessment period was again determined by quality of available data. As very up-to-date data was often unavailable to compute a given indicator for certain countries, the selection processes for performance snapshots required balancing country coverage with the timeliness of assessment, to ensure that the need for a very timely snapshot did not exclude the coverage of too many countries, and that the need for exhaustive coverage across countries did not lead to the assessment of outdated results.

The quantitative results tables present growth over the period assessed for each indicator, 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. Since the CAGR measures growth using the longest available period for each indicator (from 2005 onward), 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. 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. For a few indicators where short-term fluctuations were particularly pronounced, moving averages have been used to measure performance and growth (e.g. average scores across 2005-2007, 2006-2008 … 2012-2014). 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 2005-2007 and 2012-2014).

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 of how well one country or region is standing relative to that target, nor how fast one country or region is progressing or regressing relative to that target in the longitudinal assessment. This issue stems from the fact that the goals to be reached in achieving the ERA constitute moving targets (e.g. ERA priorities and actions to achieve them are continuously evolving along with the needs of European societies). As such, it is difficult to establish reference values to be attained in relation to specific ERA policy actions; some of these targets could become obsolete in between each EMM round. Thus, both the performance and progress of countries are benchmarked against one another and against the EU-28 average ([2]), displayed as a lead or gap to that average (in per cent for performance (not displayed in this report's tables), and in percentage point difference for the CAGR (displayed in this report's tables)). This lead/gap analysis has been colour-coded, from blue for the lowest scores to orange for the highest scores, to facilitate visual identification of patterns in performance ([3]). Additionally, performance in the most recent year is also benchmarked relative to performance across the ERA as a whole (i.e. relative to an unweighted average across the Member States and Associated Countries for which data is available for a given indicator) ([4]). This benchmarking is conveyed through the clustering approach implemented

[2] Weighted averages are used to ensure representativeness of the whole (i.e. as if the EU-28 was a single country). Refer to the 2016 ERA Monitoring Handbook for details on how EU-28 scores were computed.

[3] 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).

[4] An unweighted average is used across countries to allow computing the standard deviation used in the clustering protocol (see Footnote 5 below).

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. Country-level performance is compared to the EU-28 (weighted) and ERA (unweighted) averages, but these should not be conflated with targets. For instance, the EU-28 (weighted) and ERA (unweighted) averages are close to 20 % for some gender parity indicators, while a reasonable target would likely be closer to 50 %, which would reflect absolute parity.

2.3.2 Composite indicators

Science-Metrix designed two types of composite indicators as experimental tools to synthesise progress towards achieving the ERA both within and across priorities. The first type of composite — the Headline composite — aims to give a balanced reflection of performance across the eight Headline indicators selected by ERAC as being the most relevant in monitoring progress in achieving the ERA. Thus, the sub-priorities 2a and 2b are represented separately, as are sub-priorities 5a and 5b. The second type of composite — the Meta-composite — aims to provide a comprehensive overview of performance towards achieving each of the six ERA priorities' relevant dimensions by integrating multiple indicators within each priority. The Meta-composite has been constructed using a bottom-up approach, whereby intermediate priority composites were first constructed to synthesise performance within each priority. Since the number of relevant dimensions, and of available indicators to measure them, varies across priorities, this approach carries two benefits: it provides a synthetic view of progress towards achieving the ERA both within (the intermediate priority composites) and across (the Meta-composite) priorities, and it equalises the contribution of each priority to the Meta-composite (i.e. each priority is represented by a single intermediate composite) ([6]). In short, the Headline composite integrates only the indicators identified as the most salient by the ERAC, while the Meta-composite integrates a broader evidential base for each of the six priorities and overall (which includes, where possible, the Headline indicators but also a considerable number of others as well).

Indicator and country selection

For the composite indicators designed by Science-Metrix, computing changes in composite performance over time was not undertaken because of data limitations. In short, a minimum data coverage threshold was established to ensure the quality of the composites, and too many countries and indicators (even priorities) would have been excluded for passing this threshold had longitudinal computations been undertaken. The applied threshold consisted in a minimum coverage of 75 % of time series (or data points in the static approach), both across indicators for countries and across countries for indicators. The time series that were originally considered for

[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.

[6] For Priority 2, a differential weighting approach was used to ensure that the sub-priorities 2a and 2b, although they differ in number of indicators, contribute, in as much as is possible, equally to the composite for Priority 2. The same applies for the sub-priorities 5a and 5b of Priority 5.

building the composite in a dynamic fashion consisted of only two data points to measure progress between two reference years (e.g. between 2011 and 2015).

The threshold used in determining which indicator and country could be included was applied following data imputation. Imputation of missing data was performed by replacing missing data points by more recent or older data points with a maximum gap of two years between the reference and imputation year. For the dynamic option, it was requested that the imputation did not shorten or lengthen the time series (e.g. 2011-2015) by more than one year. In exceptional circumstances, outliers have been replaced using the same approach (refer to the 2016 ERA Monitoring Handbook for further details on outlier detection).

At the outset of this initial exploratory phase, it was decided that the composite indicators would be computed using a static approach only. For the Headline composite, the static approach was the only possible option since the Headline indicator for sub-priorities 2b ([7]) and 5b ([8]) could not be reported in a dynamic fashion. For the Meta-composite, the use of a dynamic approach would have resulted in a dataset of 21 indicators covering six out of eight priorities/sub-priorities (2b and 5b would have been omitted) and covering 27 Member States (Malta would have been omitted) as well as one Associated Country (Norway). In comparison, the static approach resulted in a dataset of 27 indicators covering all priorities/sub-priorities and covering all 28 Member States, plus 5 Associated Countries (Iceland, Norway, Switzerland, Serbia and Turkey) ([9]). The list of indicators included in the Headline composite and the Meta-composite is provided in Table 3.

In the static approach, because the most recent year of available data across selected indicators varied (i.e. the reference year of individual indicators), the reference year for the composites was set in relation to the year of the ERA Monitoring Mechanism to which this report refers. Thus, the reference year of the composites was set to '2016' although the data correspond to the actual performance of countries in different years.

[7] The Headline indicator for sub-priority 2b (i.e. availability of national roadmaps with identified ESFRI projects and corresponding investment needs) has been substituted with the complementary EMM indicator on ESFRI landmarks since it could not be included in this study's composite (it is a qualitative indicator). No time series is available on ESFRI landmarks. ESFRI landmarks were chosen over ESFRI projects since they represent successful ESFRI projects (i.e. operational).

[8] Growth in the share of publications available in open access cannot be reported accurately due to delayed open access issues (see Section 3.5 for more details).

[9] In the country selection phase for building the Meta-composite, the 75 % threshold was applied once to all indicators across all priorities. In the resulting selection, in very few instances, some countries had fewer than 75 % of the selected indicators in one, or many, of the intermediate composite indicators embedded within the Meta-composite. These instances have been clearly flagged throughout this report.

Table 3 Indicators incorporated in the Headline composite and the Meta-composite

Priority	Headline composite	Meta-composite ***
1	Adjusted Research Excellence Indicator (DG Joint Research Centre, Competence Centre on Composite Indicators)	Adjusted Research Excellence Indicator (DG Joint Research Centre, Competence Centre on Composite Indicators)
		Government budget allocations for R&D as a percentage of GDP (Eurostat)
		Number of researchers per 1 000 population (Eurostat)
		Number of papers published per 1 000 researchers (Science-Metrix using Web of Science)
2a	National GBARD (EUR) allocated to Europe-wide, bilateral or multilateral transnational public R&D programmes per FTE researcher in the public sector (Eurostat)	National GBARD (EUR) allocated to Europe-wide, bilateral or multilateral transnational public R&D programmes per FTE researcher in the public sector (Eurostat)
		Member State participation (EUR) in Public-to-Public collaborations per FTE researcher in the public sector (Eurostat and 1st ERA-Learn 2020 Annual Report on P2P Partnerships)
		International co-publication rate with ERA partners (Science-Metrix using Web of Science)
		International co-invention rate with ERA partners (Science-Metrix using PATSTAT data on PCT applications)
2b	Percentage of ESFRI Landmarks in which a Member State/Associated Country is a partner (ESFRI data) *	Percentage of ESFRI Landmarks in which a Member State/Associated Country is a partner (ESFRI data)
		Percentage of ESFRI Projects in which a Member State/Associated Country participates (ESFRI data)
3	Number of researcher postings advertised through the EURAXESS job portal per 1 000 researchers in the public sector (EURAXESS historical data and Eurostat)	Number of researcher postings advertised through the EURAXESS job portal per 1 000 researchers in the public sector (EURAXESS historical data and Eurostat)
		Share of doctoral candidates with a citizenship of another EU Member State (Eurostat)
		Share of researchers expressing satisfaction that the hiring procedures in their institution are Open, Transparent and Merit-based (MORE2 Survey)
4	Share of women in Grade A academic positions in the Higher Education Sector (Women in Science database, DG Research and Innovation)	Share of women in Grade A academic positions in the Higher Education Sector (Women in Science database, DG Research and Innovation)
		Gender dimension in research content (Science-Metrix using Web of Science)
		Share of women heads of institutions in the higher education sector (Women in Science database, DG Research and Innovation)
		Proportion of female PhD graduates (Eurostat)
		Share of women researchers (Eurostat)
5a	Share of product or process innovative firms cooperating with public or private research institutions (1) and with higher education institutions (2) (Eurostat) **	Share of product or process innovative firms cooperating with public or private research institutions (Eurostat)
		Share of product or process innovative firms cooperating with higher education institutions (Eurostat)
		Share of public research financed by the private sector (Eurostat)
		Number of public-private co-publications per million population (CWTS)
5b	Share of publications available in (Green and/or Gold) Open Access (1Science & Science-Metrix).	Share of publications available in (Green and/or Gold) Open Access (Science-Metrix using 1Science data)
6	Co-publications with non-ERA partners per 1 000 researchers in the public sector	International co-publication rate with non-ERA partners (Science-Metrix using Web of Science)
		Non-EU doctorate students as a share of all doctorate students

Priority	Headline composite	Meta-composite ***
		(Eurostat)
		Licence and patent revenue from abroad as a share of GDP (Eurostat)
		International co-invention rate with non-ERA partners (Science-Metrix using PATSTAT data on PCT applications)

Note: * The Headline indicator for Sub-priority 2b (i.e. availability of national roadmaps with identified ESFRI projects and corresponding investment needs) has been substituted since it is a qualitative indicator not suitable for the composite. ** The Headline indicator for Sub-priority 5a aims to capture the share of innovative firms cooperating with public/private and higher education sector partners; because consolidated data was not available for these two sectors, the Headline was split into two indicators. Nine indicators are therefore integrated to cover the eight Headline indicators in the Headline composite. The two indicators for Sub-priority 5a individually carry less weight than any other indicator in the composite as they are highly correlated. They each received a weight of about 0.5, approximately half the weight of the other indicators. In the Meta-composite, sub-priorities 2a and 2b, as well as sub-priorities 5a and 5b, have each been treated as a single priority (i.e. 2a&b and 5a&b) to ensure that each intermediate composite indicator includes a minimum of two indicators, as well as to allow for a more balanced distribution of indicators across priorities. There are therefore three indicators for Priority 3, four for priorities 1 and 6, five for priorities 4 and 5, and six for Priority 2. For Priority 2, a differential weighting approach was used to ensure that the sub-priorities 2a and 2b, although they differ in number of indicators, contribute equally to the composite for Priority 2 as much as is possible. The same applies for the sub-priorities 5a and 5b of Priority 5. The data source is provided in parentheses next to the indicator name.

Source: Compiled by Science-Metrix

Normalisation, standardisation & weighting of indicators in computing the composite indicators

The method for computing the composite indicators was designed to promote equal representation of all the indicators (or intermediate priority composites in the Meta-composite) integrated into a given composite, or to give them as equal a weight as possible. This method included four facets. First, for indicators where the distribution of performance scores at the country level were very skewed, logarithmic transformations were applied to the scores before computation to yield a more normal distribution. Second, country scores on an indicator (whether logarithmically transformed or not) were standardised between 0 and 1 using the minimum and maximum scores across countries for the given indicator (i.e. [country score – min score across countries] / [min score across countries – min score across countries]). This standardisation of the scores is intended to facilitate integration of indicators on different scales — that is, where the range of scores is very wide for some indicators, while it is narrower for others. Both the normalisation and standardisation of the indicators serve to optimise the uniformity with which each indicator will contribute to the resulting composite; it ensures that none of the individual indicators will exert a disproportionate effect on the composite measure at the expense of the other indicators. Third, a weighting algorithm was applied to the individual indicators to address their inter-correlations. In short, if three indicators are integrated, and two of them are highly correlated, it somehow implies that the resulting composite will integrate fewer than three distinct dimensions due to the redundancy in the latter two indicators. As such, the dimensions (less than two) captured by each of the two inter-related indicators will have a much greater influence on the resulting score than the dimension captured by the third indicator if each indicator is equally weighted in the composite indicator. The amount of redundancy in the dimensions captured by different indicators was captured by their correlation matrix, which served to algorithmically assess and compensate for existing redundancy across indicators. Briefly, redundant indicators receive a smaller weight reflecting the extent to which the dimension they intend to measure is captured by other indicators. Finally, a sensitivity analysis was performed to ensure that the weighting did improve the representation of each indicator in the composite relative to a uniform weighting scheme. This was achieved by comparing the variance, with and without the differential weighting scheme applied, in the coefficient of determination (R^2) between each component of a composite and the composite itself. For all composites, the application of a differential weighting scheme improved the resulting composite by reducing the observed variance in R^2; in other words, the influence of each component on the composite was more evenly distributed among them.

Limitations

Clustering sets of entities (e.g. cars, computers, species, countries) based on a variable number of characteristics (i.e. there can be few or many variables) can be achieved using various statistical procedures (e.g. exploratory factor analysis, multidimensional scaling, *k*-means clustering). These procedures aim to reduce the complexity (i.e. dimensionality) of a dataset towards producing groups of entities sharing similar patterns across the original set of measured characteristics. The synthetic information resulting from such procedures can then prove to be very useful in supporting decision-making in varied contexts since it focuses the analysis on the most discriminant composite dimensions (or composite indicators).

Yet just as with any other analytical methods, clustering approaches are not without drawbacks. For instance, there is a risk of oversimplification hiding important information on the individual characteristics of entities, possibly leading to oversights on the part of decision-makers developing and implementing policies using such information. For this reason, ICF recently recommended not to use clustering approaches — or equivalently composite indicators — in their appraisal of available or potential indicators with which to monitor progress across ERA priorities (ICF, 2015).

Although the study team fully understand these limitations in the use of composite indicators to monitor progress towards achieving the ERA, it also sees a value in their use to group countries according to their performance level in complying with the set of actions implemented under each ERA priority and globally across all six priorities. Indeed, when multiple indicators are used to characterise the performance of countries, it is often difficult to highlight general trends without a well-structured ranking mechanism. Note, however, that the clustering approach and composite indicators produced in this study will not overshadow any relevant information at a lower aggregation level (i.e. individual indicators measuring progress in relation to specific actions). Indeed, this synthetic analysis only aims at supplementing the presentation of data at the indicator level.

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 (Section 3.x.1). 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 (ERAC Secretariat, 2015a) 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). The Headline indicator for the relevant priority is presented first (Section 3.x.2), and subsequently contextualised with the findings of its two accompanying EMM indicators (Section 3.x.3). Thereafter, an experimental composite indicator — integrating complementary quantitative metrics collected/developed by Science-Metrix, and where relevant and feasible the EMM indicators as well (see Section 2.3.2 for explanation on why in some cases the EMM indicators could not be included in the composite indicator) — are presented and discussed (Section 3.x.4). The quantitative findings of the Headline, EMM and composite 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 dedicated subsection (Section 3.x.5).

Guide to reading the quantitative results tables

Because 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), 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 ([10]) of countries relative to one another, to the EU-28 (weighted average) 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 ([11]) 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

[10] 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).

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

level. Thus, the comparisons to the EU-28 score are intended to help individual countries situate themselves relative to the core of the EU, so as to inform their decisions on which targets are most appropriate to them and on the ways to achieve them.

The countries are also clustered into groups based on performance for the same purpose. This clustering operation is based on the distribution of scores for all of the ERA countries for which data is available; countries more than one standard deviation above the ERA average (unweighted (see Footnote 4) average across the MS/AC for which data is 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 ([12]). 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 ([13]); 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 ([14]).

In addition to a measurement of performance in 2015 (or the most recent reference year for which sufficient data was available at the time of producing this report ([15])), the indicator tables also assess changes in national performance over time, computed as a Compound Annual Growth Rate (CAGR). Note that progress is measured by comparing the latest available data to 2005 — that is, just before 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. As with the analyses on the performance of countries, a lead/gap analysis for 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 CAGR measures growth using the longest available period for each indicator (from 2005 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

[12] For each indicator, countries for which sufficient data was 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.

[13] The ERA GDP is equal to the sum of GDP across the countries for which data is 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 is available for the reference year of an indicator, 2014 was used for computing the GDP weight.

[14] 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.

[15] Refer to the 2016 ERA Monitoring Handbook for the extraction dates of the presented data.

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. For a few indicators where short-term fluctuations were particularly pronounced, moving averages have been used to measure performance and growth (e.g. average scores across 2005-2007, 2006-2008 … 2012-2014). 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 2005-2007 and 2012-2014).

Note that the lead/gap analysis in performance is presented as a percentage of the EU-28 score by which a given country is ahead/behind that average (not directly shown in this report's tables; can still be appreciated visually by the colouring of performance scores, see below); for growth, the lead/gap analysis is simply the percentage point difference between a given country and the EU-28 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 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 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 growth is a point of interest to follow throughout this report, as it shows whether countries lagging somewhat behind are catching up to their stronger counterparts in progressing towards the ERA, or whether the stronger performers are pulling further away from the pack.

The performance–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 on the bottom, so if 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 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 definition of ERA Priority 1 in the 2015 ERA Roadmap encourages participants to harmonise their national policies with ERA-wide policies, to foster optimised use of public funds for research & innovation. The context around the implementation of this priority shows some mixed features as ERA countries differ greatly in terms of their support for and efficiency of their R&I activities. At the EU level there are significant efforts to support expenditures in R&I. For example, the Union budget for 2014-2020 included a 30 % real-terms increase in the budget for Horizon 2020, the main EU programme for R&I, while a further EUR 83 billion are expected to be invested in R&I as well as SMEs through the European Structural and Investment Funds (European Commission, 2014b). In contrast, direct R&D spending has been shrinking in several ERA countries, partly as a result of a volatile economic environment and efforts toward fiscal consolidation, or in some cases because of a strong dependence on EU funding to supplement domestic R&D budget. The observed trend around reduced R&D investment differs by ERA country; in some cases, this is (partly) compensated through increased R&D tax incentives, which are not included in the definition of GBARD. In addition, several Member States are still short of meeting national R&D targets under Europe 2020 ([16]), mainly as a result of deficit in business R&D expenditure (European Commission, 2014b; Eurostat, 2016).

[16] http://ec.europa.eu/europe2020/targets/eu-targets/index_en.htm

In this context, several Member States are 'redefining their national R&I strategies based on a broad concept of innovation, encompassing education, research and innovation' (European Commission, 2014a, p.7) to achieve greater efficiencies. Germany is an interesting case as the inter-departmental innovation policy approach supports an innovation strategy that focuses on 'new technologies linked to societal challenges, on intensifying science-industry collaboration, and on improving framework conditions for innovative businesses' (European Commission, 2014a, p.7). Recommending policy alignment remains pertinent as several ERA countries maintain a governance structure around R&I that builds on multiple policy documents or strategies (see Table 4).

Table 4 ERA countries with/without national strategy for R&I as of 2016

Country	Type of strategy
	Single overarching strategy
Austria	National R&I strategy (2011)
Bulgaria	National Research Development Strategy 2015-2020 (2014)
Czech Republic	The National RDI Policy of the Czech Republic 2009-2015, with a recent update for implementation through 2020.
Denmark	Denmark — a nation of solutions (2013)
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 to achieve 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 (2015)
Germany	New High-tech Strategy 2014-2017
Greece	National Strategy for Research, Technological Development and Innovation (ESETAK) 2015-2021. Action plan to implement this strategy remains pending.
Hungary	The National Research-Development and Innovation Strategy, 2013-2020 (Investment into the Future)
Iceland	Science and Technology Policy Council Strategy 2013-2016
Ireland	Strategy for research and development, science and technology, 2016-2020
Italy	National Research Programme 2014-2020 (pending approval)
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 2012
Turkey	National Science, Technology and Innovation Strategy (2011-2016)
United Kingdom	Our Plan for Growth: science and innovation (2014)
	Multiple strategies
Belgium	Responsibility for R&I is allocated to the three regions and the three communities composing the country. Accordingly, each region/community develops multi-annual plans on R&I.
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 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 national Strategy for Education, Science and Technology 2014-2020 sits at the centre of this heterogeneous policy framework. Additional references include the Strategy for fostering innovation 2014-2020 and the Industrial Strategy (2014).
Latvia	Guidelines for National Industrial Policy for 2014-2020 and the Guidelines for Science, Technology Development, and Innovation 2014-2020
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

Country	Type of strategy
	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	Innovation Strategy and the R&D Strategy
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
Netherlands	The overarching R&I strategy is the Enterprise Policy (2011), which focuses on research, innovation and entrepreneurship, with a slight emphasis on transforming research into innovation. Science and education aspects not covered in the Enterprise Policy are governed separately by the Ministry of Education, Culture and Science (ECS). For example, through Science Vision 2025 (2014)
Poland	The strategic framework includes Strategy for Innovativeness and Efficiency of the Economy as 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 (POIR) (2014); Regional Operational Programmes (RPOs).
Portugal	Since the late 1980s, the R&I strategies have built on the Community 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 2013-2016. 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
Israel	The government follows an innovation policy of supporting some specific needs in some areas
Luxembourg	No formalised strategy officially and formally approved, although policies and strategies relating to R&I are included in the annual plan Luxembourg 2020

Note: Data unavailable: AL, FO and UA.

Source: The main source of information used to construct Table 4 is the Country Reports produced by the Research and Innovation Observatory (RIO). Section 2.1 in each country report presents information on whether surveyed countries have adopted a single overarching R&I strategy, or a suite of strategies in the area; the reports also identify those countries where no R&I strategy has been formally adopted. In the case of Switzerland, the National ERA Roadmap was considered as no recent RIO report is available. Countries for which a recent RIO report or other recent source was not available were marked as 'data unavailable'.

In line with the goal of increasing efficiencies in R&D spending, and notwithstanding differences in actual implementation across ERA countries, the allocation of public funding for R&I increasingly tends towards competitive processes and enhanced performance requirements, generally described as Research Performance Based Funding (RPBF) systems (Jonkers & Zacharewicz, 2016). There are two principal motivations for implementing RPBF systems: first, the provision of incentives to encourage high-performance research that will increase value for money (e.g. increasing the quantity and quality of research and innovation outputs that will boost the capacity of ERA countries to address grand challenges); and second, the concentration of support within the RPOs conducting the best-performing research.

Note that a single RPBF system may, in some cases, combine project-based and institutional awarding mechanisms; depending on the national setting, either or both of these mechanisms may cover salaries. According to qualitative data, the competitive allocation of institutional funding seems mostly an exception rather than the rule. A direct consequence of the variation in RPBF systems across national contexts is that an exact determination of the share of research funding allocated on a performance basis is difficult to determine within and compare across research systems (Claeys-Kulik & Estermann, 2015).

The implementation of RPBF systems also shows considerable variation across national contexts, including variations in the type and number of assessment tools integrated within these systems. For example,

> Differences include the share of organisational-level funding that is allocated through RPBF, the speed within which the system is introduced, the degree of stakeholder involvement, the impact different systems have on the autonomy of research performers, and the criteria on which research outputs are assessed as well as the other missions and behaviours which the government wants to promote in these organisations'' (Jonkers & Zacharewicz, 2016, p.6).

3.1.2 Headline indicator

The Headline indicator identified by the ERAC to assess progress around Priority 1 is the adjusted Research Excellence Indicator (REI) computed by the DG–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 exceptions of the Faroe Islands) (ERAC Secretariat, 2015a). It covers ERC grants per public R&D (data source: DG-RTD, Eurostat, OECD), which is a good proxy to appreciate the success of countries in securing ERA-wide project-based competitive funding. It covers participation in Marie Skłodowska-Curie fellowships (DG-EAC), which is a good proxy to appreciate the extent of researcher exchanges across national, sectoral and disciplinary boundaries (regardless of career stage), which are themselves expected to foster more integrated and efficient R&I ecosystems. It covers PCT patent applications per population (OECD), which is a good output indicator to capture the inventiveness of national R&I systems. Finally, it covers the share of top 10 % most highly cited publications per total publications (CWTS), which is a good proxy of the excellence of the research output of a nation. Despite the fact that this indicator covers a range of dimensions pertaining to research effectiveness, it can hardly be regarded as providing a comprehensive coverage of all relevant dimensions under Priority 1 given its very broad scope. Also, the component on highly cited publications cannot be computed beyond 2013 because scientific publications must have had the chance to accumulate citations over a sufficiently long period. Typically, a citation window consisting of the publication year plus three is used (i.e. 2012 in this study since citation data was not yet complete at the time the indicator was produced). A citation window consisting of the publication year plus two was instead used for the latest year to provide data up to 2013 (i.e. citation window = 2013-2015). For details on the methodology used in computing the adjusted REI, please refer to Vértesy (2015). Country-by-country results are fully outlined in Table 5, and are plotted on a map in Figure 1.

The strongest performers according to the REI are Switzerland (which leads by a very wide margin) followed by the UK, Denmark, the Netherlands, Sweden, Israel, Belgium and Norway. The softest performances come from the former Yugoslav Republic (FYR) of Macedonia, Montenegro, Ukraine and Albania. The group of leaders is very strong on this indicator ([17]).

Strong performers in 2013 were also predominantly those who have been trending upwards from 2010 to 2013. This rule does not hold without exception, however, as Israel, Switzerland and Sweden have been losing ground relative to the average growth, while Luxembourg, Cyprus and Malta have been closing their gaps relative to the EU-28.

[17] The strength of the leader group pulls up the average; accordingly, the group of countries just below the average (Cluster 3) is abnormally large, containing 20 members. If performance scores were normally distributed, one would expect Cluster 3 to have about 14 members.

Looking at the GDP weight of the clusters, it appears that the ERA GDP is spread fairly evenly over clusters 1, 2 and 3, while a very little share of overall GDP (only 0.1 %) appears in cluster 4, which means that soft performance (i.e. scores well below the average across ERA countries) account for a very small share of global ERA GDP.

Table 5 Adjusted Research Excellence Indicator (2010-2013)

Country	Weight in GDP	Score (2013)	CAGR (2010-2013)	Lead/Gap to EU-28 CAGR
EU-28		**44.4**	**6.4%**	**N/A**
Cluster 1	32.3%	69.0	6.9%	0.5
Cluster 2	39.4%	46.0	6.4%	0.0
Cluster 3	28.2%	22.0	2.9%	-3.5
Cluster 4	0.1%	13.1	1.8%	-4.6
Cluster 1				
CH	3.6%	97.5	4.2%	-2.1
UK	14.1%	72.5	9.1%	2.7
DK	1.8%	70.2	8.4%	2.0
NL	4.5%	70.1	9.1%	2.8
SE	3.0%	66.6	5.2%	-1.2
IL	:	61.5	2.3%	-4.1
BE	2.7%	57.2	9.5%	3.2
NO	2.7%	56.5	7.1%	0.7
Cluster 2				
FI	1.4%	54.5	5.6%	-0.8
DE	19.4%	49.9	6.0%	-0.3
AT	2.2%	48.6	2.6%	-3.8
IE	1.2%	47.3	7.3%	0.9
FR	14.6%	46.5	6.2%	-0.2
LU	0.3%	44.6	13.6%	7.2
IS	0.1%	40.2	1.2%	-5.1
CY	0.1%	36.6	8.7%	2.3
Cluster 3				
ES	7.1%	33.9	5.9%	-0.5
IT	11.1%	33.0	5.6%	-0.8
HU	0.7%	29.7	5.2%	-1.2
EE	0.1%	29.7	3.8%	-2.6
EL	1.2%	28.7	5.5%	-0.8
PT	1.2%	27.0	4.7%	-1.7
SI	0.2%	26.3	-1.0%	-7.4
CZ	1.1%	23.4	1.9%	-4.5
MT	0.1%	22.8	8.0%	1.6
LV	0.2%	20.1	4.1%	-2.3
SK	0.5%	18.6	4.0%	-2.4
PL	2.7%	18.2	3.6%	-2.8
HR	0.3%	17.8	5.2%	-1.2
TR	:	17.8	0.1%	-6.3
BG	0.3%	17.2	0.6%	-5.8
LT	0.2%	16.4	-0.6%	-7.0
RO	1.0%	15.7	1.3%	-5.1
BA	:	14.6	1.7%	-4.7
MD	:	14.3	-0.2%	-6.6
RS	0.2%	14.3	-1.5%	-7.9
Cluster 4				
MK	0.1%	13.8	0.3%	-6.1
ME	0.0%	13.4	-0.2%	-6.6
UA	:	12.9	0.3%	-6.1
AL	:	12.2	6.8%	0.4

Note: The adjusted REI is a composite indicator integrating of 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 (DG-RTD, Eurostat, OECD) and participation in Marie Skłodowska-Curie fellowships (DG-EAC). Dates refer to actual data years, except for MSC fellowships. It was calculated using the latest available data as of April 2016 (i.e. 2013), taking into consideration the presence of a citation window for the highly cited publications indicator.

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 (2015)

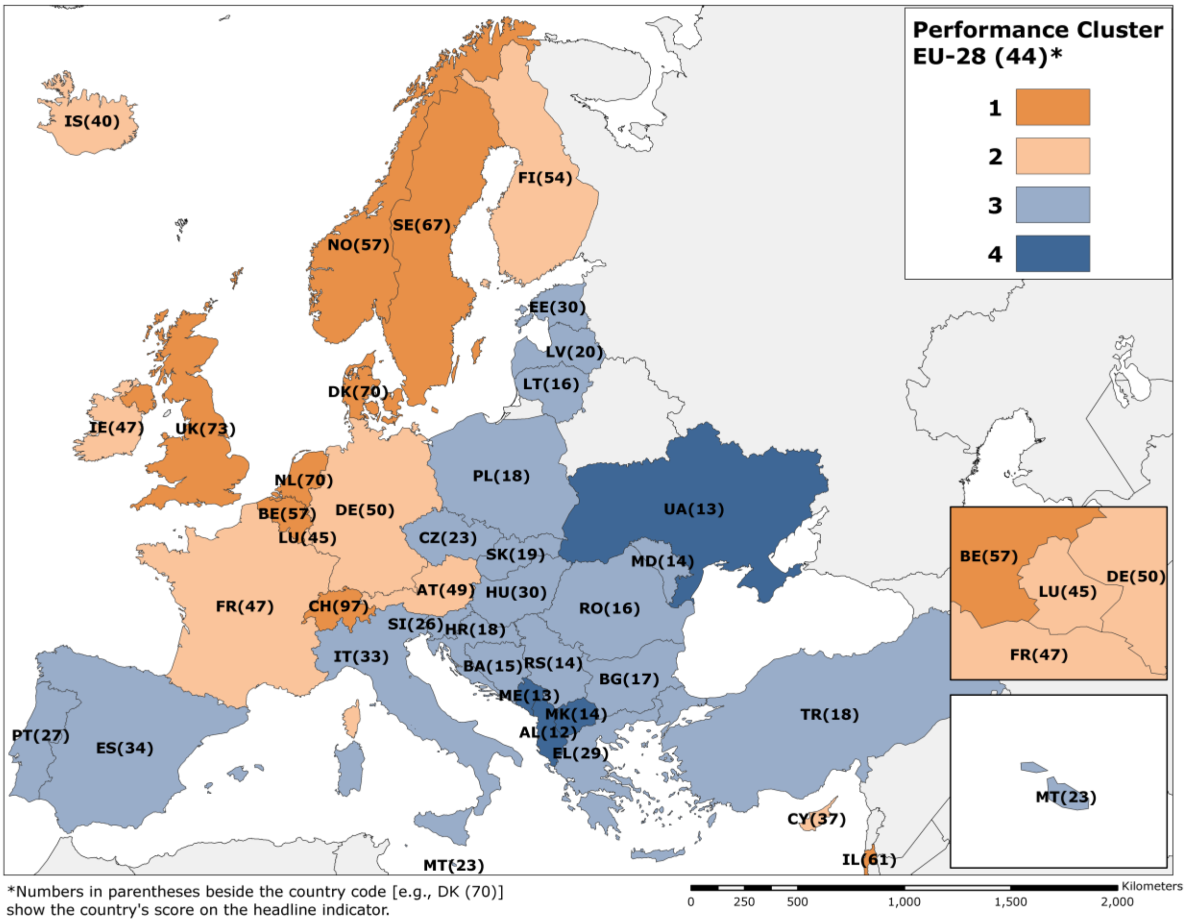

Figure 1 Map of Adjusted Research Excellence Indicator (2013)

Note: As per Table 5.

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 (2015)

3.1.3 Complementary EMM indicators

GBARD as a percentage of GDP

Public funding for R&D is a key driver, if not *the* key driver, of the strength and international competitiveness of domestic R&I systems. It is therefore highly relevant to consider input indicators of R&D investments to contextualise the relative performance of countries as measured by the adjusted Research Excellence Indicator (i.e. the previous Headline indicator). As RPBF systems — promoted to support more effective national R&I systems under ERA Priority 1 — become more and 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) ([18, 19]) are awarded on a competitive basis, through project-based and/or institutional

[18] 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.

funding. Unfortunately, data measuring such aspects of national R&I systems are relatively scarce. For example, only 11 Member States and three Associated Countries have available data for the share of GBARD allocated as project-based funding, with lots of gaps in their respective time series. Alternatively, one can 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 countries' economies in any cross-country comparative analysis. Such an indicator — that is, government budget allocations for research and development (GBARD) as a percentage of gross domestic product (GDP) — has been selected by the ERAC as the first complementary EMM indicator for Priority 1 ([20]). Note that the normalisation by the 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 they can respond very differently to such factors.

The performance of the ERA countries for this indicator (

[19] 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.'

[20] 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).

Table 6) shows a moderate and positive correlation to the performance of ERA countries based on the adjusted REI presented in Table 5 (Pearson r of 0.65), highlighting the high importance of public funding for R&D in strengthening the R&I systems of countries. A strong group of leaders (Cluster 1) composed of Denmark, Finland, Iceland, Portugal, Switzerland, Germany and Norway pulls out of the pack with leads relative to the EU-28 average ranging from 27 % to 52 %. All but one of these countries (Portugal) rank in the two top performance clusters based on the adjusted REI. The countries ranking last based on this indicator (Cluster 4) are Hungary, Bulgaria, Malta, Romania and Latvia. All rank in the two least performing clusters based on the adjusted REI.

Interview data confirmed that governments in ERA countries remain operation of domestic R&I systems, notably by maintaining some practice, roughly 38 % of ERA countries for which data is available economy and budget allocated to R&D shrink following the 2008 (Croatia and Cyprus) only later in 2012; data not shown), with their extent than their GDP (see countries with negative CAGR in

Table 6). One can actually see from the trend lines in

Table 6 that most of these countries — including Romania, Latvia, Hungary, Spain and Lithuania — have not yet recovered from this decline. This confirms that in several countries some challenges remain following the fiscal consolidation efforts undertaken to overcome the effects of the recent economic crisis in order to fully recover from the decline in R&D funding (relative to the GDP) and subsequently ensure its stability.

Despite this, stability is observed at the EU-wide level with the GBARD, percentage of the GDP, having remained relatively stable for the 2014; only a very slight decrease has been observed for the EU-28 with a CAGR of -0.5 % (

Table 6). Looking at the EU-28 trend line in

Table 6, no significant decline was observed over the longer period from 2005 to 2014. This is due to a number of countries — including, but not limited to, Luxembourg, Malta, Poland and Slovakia — which have experienced an increase over the same period (i.e. positive CAGR and lead over the EU-28 average), highlighting the heterogeneity that prevails in the growth of countries and their differentiated responses to the economic crisis. Note that the countries that have experienced the most severe decline in GBARD as a percentage of GDP include some of the less mature R&I systems within the ERA. Thus, the growth dynamics of their R&I systems, and their capacity to make progress in the implementation of the ERA might therefore depend more strongly on their ability to get continued access to EU structural funds. Note, however, that some countries that have experienced a decline in GBARD have made use of indirect fiscal measures (e.g. R&D tax incentives, not captured by GBARD) to compensate 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 only, to confirm whether there has been an overall contraction in public R&D funding across countries and to measure the extent of this contraction. Interviewees also highlighted some diverging trends in R&I investments between the public and the private sector, which makes the achievement of national targets set under Europe 2020 problematic, as noted earlier.

For the most part, and as was the case for the Headline indicator, the countries that performed well on this indicator in 2014 are also the ones with strong growth rates for 2008-2014, meaning that the leaders in GBARD/GDP are pulling further ahead of the rest of the pack. There are many exceptions to this rule though, as Malta, Slovakia, Poland, Greece and the Czech Republic have below-average performance scores but above-average growth; these countries are therefore catching up. Note that Spain, France, Italy and the UK are all large economies that show negative CAGR below the EU-28 average for growth.

As was the case for the adjusted REI (i.e. the Headline indicator for Priority 1), it appears that the ERA GDP is spread fairly evenly over clusters 1, 2 and 3, while a very small share of overall GDP (only 2.2 %) appears in cluster 4, which means that soft performance (i.e. scores well below the average across ERA countries) account for a very small share of global ERA GDP. In fact, 58 % of countries are above the ERA average (i.e. in clusters 1 and 2).

European Innovation Scoreboard composite indicator

Turning to the final EMM indicator for Priority 1, the Summary Innovation Index (SII) drawn from the European Innovation Scoreboard ([21]) is a composite indicator integrating a multitude of indicators distributed across eight dimensions covering R&I enablers (Human resources, Open, excellent and attractive research systems, and Finance and support), firm activities (Firm investments, Linkages & entrepreneurship, and Intellectual assets) and R&I outputs (Innovators and Economic effects). It thus presents a comprehensive picture of the state of a country's R&I system along the full path from inputs, through outputs, and on to outcomes/impacts. In fact, the very broad set of indicators (25 in total) make it such that it somehow covers a broader set of issues than those specific to Priority 1; in fact, some of the indicators included in the SII are also EMM indicators in other ERA priorities (e.g. public-private co-publications per million population (Priority 4) and non-EU doctorate students as a percentage of all doctorate students (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 7.

[21] Previously known as the Innovation Union Scoreboard.

The performance of the ERA countries for this indicator (Table 7) shows a high and positive correlation to the performance of ERA countries based on the adjusted REI presented in Table 5 Pearson r of 0.88). This is not so surprising since 50 % of the indicators embedded in the adjusted REI (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. The leaders on the SII are Switzerland, Sweden, Denmark, Finland, Germany and the Netherlands. The more modest results are for Poland, Lithuania, Latvia, Croatia, Turkey, Bulgaria, FYR Macedonia, Romania and Ukraine.

Comparing performance in 2015 to growth over the 2008-2015 period, one finds that the gap between the leaders and the rest has roughly remained stable, closing slightly in a number of cases. This is contrasting with the previous two indicators where the gaps appeared to be widening. For instance, one can see by comparing the CAGR scores of Cluster 3 and Cluster 4 to those of Cluster 1 and Cluster 2 that the lowest ranked countries have progressed slightly more rapidly than the leaders. The lowest ranked countries (clusters 3 and 4) more often registered positive leads to the EU-28 (orange lead/gap score) than the leaders (clusters 1 and 2). Turkey and Serbia are notably strong in terms of growth, as are FYR Macedonia and Latvia. Romania has the second-lowest performance score, as well as the lowest growth rate.

Looking at size of economy, there’s a slight correlation between higher GDP and stronger performance scores at the country level. This pattern is also visible at the level of performance clusters; there are six countries each in Cluster 1 and Cluster 4, but while Cluster 1 accounts for 33.6 % of the ERA’s GDP, Cluster 4 accounts for only 4.8 %.

Table 6 GBARD as percentage of GDP (2008-2014)

Country	Weight in GDP	Score (2014)	CAGR (2008-14)	Lead/Gap to EU-28 CAGR	Trendline (2005-14)
EU-28		**0.67%**	**-0.5%**	**N/A**	
Cluster 1	30.0%	0.93%	2.2%	2.7	
Cluster 2	28.3%	0.72%	1.7%	2.2	
Cluster 3	39.5%	0.44%	-0.9%	-0.4	
Cluster 4	2.2%	0.23%	-3.8%	-3.3	
Cluster 1					
DK	1.7%	1.02%	2.9%	3.4	
FI	1.4%	0.98%	0.7%	1.2	
IS	0.1%	0.97%	1.5%	2.0	
PT	1.2%	0.94%	1.1%	1.6	
CH	3.5%	0.89%	4.1%	4.6	
DE	19.6%	0.87%	2.1%	2.6	
NO	2.5%	0.85%	3.1%	3.6	
Cluster 2					
SE	2.9%	0.84%	1.8%	2.3	
AT	2.2%	0.80%	2.8%	3.3	
NL	4.4%	0.74%	0.4%	0.9	
LU	0.3%	0.72%	8.3%	8.8	
EE	0.1%	0.71%	2.0%	2.5	
FR	14.3%	0.69%	-3.3%	-2.8	
BE	2.7%	0.68%	0.5%	1.0	
CZ	1.0%	0.64%	3.9%	4.4	
HR	0.3%	0.62%	-0.7%	-0.2	
Cluster 3					
UK	15.1%	0.56%	-1.4%	-0.8	
ES	7.0%	0.55%	-5.0%	-4.5	
IT	10.8%	0.52%	-2.5%	-2.0	
EL	1.2%	0.44%	0.6%	1.1	
SI	0.3%	0.43%	-2.4%	-1.9	
PL	2.8%	0.43%	6.1%	6.6	
RS	0.2%	0.41%	:		
IE	1.3%	0.38%	-4.2%	-3.7	
SK	0.5%	0.38%	5.9%	6.4	
CY	0.1%	0.36%	-1.3%	-0.8	
LT	0.2%	0.35%	-4.8%	-4.3	
Cluster 4					
HU	0.7%	0.28%	-6.5%	-6.0	
BG	0.3%	0.25%	-2.7%	-2.2	
MT	0.1%	0.24%	8.2%	8.7	
RO	1.0%	0.21%	-9.6%	-9.1	
LV	0.2%	0.16%	-8.5%	-8.0	

Note: The CAGR is computed on the 2008-14 period but the trendline analysis covers 2005-14 to show the possible effect of the 2008 Financial Crisis on MS/AC economies.
Break in time series: DK (2010); EL (2008); FR (2006); LT (2005-2007); NL (2006); PL (2012); RO (2013)
Definition differs: ES (2005-2006); HU (2013); AT (2005-2014)
Estimated: EU-28 (2005-2007); EE (2005-2014); FR (2006-2007); HU (2007); PT (2014); UK (2014)
Provisional: EL (2011-2014); ES (2012-2014); CY (2014); MT (2014); NL (2013-2014); RO (2014); UK (2014); IS (2014); CH (2014)
Potential outlier: HU (2013)
Data unavailable: ME, MK, AL, TR, BA, IL, FO, MD, UA
(:) = missing data

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

Table 7 European Innovation Scoreboard Summary Innovation Index (2008-2015)

Country	Weight in GDP	Score (2015)	CAGR (2008-15)	Lead/Gap to EU-28 CAGR	Trendline (2008-15)
EU-28		**0.52**	**0.7%**	**N/A**	
Cluster 1	33.6%	0.68	0.6%	-0.1	
Cluster 2	38.2%	0.57	0.4%	-0.3	
Cluster 3	23.4%	0.40	1.2%	0.5	
Cluster 4	4.8%	0.25	1.2%	0.5	
Cluster 1					
CH	3.6%	0.79	-0.1%	-0.8	
SE	3.0%	0.70	0.1%	-0.6	
DK	1.8%	0.70	1.7%	0.9	
FI	1.4%	0.65	-0.3%	-1.0	
DE	19.4%	0.63	0.2%	-0.6	
NL	4.5%	0.63	2.0%	1.3	
Cluster 2					
IE	1.2%	0.61	0.6%	-0.2	
BE	2.7%	0.60	0.9%	0.2	
UK	14.1%	0.60	2.0%	1.2	
LU	0.3%	0.60	-0.8%	-1.5	
AT	2.2%	0.59	0.2%	-0.5	
IL	:	0.58	-0.8%	-1.5	
IS	0.1%	0.57	-0.1%	-0.8	
FR	14.6%	0.57	0.8%	0.0	
SI	0.2%	0.48	1.2%	0.4	
NO	2.7%	0.46	0.4%	-0.3	
Cluster 3					
CY	0.1%	0.45	-0.6%	-1.3	
EE	0.1%	0.45	1.1%	0.3	
MT	0.1%	0.44	3.6%	2.8	
CZ	1.1%	0.43	0.7%	0.0	
IT	11.1%	0.43	1.5%	0.8	
PT	1.2%	0.42	0.9%	0.2	
EL	1.2%	0.36	-0.2%	-1.0	
ES	7.1%	0.36	-0.8%	-1.5	
HU	0.7%	0.35	0.4%	-0.4	
SK	0.5%	0.35	1.4%	0.6	
RS	0.2%	0.32	5.4%	4.6	
Cluster 4					
PL	2.7%	0.29	0.1%	-0.6	
LT	0.2%	0.28	2.4%	1.6	
LV	0.2%	0.28	4.0%	3.2	
HR	0.3%	0.28	-0.9%	-1.7	
TR	:	0.27	5.1%	4.4	
BG	0.3%	0.24	1.4%	0.7	
MK	0.1%	0.22	4.3%	3.6	
RO	1.0%	0.18	-4.4%	-5.1	
UA	:	0.18	-0.8%	-1.6	

Note: Data unavailable: ME, AL, BA, FO, MD.

Source: Hollanders, H., Es-Sadki, N., and Kanerva M. (2016) European Innovation Scoreboard. Report prepared for the European Commission, Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs. http://ec.europa.eu/DocsRoom/documents/17822/attachments/1/translations/en/renditions/native

Comparing Headline to complementary EMM indicators

Looking across indicators for Priority 1, the performance on the Headline and the two complementary EMM indicators are all positively correlated, which is to say that the strong performers are generally the same across each of these indicators. In terms of relative strength, the Headline indicator is more tightly correlated to the EIS Summary Innovation Index (SII, Pearson r of 0.91) than it is to the GBARD/GDP (Pearson r of 0.65). It might be tempting to conclude, based on the above correlations, 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 still prevail at a country-by-country level across the various dimensions captured by the Headline and EMM indicators. These differences should never be overlooked as they likely convey crucial information for understanding the functioning and explaining the relative performance of individual R&I systems.

Looking at growth one finds a much more varied picture: a country that is growing strongly in one area is not necessarily showing a similar trend elsewhere. Correlations between growth scores across indicators are much weaker. Recall also that size of economy (as measured using GDP) is slightly linked to performance scores on the Headline indicator as well as the SII for Priority 1, with larger economies performing relatively better — to varying degrees — than smaller ones.

Looking at the GBARD as a proportion of GDP, we see that there is a growing divergence between countries, as some focus on increasing their investments in research and innovation, while others are scaling these investments back. The qualitative information shows that this divergence may be reflective of a broader phenomenon of countries either trimming down research budgets under the auspices of overall fiscal consolidation or increasing their investments in research and innovation with the goal of using this to drive further economic growth. These broader phenomena may be contributing to the divergences seen in the quantitative findings presented here, which show a growing gap between the leader group and the rest of the pack. Nonetheless, the R&D fiscal support is not completely accounted for by the GBARD as a proportion of GDP as it does not include indirect government support through fiscal measures (e.g. R&D tax incentives), which may partially compensate for the decrease in GBARD.

3.1.4 Additional policy highlights

Competitive funding allocation and use of international expert review panels: Interview data confirmed that the competitive allocation of research funding through calls for proposals is a largely shared practice among ERA countries. Nonetheless, additional efforts are needed around the inclusion of international experts in review panels. Some countries have a long tradition of this practice (including but not restricted to Austria, Denmark, Finland, Germany, the Netherlands, Norway, Portugal, Sweden and Switzerland), while a significant number of ERA countries have adopted it only recently. The relevance of international experts likewise varies by ERA country; countries such as Estonia or Slovenia often rely heavily on international experts due to the limited size of the local research communities. The inclusion of external reviewers can be difficult, however, when they lack the required language competencies, or when submission systems need to be adapted to support English-language submissions.

Qualitative data highlighted the pertinence of a nuanced approach to the competitive allocation of R&I funding. While the expectation is that competition increases efficiency in research systems, resource allocation should be consistent with differences in the research capacities and mandates of RPOs, as well as the planning of research activities over the short to long term. In instances where researchers' salaries are linked to funds allocated through competitive mechanisms, the results may be growing instability and a reduced attractiveness of research careers, or a disproportionate investment of time spent writing research proposals at the expense of the time available for actually conducting research. Some additional risks refer to a hyper-solicitation of prominent experts, or financial constraints faced by some RPOs seeking to attract the best experts in a given field.

Organising the research landscape: The number of RFOs and RPOs has reduced in several countries across Europe. RFOs have been reorganised in order to improve efficiency in funding allocations and avoid duplication, while RPOs have been clustered to reach critical mass in order to compete more strongly at the international level. Some countries have streamlined RFOs at the national level (e.g. Belgium, Denmark, Germany, Ireland, Israel, Norway) or are in the process of doing so (e.g. Finland, Hungary). Others have aligned the procedures between RFOs (e.g. Romania) or already had a centralised system (e.g. the Czech Republic, Luxembourg, Poland, Slovenia), and some countries could improve their R&I system by streamlining their RFOs at the national level (e.g. Greece, Italy, Spain, Turkey).

3.1.5 Composite indicator

The composite indicator developed by Science-Metrix for Priority 1 integrates the adjusted REI, the GBARD/GDP, the number of researchers per 1 000 population, and the number of papers published per 1 000 researchers ([22]). The main goal was to synthesise the EMM indicators (including the Headline figure), as well as to broaden the set of indicators covered, to provide the most comprehensive overview of all the relevant dimensions under Priority 1. All indicators were given the same importance in building the composite, while their weight was adjusted to account for redundancy among the selected indicators; two indicators that would be highly correlated would each be given a smaller weight so that, globally, the dimensions they reflect would not be given more importance in the resulting composite than the dimensions covered by the other indicators. The same approach has been used throughout for all priority composites and the composite of Headline indicators (as well as the Meta-composite) presented in Section 4. For details on the construction of the composite indicators, refer to Section 2.3.2.

As mentioned earlier, the adjusted REI already covers four dimensions of high relevance to more effective national R&I systems. It covers ERC grants per public R&D, which is a good proxy to appreciate the success of countries in securing ERA-wide project-based competitive funding. It covers participation in Marie Skłodowska-Curie fellowships, which is a good proxy to appreciate the extent of researcher exchanges across national, sectoral and disciplinary boundaries (regardless of career stage), which are themselves expected to foster more integrated and efficient R&I ecosystems. It covers PCT patent applications per population, which is a good output indicator to capture the inventiveness of national R&I systems. Finally, it covers the share of top 10 % most highly cited publications per total publications, which is a good proxy of the excellence of the research output of a nation. However, it does not capture research productivity, which is a key dimension in measuring the efficiency of national R&I systems. For this reason, the number of publications per 1 000 researchers in the public sector is added to the composite. Like many other productivity metrics, this indicator comes with limitations in that the typical production size of researchers varies across scientific subfields, such that differences in the specialisation patterns of countries reduce its cross-country comparability when used as a proxy for productivity. For an even more complete picture, key drivers of national R&I systems were added along two dimensions: R&I investments (GBARD/GDP) and human resources (number of researchers per 1 000 population).

Full country-by-country results for the Priority 1 composite indicator are detailed in Table 29 (Annex 1). Note that countries are sorted in descending order based on the composite performance. The table shows that on the individual component indicators, stronger performances are also located primarily at the top of the table. Some outliers from the predominant correlation patterns are visually evident by examining the colour pattern. For instance, the UK's performance on the REI is notably strong, as is Portugal's performance in the GBARD/GDP, and the performances of Cyprus and Ireland for the number of papers per 1 000

[22] The EIS Summary Innovation Index (SII) integrates over 20 indicators. Some of them are redundant with the indicators already included in the composite by Science-Metrix, while others also appear under other ERA priorities; accordingly, it was not included in the computation of this new composite.

researchers. Given its score for the composite, Cyprus has a notably low score for its number of researchers per capita.

According to this composite indicator, the leading countries for Priority 1 are Denmark, Sweden, Switzerland, Finland and the Netherlands. At the other end of the spectrum are Malta, Serbia, Lithuania, Slovakia, Romania, Bulgaria and Latvia. The distribution of countries is slightly skewed, with clusters 2 and 4 having a few more members than expected, at the expense of Cluster 3.

Size of economy (GDP) shows a very slight and positive correlation with performance. However, whereas the Headline and complementary EMM indicators all showed at least 30 % of the ERA GDP in Cluster 1, the composite indicator tells a slightly different story: Cluster 1 only accounts for 14.0 % of GDP in this case (and includes 15 % of countries), with Cluster 4 still accounting for a small share (2.5 %) of pooled ERA GDP (and includes 21 % of countries). This shift has occurred because Germany (19.6 % of ERA GDP) is in Cluster 1 for both the Adjusted Research Excellence Indicator and the EIS Summary Innovation Index (SII), and the UK (15.1 % of ERA GDP) is in Cluster 1 in the case of the GBARD/GDP. However, for this composite indicator, both of those countries fall in Cluster 2, which contains 13 countries (39 % of countries) and 70 % of the ERA GDP.

Main findings

1. Looking at harmonising national policies for research & innovation (R&I), national strategies are in place for most countries. However, alignment across multiple documents can still be improved to provide a clearer direction and ensure that the multiple bodies in the R&I ecosystem are efficiently integrated.

2. In terms of optimising the return on public investments in R&I, streamlining the processes for research funding and research processes can be of great value, as shown in some countries. Further streamlining has been undertaken in some countries to reduce fragmentation amongst the multitude of RFOs and RPOs in the research ecosystem; yet further streamlining would help to optimise funding allocation processes and to reach critical mass more often in research performance. A clearer and more readable R&I landscape would also facilitate the processes of transnational collaboration (connecting to Sub-priority 2a), international collaboration (Priority 6) and intersectoral collaboration (Sub-priority 5a).

3. Funding is also allocated through increasingly competitive and transparent processes, which makes additional contributions to increasing value derived from these investments. The criteria and processes for these funding allocation mechanisms would benefit from further fine-tuning, with best practices shared across the ERA. An appropriate balance must be sustained between competitive and basic funding, at both the project and the institutional levels. Furthermore, certain experts are over-solicited, suggesting that the responsibility for review must be more evenly spread amongst the group of international experts.

4. Research assessment mechanisms could also use further fine-tuning. At the level of overall R&I systems, assessment measures used to compare across regions and countries need to take into account the diversity of local realities across Europe, for instance in determining whether publication or patent output is a more relevant measure. At the level of individual research careers, a more holistic approach to assessment is urged, a point that connects to Priority 3.

5. The R&I system must be supported through sufficient and consistent funding, and while strong support from the EU level is noted as greatly beneficial, the gap is growing

between leader countries who sustained their R&I investments as part of a strategy for economic growth in the wake of the 2008 Financial Crisis and other countries who have decreased their R&I investments since 2008 as part of broad-based measures of fiscal consolidation. Some of these latter countries are much more dependent on EU-level structural funding. Furthermore, many countries are having trouble enticing their private sectors to invest in R&I, and are thus struggling to meet their Europe 2020 targets in this regard. Clear and strong national commitments for long-term funding of R&I would help to stabilise these situations; such commitments would facilitate finding an optimal balance of participation from ERA countries in addressing grand challenges (connecting to Priority 2a) and providing a predictable investment environment for business to collaborate with the public sector in R&I (Sub-priority 5a).

3.2 Priority 2 – Optimal transnational cooperation and competition

3.2.1 Policy context

Reale et al. (2013) assert that the goal of enhancing coordination between EU Member States' national research policies has a long tradition, dating back to the 1950s; ever since, the idea of a common policy in science and technology was considered of strategic importance for the growth and development of the European Union. Initial 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]' (p. 5). The 1970s saw the emergence of some of the first intergovernmental funding schemes — for example, COST and EUREKA — targeting cooperative research, networking and transnational collaborations involving European and non-European research organisations (Reale et al. 2013). Progressing into the 2000s, the scope of EU policies adopted a greater emphasis 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; this is the case of ERA-NET initiatives launched under FP6, Article 169 (now Article 185) and, more recently, Joint Technological Platforms (Reale et al. 2013). Joint and open programmes involving R&D activities have followed different motivations and economic rationales; however, these, together with the opening of national R&D programmes, have allowed ERA countries to enhance openness and to overcome some 'barriers and political reluctance to transfer national funds abroad' (Reale et al. 2013, p. 5).

The notion of joint programming, introduced in 2008 to support the implementation of the ERA, involves Member States entering into a voluntary partnership, agreeing on a common research agenda and implementing this agenda jointly (Science Europe, 2015b). The motivation for such arrangements is that the grand societal challenges they target are often too substantial to be addressed by one national research community without the significant cooperation of others, and that this cooperation should be managed through partnership to establish a shared research agenda. Cooperation through joint programming is intended to reduce the isolation that leads to fragmentation or ineffectiveness in European research programmes (European Commission, 2013). The coordination of existing programmes or the implementation of new ones via joint programming is intended to improve the efficiency of European public research funding in order to address the aforementioned challenges (European Commission, 2008).

In 2015, an evaluation of joint programming to address grand societal challenges, which incorporated the data available at end of December 2015 (30/32 joint calls) (Hunter, Hernani, Giry, Danielsen, & Antoniou, 2016), documented a total of 32 joint calls implemented by the Joint Programming Initiatives (JPIs). The distribution of annual calls since 2011 shows that actual implementation of joint calls by most JPIs started by 2014/15. By the end of 2015, more than EUR 335 million had been committed to JPIs; it is noted, however, that a small group of countries leads the way on these projects, as nearly two thirds of this funding has come from Germany, Sweden, the Netherlands, France, UK, Italy and Norway (Hunter, Hernani, Giry, Danielsen, & Antoniou, 2016). At the time of writing, at least 10 JPIs were operational in areas related to health, agriculture and food security, smart cities, and environment and water, among other topics (Science Europe, 2015b). The ERA-NET Cofund mechanism 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 (Hunter, Hernani, Giry, Danielsen, & Antoniou, 2016).

Taken together, public funds allocated through JPIs and the ERA-NET Cofund action of the Work Programme 2014/15 were expected to exceed EUR 600 million in 2016. The public funding resulting from the FP6 and FP7 ERA-NET/ERA-NET Plus actions is expected to total EUR 3.1 billion until the end of 2017 (Niehoff, 2014). Additional initiatives, not recognised as JPIs, also aim to address societal challenges; these initiatives include Biodiversa, E-Rare, Metrology Article 185, and the Strategic Energy Technology Plan (SET Plan) (Hunter, Hernani, Giry, Danielsen, & Antoniou, 2016).

3.2.2 Headline indicator 2a — Transnational cooperation

As the Headline indicator for Sub-priority 2a, the 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. Additionally, note 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 resulting from policy interventions at 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 8, and are plotted on a map in Figure 2.

The data for 2014 show a very strong performance for Switzerland, which has a score three times larger than that of its nearest competitor (Belgium). In fact, because the score for Switzerland is more than four standard deviations away from the average across available countries, it was not used in determining the clusters' boundaries; even though its score reflects a real figure, it was considered as an outlier because of the specificity of the H2020 contribution mechanisms that are in place for Switzerland (as well as for other Associated Countries) (see box this page).

Removing Switzerland from the ERA average provides a better distribution of countries across performance clusters; this leads to 6 countries in Cluster 1, 8 in Cluster 2, 13 in Cluster 3, and 4 in Cluster 4 (Table 8). Based on this distribution of countries by performance clusters, the strongest performers for 2014 are Switzerland, Belgium, Italy, Austria, Iceland and Sweden, while the lowest scores are observed for Serbia, Bulgaria, Slovakia and Malta.

Swiss investments in transnational R&D

As shown in Table 8, Switzerland makes very large contributions to transnational, bilateral and multilateral R&D projects, when contributions are normalised by the FTE of public-sector researchers. A substantial portion of these contributions go towards Swiss participation in the framework programmes (including Horizon 2020 under Pillar I, covering the 2014-2016 period), the European Atomic Energy Community, and the ITER activities of Fusion for Energy. These investments amount to a level of contribution per researcher that is by far the highest of all countries assessed, three times higher in fact than the next leading country.

The large contribution of Switzerland stems from the combination of its relatively large GDP and the contribution rules for AC. For its participation in the Fusion part of the EURATOM Research and Training programme (2014-2018) and the ITER activities, the contribution rule for Switzerland is based on the following proportionality factor: GDP Associated Country / (GDP EU-28 + GDP Associated Country). For its contribution to H2020 and the Fission part of EURATOM Research and Training Programme (2014-2018), the factor is as follows: GDP Associated Country / GDP EU-28.

It is worth noting that Swiss participation in Horizon 2020 was suspended in 2014 as a result of the acceptance of the Swiss People's initiative against mass immigration. Note that data shown for Switzerland in Table 8 is for 2012, because complete data for more recent years is not yet available. However, the preliminary results indeed show a substantial decrease of financial contributions to transnational, bilateral and multilateral R&D projects in 2014 (about half the amount of previous years). However, even in spite of this substantial drop, the preliminary figures available for Switzerland for 2014 would still place this country first among all those assessed in the present exercise. Also note that interim measures are being set in place by the Federal Council to ensure the continued support of researchers on a project-by-project basis.

Another potential source of bias explaining the strong score of Switzerland stems from the fact that the figures for Researchers in FTE in the Swiss Government sector are only covering the Federal or central government. However, recall that public sector researchers in this study refer to the sum of the Government and Higher Education sectors, the latter usually being much larger than the former. As a result, it is difficult to assess the magnitude of this bias, although it is likely not that large.

Turning to growth, the performance in 2014 and growth over the 2010-2014 period are not correlated, with much variation in the CAGR scores of countries within clusters 1 and 2 (merged), as well as within clusters 3 and 4 (merged). However, it is interesting to note that the average CAGR within Cluster 3 is about three times larger than the average CAGR in Cluster 1 or Cluster 2. On the other hand, those in Cluster 4 have the strongest decline; however, this is only due to Malta, which has seen its score declining by 100 %. These two findings together indicate that the countries that progressed most significantly in terms of GBARD allocated to transnationally coordinated research are within the least performing countries and have closed (e.g. Luxembourg), or are closing (e.g. Poland, Latvia and Estonia), their gap to the EU-28 average. The strongest declines are also observed within the least performing cluster, with Malta, Slovenia and Greece experiencing a widening of their gap to the EU-28 average.

There is no obvious correlation between performance clusters and the proportion of GDP for the ERA region they cover. As was the case for many indicators in Priority 1, it appears that the ERA GDP is spread fairly evenly over clusters 1, 2 and 3, while a very little share of overall GDP (only 1.2 %) appears in cluster 4 for the Headline indicator in Sub-priority 2a. This means that soft performance (i.e. scores well below the average across ERA countries) account for a very small share of global ERA GDP.

Table 8 GBARD (EUR) allocated to Europe-wide transnational, as well as bilateral or multilateral, public R&D programmes per FTE researcher in the public sector (2010-2014)

Country	Weight in GDP	Score (2014)	CAGR (2010-14)	Lead/Gap to EU-28 CAGR	Trendline (2007-14)
EU-28		**2 507**	**7.8%**	**N/A**	
Cluster 1	25.9%	10 923	5.0%	-2.8	
Cluster 2	36.6%	3 642	5.4%	-2.4	
Cluster 3	36.2%	1 140	15.0%	7.2	
Cluster 4	1.2%	63	-22.8%	-30.6	
Cluster 1					
CH	4.1%	*27 941*	:		
BE	3.1%	9 251	1.0%	-6.8	
IT	12.6%	8 395	*18.1%*	10.3	
AT	2.6%	6 958	3.4%	-4.3	
IS	0.1%	*6 927*	:		
SE	3.4%	6 067	*-2.5%*	-10.3	
Cluster 2					
DE	22.8%	*4 686*	*-1.1%*	-8.9	
NO	3.0%	4 414	-3.9%	-11.7	
NL	5.2%	4 101	10.4%	2.6	
FI	1.6%	3 795	*-0.2%*	-8.0	
LU	0.4%	3 387	35.2%	27.4	
CY	0.1%	3 018	0.7%	-7.1	
IE	1.5%	2 951	5.7%	-2.0	
DK	2.0%	2 787	-3.7%	-11.4	
Cluster 3					
UK	17.6%	2 561	11.0%	3.3	
ES	8.1%	2 385	6.2%	-1.6	
HR	0.3%	1 569	22.5%	14.8	
CZ	1.2%	1 245	-3.4%	-11.1	
RO	1.2%	1 191	*9.5%*	1.7	
EL	1.4%	1 098	*-12.6%*	-20.4	
LV	0.2%	1 030	47.1%	39.4	
SI	0.3%	955	*-18.4%*	-26.2	
EE	0.2%	939	25.7%	18.0	
PT	1.4%	749	1.4%	-6.4	
PL	3.2%	678	76.8%	69.0	
LT	0.3%	220	24.8%	17.1	
HU	0.8%	194	3.8%	-4.0	
Cluster 4					
RS	0.3%	101	:		
BG	0.3%	97	*16.0%*	8.2	
SK	0.6%	52	15.7%	7.9	
MT	0.1%	0	-100.0%	-107.8	

Note: The CAGR is computed on the 2010-14 period but the trendline shows data for the period 2007-2014.
Break in time series: EU-28 (2007, 2008, 2012, 2013); 2012 (BE, LV); 2007 (DK, NO); PT (2008, 2013); 2011 (RO, SI, FI); SE (2013); IS (2011, 2013); RS (2014)
Definition differs: 2007-2014 (EU-28, NL, SK); HR (2012-2014); NO (2007-2009); CH (2008, 2010, 2012)
Estimated: 2007-2014 (EU-28, BE, NL); DK (2014); IE (2007, 2014); HR (2013); 2012-2014 (IT, SE); LU (2007, 2014); AT (2008, 2010, 2012, 2014); SK (2007); FI (2011-2014); UK (2010-2014); CH (2008, 2010, 2012)
Provisional: 2014 (EU-28, BE, CZ, DK, IT, CY, LU, MT, NL, AT, PT, SI, UK
Potential outlier: EE (2009); CY (2008); HU (2012)
Eurostat country flags have been retained in the EU-28 aggregate

Missing countries in EU-28 aggregate: Performance (FR); Growth (DE; EL; FR; IT; RO; SI; FI; SE)
Exception to reference year: DE (2013); IS (2013); CH (2012)
Exception to reference period: DE (2011-2013); 2011-2014 (RO, FI); 2012-2014 (EL, IT, SE)
Data unavailable: FR, ME, MK, AL, TR, BA, IL, FO, MD, UA
(:) = missing data
CH is more than four standard deviations away from the mean and was therefore not used in establishing the clusters' boundaries. The data for Researchers in FTE in the Swiss Government sector are only covering the Federal or central government. However, recall that public sector researchers in this study refer to the sum of the Government and Higher Education sectors, the latter usually being much larger than the former. As a result, a bias favouring Switzerland is possible, although likely not that large.
For the Netherlands, data for the category ‘National contributions to Europe-wide transnational public R&D programmes’ do not include the joint programmes as defined in the JOREP project. All projects have to be approached separately. There is no central database with this kind of data (personal communication, EUROSTAT representative, September 2016). Nonetheless, an 'Estimated' flag is used in Eurobase instead of an 'Underestimated' flag.

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

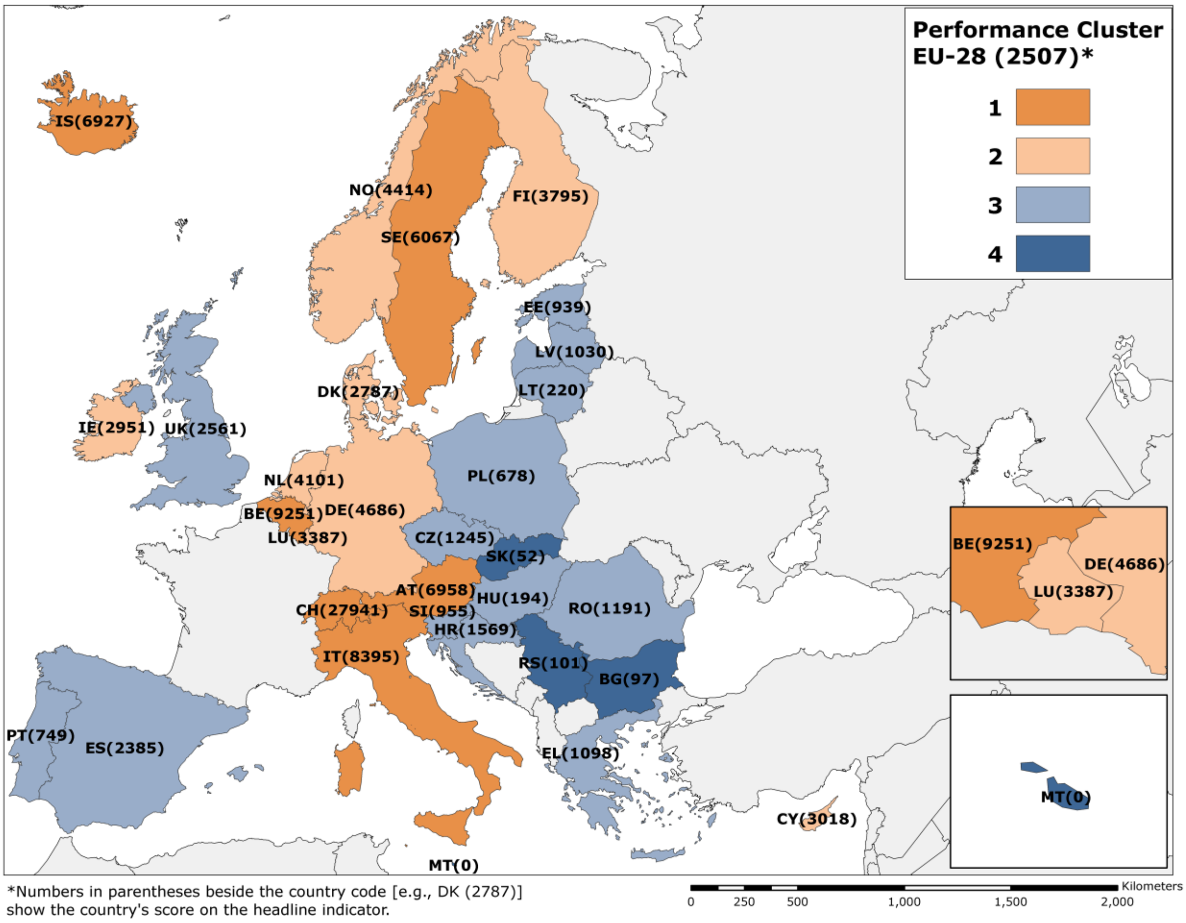

Figure 2 Map of GBARD (EUR) allocated to Europe-wide transnational, as well as bilateral or multilateral, public R&D programmes per FTE researcher in the public sector (2014)

Note: As per Table 8.

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 collaborations

The first complementary indicator for Sub-priority 2a is the investment in collaborations, including ERA-NETs, Joint Programming Initiatives initiatives. To account for country size differences, national the number of FTE researchers. This indicator provides information previous Headline indicator. Assuming that ERA-NETs and JPIs are address European grand challenges, this indicator might provide a the Headline indicator, of the alignment between transnationally the tackling of European grand challenges. However, data is only States and for three years (2012-2014); Associated Countries are Headline indicator, this indicator can be affected by a small-country countries may be more likely to find domestic partners and thus transnational cooperation than researchers from smaller countries. can be found in

Table 9.

The performance clusters are highly unbalanced relative to expectation under a normal distribution of the scores for this indicator (expectation would roughly equal 4 countries each in clusters 1 and 4, and 10 countries each in clusters 2 and 3). There are fewer countries than expected in Cluster 1 (3 or 11 %) and Cluster 2 (8 or 29 %), significantly more countries than expected in Cluster 3 (17 or 61 %), and no countries in Cluster 4. In fact, Cluster 3 can be regarded as a merge of the two least performing clusters, meaning that among the soft performance, there are no countries standing very far (more than one standard deviation) below the ERA average. This distribution of countries across clusters is due to a positive skew in the distribution of the scores. However, contrary to the previous Headline indicator, there is no obvious outlier in the pack of leaders (i.e. the skew in performance is distributed over more of the leading countries). The top performers on this indicator are Cyprus, Luxembourg and Sweden. Greece is by far the country with the smallest investment relative to its number of researchers. Other countries with low scores include the Czech Republic and Bulgaria.

When looking at the aggregated scores for the performance clusters, there appears to be a positive correlation between performance and growth. However, given the level of variation in CAGR within each cluster, it appears that countries with a very high CAGR are observed in all clusters; in fact, the correlation between performance and growth is very small at the country level. For instance, Cyprus significantly increased its lead on the EU-28 in Cluster 1 with a CAGR of 235 %, 193 percentage points ahead of the EU-28's CAGR. In Cluster 2, the same can be said of Latvia, while in Cluster 3, Croatia, Hungary and Estonia significantly reduced their respective gaps to the EU-28.

A very weak negative correlation exists between GDP and performance on this indicator. Although it is difficult to appreciate this connection at the country level given the weakness of this correlation, one can appreciate it by looking at the performance clusters. Cluster 1 includes roughly 10 % of countries and accounts for under 4 % of the ERA GDP, whereas Cluster 3 contains roughly 60 % of countries but these account for over 80 % of the ERA GDP. In fact, the four countries that each account for over 10 % of the ERA GDP — Germany, France, Italy and the UK — are all within the least performing cluster on this indicator. Still, in absolute terms, it is worth noting that they together account for nearly half of the investment in public-to-public collaborations (DE = 19 %, FR = 10 %, IT = 4 % and UK = 13 %). Additionally, note that this indicator presents a country-size bias. 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 (e.g. for gaining specific expertise or accessing specific equipment).

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 and a country-location bias (see Table 2).

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

Full results for this indicator for the 2005-2014 period can be found in Table 10. The results indicate that researchers from Cyprus, Switzerland, Ireland, the Netherlands, Austria and Luxembourg tend to publish the most articles in collaboration with other ERA partners, while FYR Macedonia, Poland, Latvia, Lithuania, Bulgaria and Turkey produce the fewest such publications per 1 000 researchers. The leader group on this indicator is quite strong, with a considerable lead over the rest of the pack.

Performance and growth on this indicator do not correlate much with one another: some countries in the top two performance clusters (clusters 1 and 2) are increasing their lead on the EU-28, while for others it is diminishing, whereas some countries in the bottom two performance clusters (clusters 3 and 4) are reducing their gap to the EU-28, while for others it is increasing. Cyprus is notable here as the country with the largest number of ERA co-publications per 1 000 researchers in 2014, and it also showed the fastest increases over the 2005-2014 period; it consistently increased its number of ERA co-publications per 1 000 researchers by roughly 13 % per year, while the next fastest increases were in the range of a 5 % annual increase. Croatia (Cluster 3) and Iceland (Cluster 2) are also showing impressive growth, while Bulgaria, Germany and Switzerland have been losing ground relative to growth in the rest of the ERA.

Size of economy shows no meaningful correlation with performance on this indicator, meaning that large and small economies are both found among standout performers or followers. The bulk of GDP sits in Cluster 3, behind the ERA average, with nearly 75 % of the ERA GDP covered in this cluster. Once again, the largest economies in the ERA are behind the overall average. However, one should note the presence of a bias in favour of small countries on this indicator, as was the case for investment in public-to-public partnerships. Other potential biases relate to the fact that countries at the geographic centre of the EU might have a higher share of intra-EU cooperation, while countries at the periphery of the EU or bordering non-EU countries might have a higher share of non-EU cooperation. There 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-EU cooperation.

Comparing Headline to complementary EMM indicators

The Headline indicator for Sub-priority 2a, GBARD allocated to transnationally coordinated research, shows a weak and positive correlation (Pearson r = 0.34) with participation in public-to-public partnerships (such as ERA-NETs). It also shows a positive correlation with the number of ERA co-publications per 1 000 researchers. While the correlation is stronger in this case, it remains moderate (Pearson r = 0.51). 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 are normalised by the number of FTE researchers in the public sector, it is worthy of mention that public funding has been increasing for both GBARD allocated to transnationally coordinated research and for public-to-public partnerships (such as ERA-NETs), the latter much more sharply than the former. In both cases, these overall increases are led by certain stand-out countries that have been stepping up their investments in transnational projects, which serve to further integrate the ERA and address shared challenges. Croatia and

Latvia, for example, increased their 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 in the least performing cluster, while for public-to-public partnerships, strong growth was observed for countries in all performance clusters. Collaborative research publications co-authored by ERA partners are also increasing (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 international 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 to track the increasing level of integration within the ERA.

Table 9 Member State participation (EUR) in Public-to-Public collaborations per FTE researcher in the public sector (2012-2014)

Country	Weight in GDP	Score (2014)	CAGR (2012-14)	Lead/Gap to EU-28 CAGR	Trendline (2012-14)
EU-28		**512**	**42.1%**	**N/A**	
Cluster 1	3.6%	2 836	123.8%	81.8	
Cluster 2	14.6%	1 176	94.7%	52.6	
Cluster 3	81.8%	302	66.9%	24.8	
Cluster 4	N/A	N/A	N/A	N/A	
Cluster 1					
CY	0.1%	3 625	235.0%	192.9	
LU	0.4%	2 836	29.4%	-12.7	
SE	3.1%	2 046	107.2%	65.1	
Cluster 2					
AT	2.4%	1 610	49.9%	7.8	
DK	1.9%	1 358	99.1%	57.0	
LV	0.2%	1 334	232.2%	190.1	
NL	4.7%	1 087	90.3%	48.2	
BE	2.9%	1 064	55.5%	13.4	
MT	0.1%	1 047	:		
FI	1.5%	983	66.4%	24.3	
RO	1.1%	927	69.4%	27.3	
Cluster 3					
SI	0.3%	769	20.6%	-21.4	
IE	1.4%	739	33.7%	-8.4	
DE	20.9%	571	21.4%	-20.7	
FR	15.3%	439	33.0%	-9.1	
EE	0.1%	367	196.1%	154.0	
UK	16.2%	345	38.3%	-3.8	
ES	7.5%	312	34.7%	-7.4	
IT	11.5%	255	3.7%	-38.4	
PL	2.9%	253	23.1%	-19.0	
PT	1.2%	224	58.3%	16.2	
HU	0.7%	199	234.0%	191.9	
LT	0.3%	163	104.9%	62.9	
SK	0.5%	142	14.6%	-27.5	
HR	0.3%	133	249.5%	207.4	
CZ	1.1%	104	37.3%	-4.8	
BG	0.3%	103	93.1%	51.0	
EL	1.3%	18	-59.5%	-101.6	

Note: Break in time series: EU-28 (2012-2013); BE (2012); 2013 (PT, SE)
Definition differs: EU-28 (2012-2014); HR (2012, 2014); 2012-2014 (NL, SK)
Estimated: 2012-2014 (EU-28, SE); 2014 (BE, DK, D, IE, LU, UK); AT (2012, 2014)
Provisional: 2014 (EU-28, BE, CZ, DK, DE, FR, IT, CY, LV, LU, MT, NL, AT, PT, SI, UK)
Eurostat country flags have been retained in the EU-28 aggregate
Missing countries in EU-28 aggregate: Growth (HR; MT)
Data unavailable: IS, NO, CH, ME, MK, AL, RS, TR, BA, IL, FO, MD, UA
(:) = missing data
The data for Researchers in FTE in the Swiss Government sector are only covering the Federal or central government. However, recall that public sector researchers in this study refer to the sum of the Government and Higher Education sectors, the latter usually being much larger than the former. As a result, a bias favouring Switzerland is possible, although likely not that large.

Source: Computed by Science-Metrix using Eurostat data (online data code: rd_p_persocc) and data from Optimat (2015) 1st ERA-Learn 2020 Annual Report on P2P Partnerships. Report prepared for the European Commission, Directorate-General for Research & Innovation. https://www.era-learn.eu/publications/other-publications/1st-annual-report-on-p2p-partnerships-2015

Table 10 Co-publications with ERA partners per 1 000 researchers in the public sector (2005-2014)

Country	Weight in GDP	Score (2014)	CAGR (2005-14)	Lead/Gap to EU-28 CAGR	Trendline (2005-14)
EU-28		**66**	**3.6%**	**N/A**	
Cluster 1	11.9%	158	5.2%	1.6	
Cluster 2	10.3%	110	4.8%	1.1	
Cluster 3	74.3%	59	5.1%	1.4	
Cluster 4	3.5%	28	4.0%	0.3	
Cluster 1					
CY	0.1%	247	13.2%	9.5	
CH	3.5%	*172*	*0.5%*	-3.2	
IE	1.3%	133	4.6%	1.0	
NL	4.4%	132	4.5%	0.8	
AT	2.2%	132	2.3%	-1.3	
LU	0.3%	132	6.2%	2.5	
Cluster 2					
IS	0.1%	121	8.6%	5.0	
SE	2.9%	121	3.7%	0.1	
ME	0.0%	118	:		
BE	2.7%	113	1.8%	-1.8	
MT	0.1%	108	8.0%	4.3	
SI	0.2%	107	5.2%	1.6	
DK	1.7%	107	1.5%	-2.2	
BA	:	*106*	:		
NO	2.5%	90	4.6%	1.0	
Cluster 3					
IT	10.8%	80	3.2%	-0.4	
FI	1.4%	79	6.9%	3.3	
EE	0.1%	71	5.6%	2.0	
CZ	1.0%	71	4.5%	0.9	
HU	0.7%	67	2.9%	-0.8	
HR	0.3%	66	8.9%	5.3	
ES	7.0%	62	7.7%	4.1	
DE	19.5%	60	0.4%	-3.2	
FR	14.3%	59	2.6%	-1.1	
UK	15.1%	52	4.9%	1.2	
PT	1.2%	52	*7.5%*	3.9	
RO	1.0%	51	7.2%	3.5	
EL	1.2%	43	:		
SK	0.5%	38	2.3%	-1.3	
RS	0.2%	36	*6.2%*	2.5	
Cluster 4					
MK	0.1%	35	6.7%	3.1	
PL	2.8%	32	3.8%	0.1	
LV	0.2%	29	5.3%	1.7	
LT	0.2%	29	7.1%	3.5	
BG	0.3%	27	-2.0%	-5.6	
TR	:	15	2.9%	-0.8	

Note: Break in time series: BE (2012); CZ, IT, UK (2005); DK, NO (2007); DE (2006); EL, RO, SI, FI (2011); FR (2010); PT (2006-2008, 2013); SE (2005, 2007, 2011, 2013); IS (2011, 2013); RS (2014)
Definition differs: FR (2005-2009); HR (2012-2014); NL (2005-2014); SK (2005-2014); SE (2005-2007); NO (2005-2009); CH (2006, 2008, 2010, 2012)
Estimated: EU-28 (2008-2010); BE, DK, DE (2014); IE (2007, 2014); EL (2006-2007); LU (2007, 2014); AT (2005, 2008, 2010, 2012, 2014); SE (2005-2014); UK (2005-2008, 2014)
Provisional: EU-28, BE, CZ, DK, DE, FR, IT, CY, LV, LU, MT, NL, AT, PT, SI, UK (2014)
Exception to reference year: CH (2012); BA (2013)
Exception to reference period: 2008-2014 (PT, RS); CH (2006-2012)
Data unavailable: AL, IL, FO, MD, UA
(:) = missing data

Source: Computed by Science-Metrix using WoS data (Thomson Reuters) and Eurostat data (online data code: rd_p_persocc)

3.2.4 Additional policy highlights 2a

Need to better understand the impact of JPIs on research agenda setting: Based on the qualitative data, there is interest in better understanding the impact of JPIs on the structuring of national research agendas, particularly as priority-setting remains dependent on national context, on the existence of national initiatives that can tap into JPIs, or even on the ability of a given country to influence others' research agendas (Science Europe, 2015b). At the national level, some dimensions to consider include the impacts on research programme design, content, evaluation practices and the like (Niehoff, 2014). Similarly, the literature suggests the pertinence of comprehensive analyses that take into account coordinated mechanisms available through framework programme initiatives, which include transnational projects addressing societal challenges, closely related to those included in JPIs.

Interviewees formulated concerns that grand challenges-driven approaches entail the risk of affecting the balance between fundamental and applied research, between the diversity of research that addresses national priorities — linked to smart specialisation initiatives, for example — and convergence of research around topics of European interest, or between short-term research activities and more sustained research efforts.

Balancing commitment of ERA countries: The qualitative data identified that the unbalanced commitment from participating states is a major challenge to improving performance in transnational research collaboration. The quantitative data also showed that the gap between the leading and marginal players seems to be opening instead of closing in terms of national investment in transnational cooperation. While the majority of countries have expressed their satisfaction regarding their participation in JPIs, around 30 % indicated that they are unsatisfied. Arguably, dissatisfaction may result from the strong orientation of JPIs towards research excellence, while lesser consideration is granted to issues around capacity building and/or innovation actions. Marginal player countries highlighted (1) difficulties in maintaining continuity in research funding from their respective governments, and (2) the difficulty of putting in place collaboration with leading players (Hunter, Hernani, Giry, Danielsen, & Antoniou, 2016, p. 37).

Some actions seeking to counteract polarisation in JPI participation are already in place. For example, Germany has set cooperation with Eastern European countries as a priority; it is looking at implementing a research excellence centre in that region and developing a researcher exchange programme between the two regions. In addition, in order to manage the observed demanding governance structures required by JPIs, countries such as France, Sweden, Spain and Norway are establishing or have already established coordination structures to manage their participation in JPIs (Hunter, Hernani, Giry, Danielsen, & Antoniou, 2016, p. 37).

Finally, according to interviews, in order to improve their success in European calls, several countries have put strategies in place to raise researchers' awareness about new development regarding European funding mechanisms and to support proposal writing. For instance, some RPOs have implemented a pre-review system consisting of several validation steps before proposals are sent for European competition. Additional support from senior researchers is also offered to junior researchers in the proposal writing process. Also mentioned were mechanisms for updating the national RPOs on recent developments at the EU level in, for example, Austria, the Czech Republic, Ireland, Romania and Norway.

Alignment of procedures between European calls and national funding agencies: The qualitative data identified the need to improve coordination between the differentiated roles of funding agencies and regulations across countries, as well as differences in operational procedures between the JPIs and the national funding systems. Some efforts have been undertaken at the regional level to align RFOs' practices. For instance, funding agencies in Austria, Switzerland and Germany have developed a common framework of rules and procedures to mutually recognise evaluations conducted by each agency. This interagency coordination allows portability of grants across the participating countries, and facilitates the launch of joint calls between the agencies.

The main success factor for this alignment is the trust built between the agencies over several years, and the willingness to align their evaluation procedures and requirements. Countries such as Denmark or Sweden have also aligned their strategies and procedures with Europe's to ensure efficient use of resources. Interview participants suggested that enhanced coordination and consistency between European and national procedures could help reduce the time required to draft research proposals and report on progress in research activities. Learning could be captured from existing experiences. NordForsk, created in 2005 by the Nordic Council of Ministers, is an example of an advanced mechanism for regional collaboration around research and research infrastructure. This organisation integrates national research councils, universities and other grant-making organisations in Nordic countries. As such, it provides a space for these different stakeholders to identify common priorities, and to develop joint programmes and procedures to support research and research infrastructures of interest for Nordic countries.

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 policy-making 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 of depth, 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, Krupavičius, & Migueis, 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 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 RIs selection processes (Maessen, Krupavičius, & Migueis, 2016).

The indicators identified by the 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 11. 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 or 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 allow the tracking of progress over time; in fact, it simply communicates that an effort is ongoing. Finally, it does not truly inform on the transnational access to RIs to assess the extent to which public investments in RIs are used in an optimal fashion.

There are 12 countries that have roadmaps in place with both ESFRI projects and funding needs identified (sorted according to the year in which the national roadmap came into effect: Romania, Bulgaria, Slovenia, Sweden, Germany, the Netherlands, Estonia, Croatia, Finland, Denmark, Switzerland and France). Additionally, 8 countries have roadmaps identifying projects but no funding requirements (Italy, Lithuania, Israel, Greece, Austria, Poland, Portugal, the Czech Republic and Norway). For Ireland, Hungary and Spain, a roadmap is in place, but identifies neither ESFRI projects nor funding needs associated therewith. The remaining 15 countries have no National Roadmap in place (noting that no data was available for Bosnia and Herzegovina or for the Faroe Islands). This last set of countries represent less than 5 % of the ERA GDP ([23]). By contrast, the 12 countries that have projects and funding explicitly identified in their roadmap account for approximately 50 % of the ERA GDP. Of the very large ERA economies, accounting for over 10 % of total GDP, only the UK does not have a roadmap.

[23] As the policy data covers a range of years, 2014 GDP data has been selected in this case for its completeness across countries

Table 11 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
RO	1.0%	2008	Yes	Yes
BG	0.3%	2010	Yes	Yes
SI	0.2%	2011	Yes	Yes
SE	2.9%	2011	Yes	Yes
DE	19.5%	2013	Yes	Yes
NL	4.4%	2013	Yes	Yes
EE	0.1%	2014	Yes	Yes
HR	0.3%	2014	Yes	Yes
FI	1.4%	2014	Yes	Yes
DK	1.7%	2015	Yes	Yes
CH	3.5%	2015	Yes	Yes
FR	14.3%	2016	Yes	Yes
IT	10.8%	2011	Yes	
IL	:	2013	Yes	
EL	1.2%	2014	Yes	
AT	2.2%	2014	Yes	
PL	2.8%	2014	Yes	
PT	1.2%	2014	Yes	
LT	0.2%	2015	Yes	
CZ	1.0%	2015	Yes	
NO	2.5%	2016	Yes	
IE	1.3%	2007		
HU	0.7%	2012		
ES	7.0%	2013		
BE	2.7%	*No roadmap*		
CY	0.1%	*No roadmap*		
LV	0.2%	*No roadmap*		
LU	0.3%	*No roadmap*		
MT	0.1%	*No roadmap*		
UK	15.1%	*No roadmap*		
SK	0.5%	*No roadmap*		
IS	0.1%	*No roadmap*		
ME	0.0%	*No roadmap*		
MK	0.1%	*No roadmap*		
AL	:	*No roadmap*		
RS	0.2%	*No roadmap*		
TR	:	*No roadmap*		
MD	:	*No roadmap*		
UA	:	*No roadmap*		

Note: References to a 'Latvian Roadmap of National Level Research Centres' may be found online (see e.g. http://connection.ebscohost.com/c/articles/77424776/latvian-roadmap-national-level-research-centres), which describe it as a 'long-term planning instrument that lists research infrastructures on national importance, either new or in need of upgrading' but the roadmap per se is not available.

Source: National roadmaps for research infrastructures: https://ec.europa.eu/research/infrastructures/index_en.cfm?pg=esfri-national-roadmaps

3.2.6 Complementary EMM indicators

ESFRI participation in developing projects

Participation in ESFRI projects has been divided into two components: nascent projects currently in developmental stages, and operational landmarks. The present indicator tracks the former, assessing the degree to which individual countries are implicated in projects that are in their development phases. Full results are presented in Table 12.

The countries with the more active presence in ESFRI projects are found in Cluster 1, namely the UK, France, Spain, Italy and the Netherlands. The UK and France are particularly strong, each participating in over 60 % of the ESFRI projects currently in development. The countries with the least involvement ([24]) are Estonia, Croatia, Cyprus, Latvia, Lithuania, Luxembourg, Malta, Austria, Montenegro, FYR Macedonia, Albania, Serbia and Ukraine, which do not participate in any of the ESFRI projects currently in development. There is a very clear correlation between size of economy and performance on this indicator, as the top 5 countries based on performance account for over 50 % of the ERA GDP, while the bottom 20 countries account for less than 15 % of ERA GDP.

ESFRI Landmark projects

Turning now to the second complementary EMM indicator for Sub-priority 2b, the ESFRI Landmark participation indicator shows the number of operational landmark projects in which a country is involved, as a proportion of the total number of landmarks. The results for each country are listed in Table 13.

The more active countries are France, Germany, Italy, the Netherlands, Sweden, the UK, Belgium and the Czech Republic. France is especially strong, participating in over 80 % of landmark projects, with Germany and Italy each participating in over 65 %. The least frequent participants are Latvia, Iceland, Montenegro, FYR Macedonia, Albania, Moldova, and Ukraine, none of whom participate in any of the operational landmarks. Many of these countries do not participate in any developing ESFRI projects either.

This indicator once again shows a strong correlation between size of economy and participation in operational ESFRI landmarks. The four largest economies in the ERA, each accounting for over 10 % of the total ERA GDP, fall in the top six ranks according to this indicator. Cluster 1 covers 8 countries and accounts for almost two thirds of the ERA GDP, whereas clusters 3 and 4 combined account for 22 countries but less than 6 % of ERA GDP.

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 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. Across the ERA, participation in ESFRI projects, both those in development phases and those that are already operational, is led primarily by small group of countries, chiefly the largest European economies.

[24] In the case of this indicator, the lowest scores are found in Cluster 3, because the average and standard deviations are such that no country could be more than one standard deviation below the mean; therefore, no country could possibly fall in Cluster 4.

Table 12 Share of developing ESFRI Projects in which a Member State/Associated Country participates (2016)

Country	Weight in GDP	Score (2016)
EU-28		**20.7%**
Cluster 1	54.9%	54.3%
Cluster 2	38.0%	26.2%
Cluster 3	7.1%	3.0%
Cluster 4	N/A	N/A
Cluster 1		
UK	17.3%	66.7%
FR	14.7%	61.9%
ES	7.3%	52.4%
IT	11.0%	52.4%
NL	4.6%	38.1%
Cluster 2		
BE	2.8%	33.3%
EL	1.2%	33.3%
PL	2.9%	33.3%
FI	1.4%	33.3%
CZ	:	28.6%
DE	20.4%	28.6%
NO	2.4%	28.6%
DK	1.8%	19.0%
PT	1.2%	19.0%
RO	1.1%	19.0%
SE	3.0%	19.0%
CH	:	19.0%
Cluster 3		
IE	1.4%	14.3%
BG	0.3%	9.5%
SK	0.5%	9.5%
IL	:	9.5%
HU	0.7%	4.8%
SI	0.3%	4.8%
IS	0.1%	4.8%
TR	:	4.8%
MD	:	4.8%
EE	0.1%	0.0%
HR	0.3%	0.0%
CY	0.1%	0.0%
LV	0.2%	0.0%
LT	0.3%	0.0%
LU	0.4%	0.0%
MT	0.1%	0.0%
AT	2.3%	0.0%
ME	:	0.0%
MK	0.1%	0.0%
AL	:	0.0%
RS	:	0.0%
UA	:	0.0%

Source: ESFRI data

Table 13 Share of operational ESFRI Landmarks in which a Member State/Associated Country is a partner (2016)

Country	Weight in GDP	Score (2016)
EU-28		**30.2%**
Cluster 1	73.7%	60.3%
Cluster 2	20.4%	33.7%
Cluster 3	5.6%	9.9%
Cluster 4	0.3%	0.0%
Cluster 1		
FR	14.7%	82.8%
DE	20.4%	69.0%
IT	11.0%	65.5%
NL	4.6%	58.6%
SE	3.0%	55.2%
UK	17.3%	55.2%
BE	2.8%	48.3%
CZ	:	48.3%
Cluster 2		
DK	1.8%	44.8%
FI	1.4%	44.8%
EL	1.2%	34.5%
NO	2.4%	34.5%
ES	7.3%	31.0%
PL	2.9%	31.0%
PT	1.2%	31.0%
AT	2.3%	27.6%
CH	:	24.1%
Cluster 3		
EE	0.1%	20.7%
SI	0.3%	20.7%
IL	:	20.7%
HU	0.7%	13.8%
RO	1.1%	13.8%
LT	0.3%	10.3%
BG	0.3%	6.9%
IE	1.4%	6.9%
MT	0.1%	6.9%
SK	0.5%	6.9%
RS	:	6.9%
HR	0.3%	3.4%
CY	0.1%	3.4%
LU	0.4%	3.4%
TR	:	3.4%
Cluster 4		
LV	0.2%	0.0%
IS	0.1%	0.0%
ME	:	0.0%
MK	0.1%	0.0%
AL	:	0.0%
MD	:	0.0%
UA	:	0.0%

Source: ESFRI data

3.2.7 Additional policy highlights 2b

Funding instruments and sustainability: Interviewees indicated that the constraints on private sector access to RIs funded by the structural funds is a significant limitation, especially during the operational phase. Similarly, for the sake of the long-term sustainability of RIs, self-financing long-term mechanisms for operating and maintenance costs, as well as closer cooperation with the private sector, should be addressed in a more systematic way from the initial planning phase of major RIs.

Alignment of RI national strategies: RI strategies have reached different levels of maturity within ERA countries. An increasing number of countries have adopted or are close to adopting national RI roadmaps (as shown in Table 11). Interviewees from some countries — for example, Ireland — have linked their national roadmap to the smart specialisation strategy, while some others are currently engaged in efforts to optimise RIs — for example, Sweden. A few countries have established a stable structure to facilitate strategic decisions on investment in RI — for example, Denmark, the Netherlands or Finland. For the largest RI of European interest, the European ESFRI Roadmap was considered by interviewees as a central tool for aligning national RI strategies because national roadmaps often mimic the ESFRI Roadmap.

As explained in the Priority 1 policy highlights, the long-term commitment at national level may be an issue for funding research in general. It applies as well for RIs. The commitment to ESFRI roadmaps is crucial as the alignment of several countries' strategies is required to have major European RIs being built. In this regard, the Lund spallation source, while representing a great achievement in terms of transnational cooperation and an important opportunity in terms of regional development, required a lengthy period of time to reach the final agreement (25 years). In order to bring more discipline to the timelines, in the European Roadmap ESFRI has decided to only maintain those projects that have reached a significant level of maturity after 10 years and that remain relevant from a scientific point of view.

Interviewees formulated several recommendations regarding the optimisation of smaller RIs, including putting more emphasis on the concept of common facilities in universities; developing a clustering process of national and regional research facilities that can be complementary/secondary to large-scale facilities; promoting public–private cooperation; developing e-infrastructure that can serve the needs of researchers in different disciplines.

Regional disparities in the distribution of RIs: The interview data revealed some debate around the location of the largest RIs across Europe and that a more holistic view would be appreciated regarding the location of the next generation of large RIs. Besides the value of effective access to an RI, regardless of geographical proximity, some elements of further consideration include the potential for economic development and capacity building in the area where the infrastructure is to be located. Regarding the existing RIs, there is also a need to improve the current lack of balance in terms of access, depending on the researcher's geographical location. The European Charter for Access, available online ([25]), has been developed to address such an issue.

3.2.8 Composite indicator

The composite indicator developed by Science-Metrix to cover Priority 2 includes various indicators used to measure performance in sub-priorities 2a and 2b. The composite indicator for Priority 2 integrates six components: GBARD (EUR) allocated to Europe-wide, bilateral or multilateral transnational public R&D programmes per FTE researcher in the public sector, Member State participation (EUR) in Public-to-Public collaborations per FTE researcher in the public sector, international co-publication rate with ERA partners (used in place of the EMM

[25] https://ec.europa.eu/research/infrastructures/pdf/2016_charterforaccessto-ris.pdf

indicator on co-publications with ERA partners per 1 000 researchers ([26])), international co-invention rate with ERA partners, percentage of ESFRI landmarks in which a Member State/Associated Country is a partner, and percentage of ESFRI projects in which a Member State/Associated Country participates ([27]). For details on the construction of the composite indicators, refer to Section 2.3.2. Full details for this indicator are presented in Table 30 (Annex 1).

The strongest countries in ERA Roadmap Priority 2 according to the composite indicator are Belgium, Luxembourg, the Netherlands and France, while the lowest scores are for Bulgaria, Croatia, Serbia, Lithuania and Turkey ([28]). The distribution of scores across the four performance clusters for this composite indicator nearly follows expectation under the assumption of a normal distribution of the scores. There are slightly more countries than expected in the middle two clusters, which are of equal size, each including 12 countries (against 11 expected under normality, or 34 % of covered countries in each cluster). Cluster 1 includes 12 % of countries (against an expectation of 16 %), with 15 % in Cluster 4 (against an expectation of 16 %). Looking at the size of economy, GDP is moderately correlated to performance scores on the composite indicator, meaning that larger economies are moderately more likely to be found among the strong performers than smaller economies. Cluster 1 covers 12 % of countries and accounts for nearly 25 % of ERA GDP. The largest bulk of GDP is found in Cluster 2 (66 % of ERA GDP with only 36 % of countries). Clusters 3 and 4 cover only 9 % of ERA GDP, with about half of the covered countries.

[26] In the composite indicator, the number of co-publications with ERA partners was normalised by the total number of publications of a country since it increased country coverage as well as provided one additional year of data (i.e. 2015).

[27] For Priority 2, a differential weighting approach was used to ensure that the sub-priorities 2a and 2b, although they differ in number of indicators, contribute, in as much as is possible, equally to the composite for Priority 2. Also note that the Headline indicator for Sub-priority 2b could not be included in the composite because it is a binary indicator.

[28] It is worth noting that Turkey is missing scores for two of the five indicators integrated into the Priority 2 composite, meaning that the composite may not be as representative of its performance as it is of the performance of other countries shown. Note also that the composite indicator is normalised by the number of scores available, and so while Turkey's score may be less reflective due to diminished coverage across indicators, the score is calculated in a way that compensates for Turkey having only three scores available rather than five.

Main findings

Sub-priority 2a

1. There is a convergence towards the joint definition of research agendas amongst participating countries, although this convergence is raising concerns about the balance between fundamental and applied research, and is also raising possible tensions with the smart specialisation approach. The joint establishment of research agendas also shows connections to collaboration with third countries (Priority 6).

2. National and international funding opportunities could benefit from further harmonisation, including through synchronised calls for applications, harmonised funding allocation processes, and mutual recognition of processes between the national and international levels. Transnational researcher mobility (Priority 3) connects with this point as well.

3. Grand challenges are being addressed through Joint Programming Initiatives (JPIs), of which 10 have been in place since 2008, alongside ERA-NETs and other initiatives. Funding for these initiatives is increasing, although mostly from a group of seven countries that are leading the way. Opportunities exist to expand these initiatives by linking them to smart specialisation strategies, and by finding new avenues to further integrate countries that are making smaller financial contributions to these efforts.

4. Leading countries are putting in place mechanisms to improve proposal writing to respond to joint calls for R&I funding programmes. However, application rates and success rates vary greatly across national contexts, and the low success rate overall is discouraging many from putting in the large effort necessary to complete the intensive applications required. Combined, these forces may accentuate the gaps between the leading group of countries and the others. One strategy to address this potential risk could be to increase the amount of funding available, which would increase the number of projects that could be funded, and ease the disinclination to apply. Another strategy could be to reform the allocation process to make preliminary applications less onerous, which would also lower an important barrier to participation.

5. The increasing rate of co-publications suggests an intensification of inter-ERA partnerships. However, the relevance of this research to grand challenges, and the impact of this research in bringing about the societal benefits sought, needs to be assessed in a more robust fashion to demonstrate the value that this research is supposed to be delivering on the R&I investment. The uptake of this research towards addressing societal issues also connects to knowledge transfer (Sub-priority 5a).

Main findings

Sub-priority 2b

1. Many countries have developed and implemented national roadmaps for research infrastructures, aligned with the overall ESFRI Roadmap. However, these national-level roadmaps, while a great achievement in themselves, would benefit from more clearly and consistently outlining the financial needs associated with the infrastructures identified as priorities. Furthermore, the long-term operational costs and sustainable funding would be valuable to consider from the inception phase of the project, and national-level funding mechanisms could be better harmonised to speed up timelines for infrastructure development.

2. Participation in ESFRI projects is closely tied to the overall size of economy. Regional disparities in economic development could therefore figure more prominently in the selection of sites for future research infrastructures, both from ESFRI roadmaps and national strategies.

3. Time-sharing procedures for large-scale research infrastructures are well known and understood within the research community, contributing to effective usage of the infrastructures. Smaller-scale research infrastructures might benefit from similar time management policies, to yield additional benefits along similar lines. Furthermore, comprehensive inventories of existing national research infrastructures would help to promote the visibility of research infrastructures at the national and transnational levels, while also helping to avoid duplication of efforts.

4. Difficulties enticing the private sector to engage in R&I (Priority 5a) could be partially addressed by including the private sector in the conception, design and operation of research infrastructures.

5. Partnerships with third countries (Priority 6) could be promoted in similar ways.

3.3 Priority 3 – Open labour market for researchers

3.3.1 Policy context

Progress in researcher mobility, the focus of Priority 3, has derived substantial support from a number of EU policy initiatives, including the development and implementation of the EURAXESS network and accompanying portal for job postings, the new Scientific Visa Directive, a Human Resources Strategy for Researchers based on the Charter & Code, the Principles of Innovative Doctoral Training, and support for a new European supplementary pension fund for researchers. Furthermore, Marie Skłodowska-Curie Actions (MSCA) have set standards for research training, attractive employment conditions and open recruitment for all EU researchers (Deloitte, 2014, p.6; European Commission & Directorate General for Research and Innovation, 2015a, p.22).

However, the gains made in researcher mobility have not been evenly distributed across national contexts, as some researchers (especially those in early career stages) are still affected by hiring processes that are not sufficiently open, transparent and meritocratic; additionally, in some national contexts, the working conditions once on the job are overall still quite poor, distinct from issues surrounding hiring processes. Overall, there is need to improve the alignment between the optimistic view of national authorities in regard to recruiting systems, and the perception of the researchers themselves about the transparency and openness of those systems (Deloitte, 2014).

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 established by the Commission for reinforcing the ERA (European Commission, 2012). Indeed, evidence suggests that researchers who have moved internationally have a greater research impact than those who have not and that countries with more open research systems perform better in terms of innovation (European Commission & Directorate-General for Research and Innovation, 2014a). This indicator carries a number of drawbacks. Since some MS/AC 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 percentage of relevant jobs. On the other hand, as jobs can be advertised on multiple platforms, merging data from EURAXESS and national portals would lead to double counting. Also, 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. 'The EURAXESS portal should be considered mainly as a "trend reference tool" as it solely provides information about the number of job adverts published on a yearly basis' (ERAC Secretariat, 2015a). Full results are detailed in Table 14, and are plotted on a map in Figure 3.

As seen in that table, Croatia is a standout performer on this indicator. In fact, its score is more than four standard deviations above the ERA average across the covered countries. As such, it was not included in computing the ERA average and standard deviation used in establishing the boundaries of the performance clusters (see Footnote 5 for more details on this exclusion). In spite of this, the performance clusters remain unbalanced relative to expectation under a normal distribution of the scores for this indicator (expectation would roughly equal 5 countries each in clusters 1 and 4, and 11 countries each in clusters 2 and 3). While there are (or nearly are) as many countries as expected in Cluster 1 (5) and Cluster 2 (9), there are significantly more countries than expected in Cluster 3 (19), and no country in Cluster 4. In fact, Cluster 3 can be regarded as a merge of the least two performing clusters, meaning that among the soft performance, there are no countries standing very far (more than one standard deviation) below the ERA average. This distribution of countries across clusters is due to a positive skew in the distribution of the scores, which persists even after removing the score of Croatia in determining the cluster boundaries.

Nevertheless, because the high score of Croatia might reflect the 'real' use of EURAXESS by its institutions, the country is still presented and ranks in Cluster 1. It is joined by Sweden, Poland, Ireland and the Netherlands in Cluster 1. In 2014, each of these countries advertised more than 100 job postings through EURAXESS, per 1 000 public researchers. As previously noted, there is no Cluster 4. Countries with the lowest levels of participation in EURAXESS are found in Cluster 3 and include Portugal, Germany, Finland, Montenegro, Latvia, Lithuania, Slovakia, Bulgaria, Hungary, Turkey and Serbia, each of which advertises fewer than 10 job postings through EURAXESS, per 1 000 public researchers.

Between 2012 and 2014 Croatia quadrupled its score annually, thus having the strongest lead over the EU-28 growth (300 percentage points lead in CAGR). In general, the correlation between performance and growth on this indicator is positive, but not very robust: removing Croatia from the assessment (as it is exceptional in both its performance and its growth), one finds no meaningful correlation whatsoever between performance and growth. In brief, this means that Croatia has a sizable lead, and one that it seems poised to increase. Other countries that have increased their usage of EURAXESS include Slovakia, Latvia and Turkey, while the Czech Republic, Romania, Luxembourg, Hungary and Finland have decreased their usage notably over the 2012-2014 period.

The connection between GDP and performance on this indicator is basically nil, with large and small economies having roughly equal chance of being among the top performers. The top 5 countries in Cluster 1 (representing about 16 % of countries) account for about 12 % of ERA GDP, the 9 countries in Cluster 2 (27 % of countries) account for about 30 %, and the 19 countries in Cluster 3 (58 % of countries) account for a little over 60 %. The UK is the only large economy, accounting for more than 10 % of ERA GDP, that lies above Cluster 3 on this indicator.

Table 14 Number of researcher postings advertised through the EURAXESS job portal, per 1 000 researchers in the public sector (2012-2014)

Country	Weight in GDP	Score (2014)	CAGR (2012-14)	Lead/Gap to EU-28 CAGR	Trendline (2012-14)
EU-28		**47.0**	**7.8%**	**N/A**	
Cluster 1	11.6%	180.5	70.2%	62.4	
Cluster 2	38.6%	64.7	1.4%	-6.4	
Cluster 3	49.8%	9.6	12.7%	4.8	
Cluster 4	N/A	N/A	N/A	N/A	
Cluster 1					
HR	0.3%	362.0	308.2%	300.4	
SE	2.9%	156.1	17.0%	9.1	
PL	2.8%	146.7	-4.7%	-12.5	
IE	1.3%	139.1	17.2%	9.4	
NL	4.4%	98.7	13.4%	5.6	
Cluster 2					
CY	0.1%	81.7	-1.4%	-9.2	
EL	1.2%	78.8	-8.8%	-16.6	
LU	0.3%	73.7	-26.0%	-33.8	
AT	2.2%	71.3	14.0%	6.2	
NO	2.5%	69.1	11.2%	3.4	
UK	15.1%	63.8	4.9%	-2.9	
BE	2.7%	51.9	0.8%	-7.0	
FR	14.3%	49.8	16.7%	8.8	
IS	0.1%	42.6	:		
Cluster 3					
SI	0.3%	28.0	21.2%	13.4	
IT	10.8%	26.4	10.7%	2.9	
EE	0.1%	21.8	13.7%	5.9	
DK	1.7%	17.8	3.0%	-4.9	
RO	1.0%	17.0	-34.8%	-42.6	
CH	3.5%	*16.1*	:		
ES	7.0%	13.0	21.3%	13.5	
CZ	1.0%	11.4	-39.1%	-46.9	
PT	1.2%	7.3	31.0%	23.2	
DE	19.6%	5.5	8.5%	0.7	
FI	1.4%	5.4	-29.4%	-37.2	
ME	0.0%	3.1	:		
LV	0.2%	2.7	72.3%	64.5	
LT	0.2%	1.7	-19.2%	-27.0	
SK	0.5%	1.4	111.8%	104.0	
BG	0.3%	1.4	33.1%	25.3	
HU	0.7%	1.0	-29.4%	-37.2	
TR	:	0.7	52.4%	44.6	
RS	0.2%	0.6	-12.1%	-19.9	

Note: Break in time series: EU-28 (2012, 2013); BE (2012); 2013 (PT, SE, IS); RS (2014)
Definition differs: EU-28 (2012-2014); HR (2012-2014); NL (2012-2014); SK (2012-2014); CH (2012)
Estimated: EU-28 (2012-2014); 2014 (BE, DK, DE, IE, LU); AT (2012, 2014); SE (2012-2014); UK (2014)
Provisional: 2014 (EU-28, BE, CZ, DK, DE, FR, IT, CY, LV, LU, NL, AT, PT, SI, UK)
Eurostat country flags have been retained in the EU-28 aggregate
Missing countries in EU-28 aggregate: MT
Exception to reference year: CH (2012)
Data unavailable: MT, MK, AL, BA, IL, FO, MD, UA
(:) = missing data

The data for Researchers in FTE in the Swiss Government sector are only covering the Federal or central government. However, recall that public sector researchers in this study refer to the sum of the Government and Higher Education Sectors, the latter usually being much larger than the former. As a result, a bias favouring Switzerland is possible, although likely not that large.

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)

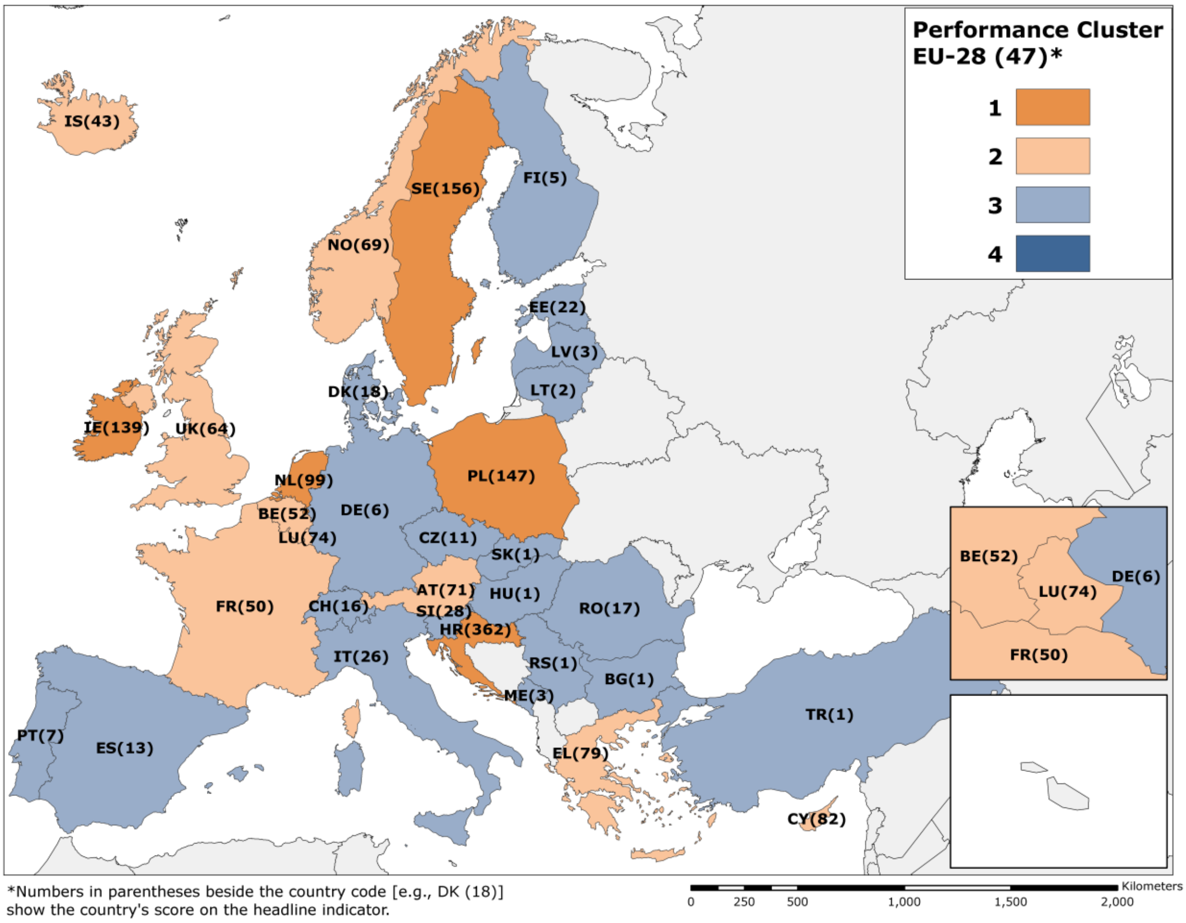

Figure 3 Map of number of researcher postings advertised through the EURAXESS job portal, per 1 000 researchers in the public sector (2014)

Note: As per Table 14.

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, MS/AC 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, MS/AC 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 such, 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 indeed act as a proxy to monitor the extent to which a country's academic system is open to other European doctoral candidates (the openness may be in the portability of a national grant or other mechanism that may facilitate the switch to a new country academic institution). 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. 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 and country-location bias (see Table 3). Full results are found in Table 15.

The top-performing country on this indicator is Switzerland, where slightly more than 35 % of doctoral students hold a citizenship from another country within the EU. The Netherlands, Austria and Denmark round out the members of Cluster 1, with each country having a share of between 15 % and 20 %. The softest results are from FYR Macedonia, which has no doctoral students with citizenship of another EU Member State. Other countries lagging behind by a wide margin include Poland and Turkey in Cluster 3. Note that less than half of countries (34 %) fall in the top two performing clusters. This is due to the relatively strong scores of countries in Cluster 1 and 2, which pull up the ERA average as well as the EU-28 score. In fact, most of the countries in these clusters have a lead of at least 40 % over the EU-28 score.

There is no meaningful correlation between performance on this indicator and size of economy, meaning that large and small countries are both represented among the leading performers. This finding is reflected in the fact that the proportion of GDP accounted for in each cluster roughly follows the proportion of countries they each contain. Cluster 1 accounts for 12.5 % of countries and 12.2 % of ERA GDP, Cluster 2 accounts for 21.8 % of countries and 25.3 % of GDP, Cluster 3 accounts for 62.5 % of countries and 62.4 % of GDP, and Cluster 4 accounts for 3 % of countries and less than 1 % of GDP. As was the case for all indicators in Sub-priority 2a, larger countries might be disadvantaged due to the small-country bias (i.e. smaller countries are often more dependent on external resources due to fewer domestic opportunities).

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

The MORE2 Higher Education Institutions (HEI) survey carried out in spring 2012 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 having answered positively to the three following questions:

(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 oriented 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 such, there is an issue of timeliness associated with this data which makes it difficult to study trends. Full results can be found in Table 16 and these only cover the year 2012.

The distribution of countries across performance clusters is well balanced on this indicator since the scores are symmetrically distributed around the ERA average; the percentage of countries in each cluster matches expectation under the assumption of a normal (or Gaussian) distribution of the scores. For instance, there are 15 % of countries in each of the top and least performing clusters, respectively Cluster 1 and Cluster 4, against an expectation of 16 %. There are also 33 % of countries in Cluster 2 and 36 % in Cluster 3, against an expectation of 34 % in each of them. The highest score on this indicator comes from the UK, where over 70 % of researchers expressed satisfaction with the hiring processes in place at their home institutions. The other strong performers are Luxembourg, Poland, Estonia and Ireland, all of whom have a score between 55 % and 65 %. At the other end of the spectrum, less than 35 % of researchers in each of Lithuania, Croatia, Slovenia, Bulgaria and Italy expressed the same confidence in their respective hiring processes.

Similarly, GDP is spread quite evenly throughout the clusters (relative to their size), with around 15 % in each of clusters 1 and 4, and around 35 % in clusters 2 and 3. The correlation between GDP and performance is basically nil in this case, meaning that large and small economies tend to perform equally well.

Table 15 Share of doctoral candidates with a citizenship of another EU Member State (2013)

Country	Weight in GDP	Score (2013)
EU-28		**7.4%**
Cluster 1	12.2%	23.6%
Cluster 2	25.3%	11.2%
Cluster 3	62.4%	4.2%
Cluster 4	0.1%	0.0%
Cluster 1		
CH	3.6%	37.6%
NL	4.6%	19.8%
AT	2.3%	19.6%
DK	1.8%	17.3%
Cluster 2		
UK	14.3%	13.2%
IE	1.3%	12.6%
BE	2.7%	11.8%
IS	0.1%	11.5%
CZ	1.1%	10.4%
SE	3.1%	10.2%
NO	2.8%	8.7%
Cluster 3		
FR	14.8%	8.0%
SK	0.5%	7.6%
FI	1.4%	7.2%
SI	0.3%	6.4%
HU	0.7%	5.7%
MT	0.1%	5.1%
EE	0.1%	5.0%
PT	1.2%	4.3%
IT	11.2%	4.2%
ES	7.2%	4.2%
LV	0.2%	4.1%
RS	0.2%	4.1%
DE	19.7%	3.8%
CY	0.1%	3.7%
LT	0.2%	2.6%
HR	0.3%	2.4%
BG	0.3%	2.0%
RO	1.0%	1.7%
PL	2.8%	1.0%
TR	:	0.6%
Cluster 4		
MK	0.1%	0.0%

Note: Eurostat country flags have been retained in the EU-28 aggregate
Missing countries in EU-28 aggregate: EL; LU
Exception to reference year: 2014 (RS, TR)
Data unavailable: EL, LU, ME, AL, BA, IL, FO, MD, UA
(:) = missing data

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

Table 16 Share of researchers expressing satisfaction that the hiring procedures in their institution are Open, Transparent and Merit-based (2012)

Country	Weight in GDP	Score (2012)
EU-28		**49.0%**
Cluster 1	18.7%	61.2%
Cluster 2	38.8%	49.7%
Cluster 3	30.2%	38.1%
Cluster 4	12.3%	26.1%
Cluster 1		
UK	14.3%	72.5%
LU	0.3%	63.4%
PL	2.7%	58.0%
EE	0.1%	56.1%
IE	1.2%	56.1%
Cluster 2		
CH	3.6%	54.1%
NL	4.5%	54.1%
LV	0.2%	53.8%
NO	2.8%	53.7%
DK	1.8%	51.8%
SE	2.9%	49.1%
IS	0.1%	49.0%
BE	2.7%	47.1%
MT	0.1%	45.4%
DE	19.2%	44.3%
CZ	1.1%	44.1%
Cluster 3		
ES	7.3%	43.0%
CY	0.1%	42.4%
FI	1.4%	40.0%
TR	:	38.9%
AT	2.2%	38.2%
MK	0.1%	37.6%
RO	0.9%	37.6%
FR	14.5%	37.4%
SK	0.5%	37.3%
EL	1.3%	35.8%
PT	1.2%	35.3%
HU	0.7%	34.0%
Cluster 4		
LT	0.2%	31.1%
HR	0.3%	29.8%
SI	0.3%	28.5%
BG	0.3%	27.4%
IT	11.2%	14.0%

Note: Note: Data unavailable: ME, AL, RS, BA, IL, FO, MD, UA
(:) = missing data
Source: MORE2 Survey data

Comparing Headline to complementary EMM indicators

Looking at the connection between the indicators so far presented for Priority 3, there is no meaningful correlation (neither positive nor negative) between performance on the Headline indicator and the proportion of PhD students in a given country holding citizenship in another EU Member State (Pearson r of -0.003). 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.

As one would expect satisfaction with the openness, transparency and meritocracy of the hiring processes to increase with the use of EURAXESS, one would expect a positive correlation between the Headline indicator and the share of researchers expressing satisfaction with the openness, transparency and meritocracy of the hiring processes in their research institution. At least two factors could blur such a signal with the data currently available. Firstly, 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. Secondly, increased satisfaction with the hiring processes is expected to come after the implementation of various actions such as the use of EURAXESS. The data on satisfaction with the hiring processes dating back to 2012 is therefore inadequate to assess the impact of the use of EURAXESS measured in 2014 (as presented in the performance and score columns of Table 16 and Table 14, respectively). In fact, it is the satisfaction data that should be lagged relative to the EURAXESS data. Such an analysis is currently impossible with the available data. However, using the 2012 data for both indicators, one finds a moderate and positive correlation between the two (Pearson r of 0.48), while there is no such correlation when using the 2012 data for satisfaction and the 2014 data for EURAXESS (Pearson r of 0.10). With properly lagged data, one might find an even stronger correlation between the two indicators.

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. Also recall that even when moderate to strong correlations exist within a set of indicators, important variations can still prevail on a country-by-country level across the various dimensions captured by the selected indicators. These differences should never be overlooked as they likely convey crucial information for understanding the functioning and explaining the relative performance of individual countries.

Use of the EURAXESS platform seems to be growing strongly in a handful of countries, while only taking root in others. Meanwhile, roughly one out of every dozen PhD candidates in the ERA comes from another European country, and about half of all researchers expressed satisfaction in the hiring processes in their home institutions. However, there is strong diversity country to country on these indicators as well, suggesting that the landscape of researcher mobility has a varied topography, a finding that the qualitative analysis reflects as well. In such a circumstance, it comes as little surprise that a single indicator will be less effective in tracking overall behaviour than in a circumstance of greater consistency across national contexts.

3.3.4 Additional policy highlights

Human resources strategy for researchers: The European Charter for Researchers 'is a set of general principles and requirements which addresses the roles, responsibilities and entitlements of researchers and their employers or funding organisations', while the Code of Conduct for the Recruitment of Researchers 'is a set of principles and requirements that aim to improve recruitment, to make selection procedures fairer and more transparent, and proposes different means of judging merit' (European Commission & Directorate-General for Research and Innovation, 2015b, p.2). They are issued by the European Commission and are generally jointly referred to as the Charter & Code. By 2015, the Charter & Code principles have been endorsed by more than 730 research organisations (about a half of public research organisations) located in 35 ERA countries. This growing trend is still ongoing. Up to 2015, the Commission's Human

Resources Strategy for Researchers (HRS4R) delivered the 'HR Excellence in Research' award to 252 research institutions as a recognition of their effort in implementing the Charter & Code principles (European Commission & Directorate-General for Research and Innovation, 2015c, p. 13).

Moreover, more than 90 % of all universities or research institutes that had gained the HR Excellence in Research logo by 2013 had reviewed or were in the process of reviewing recruitment processes in implementing Charter & Code principles (Deloitte, 2014). An important goal for this programme is to encourage the participation of RPOs in the HRS4R, and more broadly to encourage an ongoing, reflexive and critical reflection on hiring practices, 'amending them where necessary to improve their openness and transparency as benchmarked against the Charter & Code' (SGHRM, 2015, p.4).

The Steering Group on Human Resources and Mobility (SGHRM) strategy for 2020 adopted a more holistic approach to research human resources in order to recognise 'researchers as professionals' (SGHRM, 2016). This includes the launch of the RESAVER (see below), the facilitation of the adoption of doctoral training and professional development, recommendations about OTM-R, and reinforcement of the HRS4H principles. Two topic-specific working groups have also been formed to address: 'intersectoral mobility, asymmetric mobility and skills' and 'welcoming culture for non-EU researchers'. Finally, two working groups were created to address two 3O's-related topics and promote the adoption of best practices: 'Modernisation of scientific career assessment in an Open Science environment' and 'Open Science education and training of researchers (SKILLS)'.

Open, transparent and merit-based recruitment: A working group established in September 2014 under the ERA Steering Group on Human Resources and Mobility has developed an open, transparent and merit-based recruitment (OTM-R) package that includes principles and guidelines on what an OTM-R system should look like. It has also developed a benchmarking tool to facilitate self-assessments and thereby promote the institutional practice of evaluating current practices with respect to their fit with the principles. The working group also provides 'a step-by-step guide to improve (if, when and where needed) the organisation's OTM-R practices' (SGHRM, 2015, p.10).

Efforts have been made at the national and RPO levels to improve transparency in the recruitment processes in most ERA countries. Some specific interventions include the posting of job ads on publicly accessible portals (including EURAXESS jobs), as well as striving to achieve the 'HR Excellence in Research' logo (Deloitte, 2014, p.7). However, the elaboration of internal guidelines setting out clear and explicit rules and procedures for the recruitment of all researcher positions is not yet common practice among RPOs. In practice, OTM-R principles seem to apply more at the early stage of researchers' careers (PhD and post-doc), while recruitment of senior researchers remains more frequently based on informal information gathered through previous collaboration. In addition, the qualitative data document the persistence of preferential selection of previously known or otherwise connected candidates and other non-competitive practices for the hiring of researchers.

Use of EURAXESS: This European job portal, present in 40 European countries through more than 200 service centres, supports researchers' mobility by providing information about research career opportunities in Europe, while also providing help on a broad range of practical issues related to international professional mobility, including 'visas, social security rights, housing and child care' (Deloitte, 2014, p.10). The OTM-R toolkit indicates that the two first steps to be implemented are the publication of job vacancies on relevant national websites and Europe-wide online platforms like EURAXESS. The EURAXESS Job Portal, aimed at providing a broad and universal advertisement solution for faculty and research positions, still receives mixed reviews by members of umbrella organisations such as LERU or CESAER (Maes, 2014; CESAER, 2014a; CESAER, 2014b). Additionally, several interviewees emphasised that a job posting may be open without using EURAXESS, while an open job advertisement does not necessarily ensure a truly open recruitment.

Qualitative data uncovered significant progress in advertising positions more widely and more fervently in the English language through several channels, including EURAXESS. Several countries have made it compulsory to publish research job vacancies through EURAXESS (e.g. Austria, Croatia, Poland, Italy, Lithuania, Romania and Slovenia) (European Commission, 2014a; SGHRM, 2015). The Netherlands posts job opportunities on Academic Transfer (an external platform in the Netherlands with whom EURAXESS collaborates), from where they are exported to the EURAXESS European portal, and from where, again, they are exported/mirrored in the national portal of the Netherlands, thereby reducing the administrative burden of multiple job posting.

In countries where posting on EURAXESS has become compulsory at national level, this requirement has not necessarily resulted in a higher uptake of the European job portal. This may first be explained by its recent implementation, and second by the limited number of job openings in recent years. In other countries — for example, Sweden or Ireland — the use of EURAXESS, while not compulsory, has been well accepted and is becoming increasingly systematic. Additionally, some Swiss universities have developed a EURAXESS contact point. Finally, countries such as Spain and Portugal have recently made efforts to improve awareness about EURAXESS.

In moving forward, the continued promotion of EURAXESS could benefit from raising awareness about its existence, as well as how it could efficiently complement other online systems for advertising research positions established at different levels (Maes, 2014, p.3; Deloitte, 2014).

Researchers' mobility: Based on the literature review and interviews, some persistent barriers to mobility include insufficient autonomy of universities and burdensome administrative processes around international recruitment. In addition, some incompatibilities remain between career progression and mobility. For instance, interviewees commented that researchers returning to Italy after having spent some years abroad may have to restart their careers at an entry level, thus deterring mobility of established researchers. In other cases, notwithstanding efforts to adopt a common pension system for researchers within the ERA, disparities in social security coverage remain, discouraging mobility from countries with more protective systems (e.g. Sweden).

Grant portability within the ERA remains more the exception than the rule. Examples of good practices that have been developed are the 'Money Follows Researcher' model and the flexibility offered in Finland, not only for researchers to take their grant abroad but also to take it into industry.

Nonetheless, legal barriers seem to have been removed in most countries and the major remaining issue for recruiting established international researchers seems to be the national language requirement for teaching. Here again, a distinction has to be made between the early and more senior stages of a career. The most attractive systems, such as Switzerland, the United Kingdom and Ireland, do not present this language barrier.

Funding systems and research conditions are determined nationally, the resulting heterogeneity of wage levels, working conditions and the recent economic crisis have also generated an asymmetric flow of researchers from eastern and southern Europe to the north-west. For instance, the fact that foreign researchers must be paid local salaries when recruited with Horizon 2020 funds makes low-paying countries very unattractive. At the same time, incentives for collaboration within Europe usually reinforce the north-western European nexus. Some interviewees see this phenomenon as an opportunity to improve their national system to make it more attractive by better aligning salaries and reinforcing mechanisms underpinning pan-

European collaboration in ways that are more aware of the remaining divides between leading countries and the rest of Europe.

Initiatives undertaken by some ERA countries to promote researcher mobility include the following (CESAER, 2015b):

(1) Talent and Extended Mobility (TANDEM) in the European Innovation Union, a partnership of five organisations from Greece, Slovakia, Estonia, Denmark and Switzerland, developed a toolkit to support research institutions in establishing Dual Career Advice and Integration Services. An important focus of this initiative is to address the cultural integration issues that can sometimes inhibit researcher mobility.

(2) TU Delft and ETH Zurich collect and provide access to local job market information, including ways in which networking takes place in these local markets, to facilitate connections between job seekers and potential employers. This labour market information is specifically targeted to the spouses and partners of researchers, to ease their own professional transition when a researcher and their family establish roots in a new area, because difficult professional transitions for a spouse can sometimes inhibit researcher mobility (29).

(3) The Technical University of Denmark has established an International Faculty Services (IFS) unit, which aims to give potential employees a clear picture of the working environment at DTU, as well as a broader picture of Danish life and society, and what the candidate and their family can anticipate should they decide to move. This IFS programme is integrated with the job interview itself, signalling an appreciation for the integration of professional and personal factors considered in decision-making involved in seeking research employment internationally.

European pension scheme and social security: In order to remove obstacles to mobility resulting from social security issues, in particular pension rights, the European Commission has made progress in setting up pan-European supplementary pension funds for researchers. In December 2014, the Commission awarded a contract to Aeon Belgium for EUR 4 million, over four years, to support the Retirement Savings Vehicle for European Research Institutions (RESAVER). This consolidated pension arrangement was launched in 2015, and the progressive roll out across the European Economic Area will be complete by 2018 (European Commission & Directorate-General for Research and Innovation, 2014b). Practical implementation of the RESAVER will need to address heterogeneity of national pension schemes, from the no national pension scheme scenario, such as in Denmark, to mandatory employer contributions, as in Germany. In a more general fashion, social benefits remain diverse and are often precarious at the early stage of a research career. To address this issue, Germany has set a preference for working contracts rather than grants, in order to allow young researchers to have access to health insurance and pensions.

3.3.5 Composite indicator

The composite indicator developed by Science-Metrix for Priority 3 integrates only the Headline and complementary EMM indicators. For details on the construction of the composite indicators, refer to Section 2.3.2. Full numerical results are available in Table 31 (Annex 1).

The distribution of scores across the four performance clusters for this composite indicator nearly follows expectation under the assumption of a normal distribution of the scores. There are 6 countries in Cluster 1 (5 expected), 12 in Cluster 2 (11 expected), 10 in Cluster 3 (11 expected), and 5 in Cluster 4 (5 expected). The highest performing countries on the composite indicator for Priority 3 are the UK, Luxembourg, the Netherlands, Ireland, Sweden and Switzerland, each of which has a score over 70 out of a possible 100 in Cluster 1. The EU-28 average is 63. The lowest

[29] http://www.euraxess-tandem.eu/fileadmin/content/publications/Summary_CH_Europe_final.pdf

scores are from Hungary, Lithuania, Serbia, Bulgaria, and Turkey, who each have a score of under 35 in Cluster 4.

Performance on the composite indicator has no meaningful connection to size of economy for individual countries. However, the distribution of GDP amongst the clusters still tells an interesting story: Cluster 1 accounts for over 25 % of ERA GDP, while Cluster 4 accounts for less than 2 %, even though the two clusters cover approximately the same share of countries (18 % and 16 %, respectively). Furthermore, the 12 countries (36 % of covered countries) in Cluster 2 account for about 30 % of ERA GDP, while the 10 countries (30 %) in Cluster 3 account for over 40 %.

As discussed in Section 3.3.3, the variations across contexts and dimensions of Priority 3 mean that a single indicator will be less successful in giving a well-rounded comparative assessment of performance. In this circumstance, the composite indicator is especially valuable to provide a perspective that integrates the various lenses of several indicators.

Main findings

1. Recruitment processes are growing more open, transparent and merit based, promoting researcher mobility within the ERA. However, there are important variations from country to country in utilising the EURAXESS system (depending on alternative advertising media available, mandatory requirements to use EURAXESS, and other factors). Furthermore, the optimistic perception of the policy community with respect to implementing an open, transparent and merit-based system is out of step with the prevailing view within the research community itself, where the benefits of these systems seem to be tangible primarily in early career stages but not beyond. Furthermore, the administrative barriers to hiring international candidates remain an important factor, with universities requiring a greater autonomy in international recruitment. The Science Visa Directive has led to progress on the legal front.

2. International researchers' equal access to national granting programmes, and the portability of grants (under funding-follows-research schemes), are promising policies that have yet to see comprehensive, broad-based adoption. Such policies can greatly increase the international mobility of research talent.

3. A broader conception of human resourcing could contribute to increased benefit, including recruitment as well as working conditions. Some important dimensions for consideration here include pension right transferability; the heterogeneity of conditions on the job, beyond salary levels (noting that these broad sets of conditions are contributing to a brain-drain in Eastern European countries); and language competency conditions, especially related to teaching requirements.

3.4 Priority 4 – Gender equality and gender mainstreaming in research

3.4.1 Policy context

Previous ERA monitoring iterations have documented the pervasive gender equality gaps that exist within and between ERA countries (European Commission & Directorate General for Research and Innovation, 2015a). This study documents the ongoing efforts that the countries have set in place, both at national and institutional levels, to enhance incentives and strategies for gender equality in research content, in research careers and in top-level decision-making within research organisations. Although the priority granted to gender issues enjoys different footing within the ERA region, and gender initiatives show various degrees of progress, a basic monitoring is already in place in the large majority of ERA countries. Diverse approaches to promoting gender equality have been identified. Some actions seek gender mainstreaming in existing practices — for example, research careers, mechanisms for the allocation of research funding — while in some other cases countries and organisations within the ERA have introduced specific initiatives on gender (e.g. doctoral programmes, grants) (Lipinsky, 2014). Interviewees indicated that programmes promoting gender equality are much more developed in Northern European countries. These initiatives cover (1) programmes to attract young women to education in science, engineering and mathematics, and to research careers; (2) resources to promote career progression, work-life balance and reduced wage gaps; and (3) gender balance in decision-making including recruitment and funding allocation processes.

Based on the literature review, although it is still not mandatory under EU laws to adopt specific policy tools to implement gender equality initiatives, several ERA countries have well-identified national organisations responsible for advancing gender equality in institutions in the public research sector (Lipinsky, 2014). For instance, the Flemish Interuniversity Council has formed a High-Level Task Force Gender (Kelchtermans & Zacharewicz, 2016), and Universities Austria (UNIKO) has put in place a Task Force Gender und Diversity (Universities Austria (UNIKO), n.d.). In the Czech Republic, the National Contact Centre for Gender & Science is a national resource for gender equality issues (National Contact Centre for Gender & Science, n.d.). The Norwegian Ministry of Education and Research appointed the Committee for Mainstreaming – Women in Science in 2004 and has renewed its mandate for the third time for the 2014-2017 period (Norwegian Association of Higher Education Institutions, n.d.). Countries such as Austria, Spain and Norway have adopted legal provisions to stimulate or obligate universities to explicitly create equality plans; Denmark, Sweden, Iceland and Finland require workplaces over a certain size to draw up gender action plans. Efforts around Priority 4 illustrate the need for institutional and cultural change, including raising awareness of unconscious gender bias on issues that affect research careers between genders, including work-life balance, recruitment and promotion processes, and so on.

Under the leadership of the Helsinki Group ([30]) and the stakeholders' organisations, a good practices sharing process is ongoing. Among the good practices being shared, the qualitative data collection identified the following: (1) some RFOs are setting a gender management plan as a mandatory requirement to be included in research proposals; (2) ways to include a gender dimension into research content are being disseminated across RPOs through exchanges in the stakeholder organisations; and (3) ways to avoid unconscious bias in the recruiting and funds allocation processes are being disseminated across RPOs in the same manner. It is not possible,

[30] The Helsinki Group on Gender in Research and Innovation (HG) was established by the European Commission in 1999 to provide guidance in addressing 'disadvantage of women' in research and science. HG has the mandate to (1) support gender equality in research and innovation across Europe, (2) facilitate the dissemination and adoption of best practices regarding women promotion in science, and (3) bring its expertise to the European Commission in building and aligning the quantitative data necessary to monitor gender equality. For details see: https://era.gv.at/directory/85.

at this stage, to assess to what extent these practices are the rule rather than the exception. Additionally, in autumn 2016, Science Europe will release two documents aimed at sharing good practices. The first is a set of recommendations on data collection for the monitoring of gender issues, and the second concerns gender bias in peer-review assessment.

3.4.2 Headline indicator

The European Commission has noted that: '[t]he persistence of gender bias in careers, of gender imbalance in decision-making roles, and the lack of a gender dimension in research programmes remain common challenges' (European Commission & Directorate-General for Research and Innovation, 2014a). In light of this, a key priority for reinforcing the European Research Area is emphasising gender equality and gender mainstreaming in research (European Commission & Directorate-General for Education and Culture, 2011). Accordingly, the core actions under Priority 4 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 the 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 2015 being the latest iteration (European Commission & Directorate-General for Research and Innovation, 2016c).

Note, however, that there are a few drawbacks of 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. However, it can in some cases be updated more regularly. For this report, a special update was carried out by the HG and its Statistical Correspondents. Although 2015 data has been received for a number of countries (see Table 33, Annex 1), 2014 was retained as the reference year for this indicator to maximise its cross-country comparability; 2014 actually provides updated data compared to *She Figures 2015*, which was recently released with 2013 figures (European Commission & Directorate-General for Research and Innovation, 2016c). 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 the 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 than 50 % of the population and this can vary across countries. In the younger cohort, women can represent less than 50 % of the population. 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 17, and are plotted on a map in Figure 4.

The top performing country for this indicator is FYR Macedonia with 66.7 % of Grade A positions held by women. Note, however, that the score for this country is based on a very small population of Grade A researchers (only 9 in total). Thus, the score is prone to important yearly fluctuations. Additionally, because FYR Macedonia is more than four standard deviations away from the ERA average, it was not used in establishing the boundaries of the four performance clusters (see Footnote 5 for more details on this exclusion). Removing FYR Macedonia from the ERA average provides a better distribution of countries across performance clusters; this leads to 19 % of countries in Cluster 1 (against an expectation of 16 % based on a normal distribution of the scores), 28 % in Cluster 2 (34 %), 41 % in Cluster 3 (34 %) and 13 % in Cluster 4 (16 %).

Based on this distribution of countries by performance clusters, the strongest performers for 2014 include FYR Macedonia, Malta, Croatia, Latvia, Bulgaria and Lithuania. Note that FYR Macedonia and Malta are the only two countries scoring in the 40 %-60 % range reflecting gender parity. Women hold less than 30 % of Grade A research positions in the higher education sector in all other countries (i.e. those in clusters 2, 3 and 4); that is to say, in all other countries, there are at least twice as many men as women in the top tier of academic research (this still holds true for Lithuania in Cluster 1). The lowest scores are found in Luxembourg, Belgium, the Czech Republic and Cyprus, where less than 17 % of Grade A positions are held by women; this equates to having less than one woman for every five men.

The findings corroborate the persistence of a glass ceiling effect in ERA countries, as documented in the literature. While the proportion of women is relatively high in tertiary education (see complementary EMM indicator in Section 3.4.3), there is a significant reduction in the share of women that reach advanced stages of an academic career, especially in top-level positions (European Commission & Directorate-General for Research and Innovation, 2016c). Interview data revealed that RPOs and RFOs are largely aware of this situation and have introduced monitoring mechanisms. Although the systematic monitoring of gender balance is still not comprehensive, some interesting practices were identified in the case of the Danish Council for Independent Research (DFF), which monitors gender balance on a regular basis; the funding Academy Board of Finland, which sets annual criteria for research funding; the German DFG, which evaluates gender bias in programmes and funds allocation processes; and the Norwegian Research Council's project and institutional funding programmes, which include gender equality as core criteria in evaluation processes.

Looking now to growth along this indicator, from 2007 to 2014, one finds that nearly all countries for which data is available show a trend of increasing participation of women in Grade A research positions, although there is considerable variation from country to country, and the leaders are sustaining their lead (Table 17). Malta is performing well, and growing remarkably. As for other countries, progress is much more gradual and broad-based, with no group of countries poised to pull away from the rest. Based on the 2007-2014 period, some countries that are not showing any demonstrable growth are Hungary, Switzerland and Romania. That being said, it does not mean that these countries have not started increasing the share of women among Grade A positions in recent years (current data does not enable looking at such recent changes; however, some initial data for 2015 are presented in Table 33 (Annex 1) for reference).

Size of economy does not play a major role in determining performance on this indicator, though the correlation is slightly negative (Pearson r of -0.31), meaning that smaller economies tend to fare marginally better in the representation of women in Grade A research positions. For instance, the top two clusters account for less of the ERA GDP than would be expected based on the number of countries they include. Cluster 1 covers 19 % of countries and yet only accounts for about 1 % of ERA GDP. Cluster 2 covers 28 % of countries and only accounts for about 8 % of ERA GDP. The bulk of ERA GDP is located in Cluster 3; these 13 countries (41 % of those covered) account for over 90 % of GDP. Finally, Cluster 4 covers 13 % of countries accounting for roughly 4 % of ERA GDP.

Table 17 Share of women in Grade A positions in the Higher Education Sector (2007-2014)

Country	Weight in GDP	Score (2014)	CAGR (2007-14)	Lead/Gap to EU-28 CAGR
EU-28		**23.5%**	**3.4%**	**N/A**
Cluster 1	1.1%	41.7%	12.3%	9.0
Cluster 2	11.4%	26.4%	4.7%	1.3
Cluster 3	83.3%	20.1%	3.0%	-0.3
Cluster 4	4.2%	15.0%	5.3%	2.0
Cluster 1				
MK	0.1%	*66.7%*	:	
MT	0.1%	44.5%	*34.6%*	31.3
HR	0.3%	38.0%	*6.4%*	3.0
LV	0.2%	*34.4%*	*2.8%*	-0.5
BG	0.3%	34.2%	5.5%	2.1
LT	0.2%	32.6%	12.3%	9.0
Cluster 2				
RO	1.0%	*29.7%*	*-1.1%*	-4.4
IE	1.2%	*28.2%*	*12.7%*	9.3
FI	1.4%	27.9%	2.5%	-0.9
TR	:	*27.8%*	:	
IS	0.1%	*26.3%*	*7.1%*	3.8
NO	2.7%	26.2%	5.4%	2.1
SK	0.5%	25.3%	3.3%	-0.1
PT	1.2%	*25.0%*	*2.0%*	-1.3
SI	0.2%	25.0%	6.0%	2.6
SE	3.0%	24.3%	4.3%	1.0
Cluster 3				
EE	0.1%	23.5%	*3.2%*	-0.2
FR	14.6%	22.9%	*2.5%*	-0.9
PL	2.7%	22.7%	1.6%	-1.7
AT	2.2%	*21.5%*	*6.0%*	2.6
IT	11.1%	21.4%	2.1%	-1.3
ES	7.1%	21.0%	1.9%	-1.5
EL	1.2%	20.4%	*4.3%*	1.0
CH	3.6%	*19.3%*	*-1.9%*	-5.3
DK	1.8%	18.1%	*5.4%*	2.0
HU	0.7%	17.9%	-0.7%	-4.1
DE	19.5%	17.9%	5.9%	2.6
UK	14.1%	*17.5%*	:	
NL	4.5%	17.0%	6.3%	2.9
Cluster 4				
LU	0.3%	*16.5%*	*8.6%*	5.3
BE	2.7%	*15.6%*	*6.4%*	3.1
CZ	1.1%	14.3%	1.7%	-1.7
CY	0.1%	13.6%	*4.6%*	1.2
IL	:	*12.7%*	:	

Note: Exception to reference year: 2013 (BE, LV, LU, AT, RO, CH); 2012 (IE, PT, IS, MK); TR (2007); 2006 (UK, IL)
Exception to reference period: BE (2007-2014), DK (2006-2014), EE (2004-2014), IE (2003-2012), EL (2000-2014), FR (2006-2014), CY (2006-2014), LV (2007-2013), LU (2006-2013), MT (2004-2014), AT (2006-2013), PT (2003-2012), RO (2007-2013), IS (2007-2012), CH (2007-2013)
Data unavailable: ME, AL, RS, TR, BA, IL, FO, MD, UA
Data prone to yearly fluctuations due to small denominator: MK (6/9 = 66.7 %)
(:) = missing data
MK is more than four standard deviations away from the mean and was therefore not used in establishing the clusters' boundaries.
Trend column not presented due to sparse time-series.

Source: Women in Science database, DG Research and Innovation

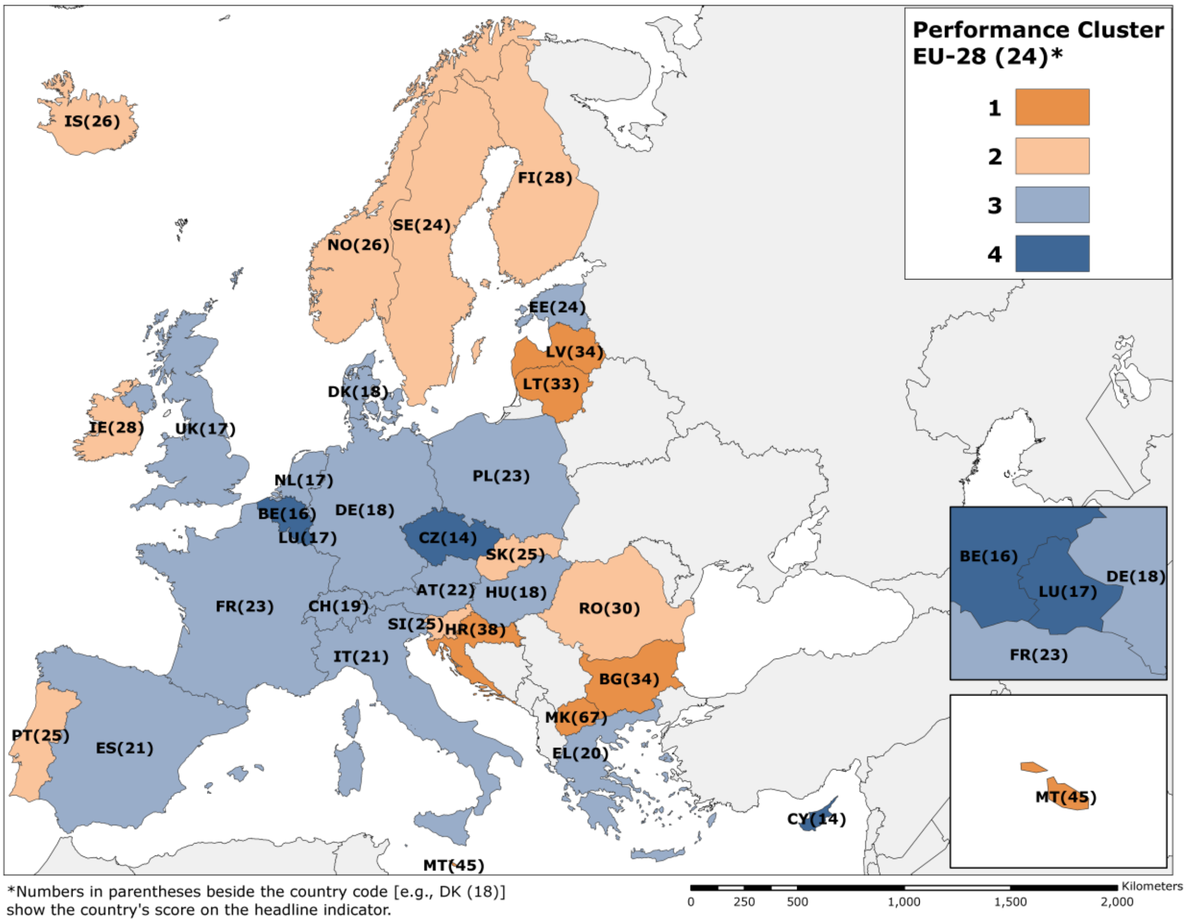

Figure 4 Map of the share of women in Grade A positions (in %) in the Higher Education Sector (2014)

Note: As per Table 17.
Source: Women in Science database, DG Research and Innovation

3.4.3 Complementary EMM indicators

The two complementary EMM indicators selected for Priority 4 focus on the participation of women in tertiary education and on the inclusion of the gender dimension in research content.

Gender dimension in research content (GDRC)

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 ([31]); this assessment was divided by domains of research because the gender

[31] The proportion of scientific papers accounting for the biological characteristics or the social and cultural features of both women and men.

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 ([32])) 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 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 dimensions are more relevant and therefore integrated more frequently ([33]). 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 2016 ERA Monitoring Handbook for further details on the computation of this indicator. Full results are presented in Table 18.

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 gender dimension is integrated, at least in terms of order of magnitude as well as differences across the domains of science.

The gender dimension figures most prominently in research from Slovakia, Lithuania and Malta, which each include this dimension more than two times more often than the global norm (GDRC > 2.00). Portugal, Turkey and Greece round out the leader group (i.e. Cluster 1), including the gender dimension just under two times more often than the global norm (GDRC ≥ 1.80). The gender dimension figures much less prominently in the research of Luxembourg, Montenegro, Bulgaria and the Republic of Moldova, each of which includes the gender dimension less than half as often as the global average (GDRC < 0.50).

Performance and growth on this indicator show no correlation; clusters 1 and 4 — those with the highest and the lowest scores — show the most growth, on average, while clusters 2 and 3 — those in the middle — remain mostly stable. For Cluster 4, growth is concentrated in Montenegro, while it is more diffuse in Cluster 1. After Montenegro in Cluster 4, Slovakia, Malta and Turkey

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

[33] 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.

show the strongest growth and are all in Cluster 1. Bulgaria and the Republic of Moldova, which are both in Cluster 4, exhibit the strongest decline. However, the trend appears to have inverted in recent years for the latter. Serbia, Romania and Slovenia are losing ground in clusters 2 and 3. Here again, the trend seems to have inverted in recent years for Serbia and Slovenia. Overall, the EU-28 average performance is on par with the world level and fairly stable through time.

Looking at the size of economy, it appears to play only a very minor role in determining performance on this indicator, though smaller economies show slightly stronger results than larger economies do (Pearson r of -0.24). Cluster 1 accounts for under 4 % of ERA GDP with 16 % of countries, Cluster 2 accounts for about 10 % with 24 % of countries, Cluster 3 (which contains by far the most countries with a share of 49 %) accounts for over 85 %, and Cluster 4 accounts for about 1 % with 11 % of countries.

Share of female PhD graduates

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 2). Here again, shares in the range from 40 % to 60 % were considered as reflecting gender parity. Results for this indicator are presented in Table 19.

The performance scores of countries on this indicator are nearly normally distributed such that the distribution of countries across performance clusters is quite symmetrical (see Footnote 5 on the clustering approach); there are 15 % of countries in Cluster 1 (16 % expected), 30 % in Cluster 2 (34 %), 36 % in Cluster 3 (34 %) and 18 % in Cluster 4 (16 %). The strongest performers are Latvia, Lithuania, Portugal, Romania and Croatia, who each have close to, or at least, 50 % of female PhD graduates. In comparison, the EU-28 level stands at 47 %. At the other end of the spectrum, Greece, Belgium, France, Switzerland, Austria and the Czech Republic all have scores under 44 %, slightly below the EU-28 level. In this case, all countries fall in the 40 %-60 % range considered as reflecting gender parity. From this data and the Headline indicator, it is therefore quite clear that a glass ceiling effect persists in ERA countries.

There is no obvious correlation pattern between performance and growth on this indicator. Also, the CAGRs of countries based on the 2005-2012 period are not pronounced (i.e. the share of female PhD graduates is rather stable, changing only slightly over time) with two exceptions: Malta with a strong lead to EU-28 (CAGR of 10.8 %), and Cyprus with a strong gap to EU-28 (-6.5 %). However, note that the trend for Malta is rather unstable with multiple changes in direction over the study period.

There is a slightly negative correlation between GDP and performance on this indicator (Pearson r of -0.31), as was observed for the previous two indicators, meaning that smaller economies tend to fare marginally better in the representation of female PhD graduates. Cluster 1 covers 15 % of countries and yet only accounts for about 2.8 % of ERA GDP. Cluster 2 covers 30 % of countries and only accounts for about 18 % of ERA GDP. Cluster 3 covers 36 % of countries and accounts for over 50 % of GDP. Finally, Cluster 4 covers 18 % of countries accounting for roughly 26 % of ERA GDP.

Comparing Headline to complementary EMM indicators

The Headline indicator appears to be weakly and positively correlated to the two complementary EMM indicators for Priority 4 (Pearson r of 0.30 with GDRC and of 0.35 with the share of female PhD graduates). Obviously, the Headline indicator (i.e. the share of women researchers in Grade

A positions) does not suffice to capture all relevant dimensions under the gender equality and gender mainstreaming in research priority.

That being said, the weak correlation of the Headline indicator with GDRC might, in some cases, indicate that having a stronger representation of women among Grade A research positions at higher education institutions can lead to a greater integration of the gender dimension in the content of their research. Similarly, the weak correlation of the Headline with the share of female PhD graduates might, in some cases, indicate that having a stronger representation of women in tertiary education increases the odds of having a stronger representation of women among Grade A research positions at higher education institutions. However, this is quite obvious as the former is a prerequisite of the latter. In fact, the weak correlation between these latter two indicators highlights the fact that barriers to the career progression of women vary across the European landscape, with some countries doing better at earlier stages of the academic career but doing worse in later stages.

Altogether, the three indicators under Priority 4 consistently show a somewhat stronger performance of the smaller economies, relative to the larger ones, in comparison to most of the indicators presented in other priorities.

Table 18 Gender dimension in research content (2005-2014)

Country	Weight in GDP	Score (2011-2014)	CAGR (2005-08 to 2011-14)	Lead/Gap to EU-28 CAGR	Trendline (2005-08 to 2011-14)
EU-28		**0.97**	**-0.5%**	**N/A**	
Cluster 1	3.2%	2.23	12.9%	13.4	
Cluster 2	8.3%	1.40	-0.7%	-0.1	
Cluster 3	87.9%	0.91	0.8%	1.3	
Cluster 4	0.6%	0.31	17.0%	17.5	
Cluster 1					
SK	0.5%	2.88	33.9%	34.4	
LT	0.2%	2.62	4.1%	4.6	
MT	0.1%	2.27	20.7%	21.2	
PT	1.2%	1.92	5.2%	5.7	
TR	:	1.88	3.2%	3.7	
EL	1.2%	1.80	10.3%	10.8	
Cluster 2					
RS	0.2%	1.59	-7.9%	-7.4	
HU	0.7%	1.53	-4.8%	-4.3	
BA	:	1.50	8.7%	9.2	
SE	2.9%	1.37	-4.4%	-3.9	
SI	0.3%	1.36	-7.2%	-6.7	
PL	2.8%	1.34	3.8%	4.3	
IL	:	1.33	1.3%	1.8	
FI	1.4%	1.32	1.3%	1.8	
IS	0.1%	1.25	3.2%	3.7	
Cluster 3					
NO	2.5%	1.14	-3.2%	-2.7	
BE	2.7%	1.12	2.4%	2.9	
UK	15.1%	1.12	-2.6%	-2.1	
DK	1.7%	1.10	-0.6%	-0.1	
NL	4.4%	1.07	0.9%	1.4	
RO	1.0%	1.05	-7.7%	-7.2	
HR	0.3%	1.03	-0.7%	-0.2	
CH	3.5%	0.98	6.1%	6.6	
AT	2.2%	0.98	-1.6%	-1.1	
CZ	1.0%	0.85	1.3%	1.9	
ES	7.0%	0.85	-2.1%	-1.6	
IE	1.3%	0.84	9.1%	9.6	
IT	10.8%	0.80	-0.3%	0.2	
DE	19.6%	0.76	4.0%	4.5	
EE	0.1%	0.69	-4.8%	-4.3	
CY	0.1%	0.67	10.4%	10.9	
LV	0.2%	0.65	6.1%	6.6	
FR	14.3%	0.64	-2.4%	-1.9	
Cluster 4					
LU	0.3%	0.47	1.5%	2.0	
ME	0.0%	0.40	*94.3%*	*94.8*	
BG	0.3%	0.34	-19.6%	-19.1	
MD	:	0.04	-8.1%	-7.6	

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. For more details on the methodology, please refer to Section 2 of this report or to its companion Handbook.
Exception to reference period: ME (CAGR is computed using 2007-2010 as the start year and 2011-2014 as the end year)
Data unavailable: MK, AL, FO, UA
(:) = missing data

Source: Computed by Science-Metrix using WoS data (Thomson Reuters)

Table 19 Share of female PhD graduates (2005-2012)

Country	Weight in GDP	Score (2012)	CAGR (2005-12)	Lead/Gap to EU-28 CAGR	Trendline (2005-12)
EU-28		**47.3%**	**1.2%**	**N/A**	
Cluster 1	2.8%	56.6%	1.2%	0.0	
Cluster 2	17.7%	51.3%	0.0%	-1.3	
Cluster 3	54.0%	46.9%	2.2%	0.9	
Cluster 4	25.5%	42.9%	1.8%	0.5	
Cluster 1					
LV	0.2%	59.9%	0.3%	-1.0	
LT	0.2%	57.0%	-0.4%	-1.6	
PT	1.2%	56.3%	1.7%	0.5	
RO	0.9%	55.3%	1.7%	0.5	
HR	0.3%	54.6%	2.7%	1.5	
Cluster 2					
PL	2.7%	53.2%	1.7%	0.5	
IT	11.2%	53.2%	0.4%	-0.8	
IS	0.1%	52.5%	-1.2%	-2.4	
BG	0.3%	51.7%	1.0%	-0.3	
FI	1.4%	50.9%	0.5%	-0.7	
LU	0.3%	50.9%			
EE	0.1%	50.5%	1.9%	0.7	
SI	0.3%	50.4%	0.8%	-0.4	
CY	0.1%	50.0%	-6.5%	-7.7	
IE	1.2%	49.2%	1.2%	0.0	
Cluster 3					
SK	0.5%	48.7%	0.7%	-0.6	
MK	0.1%	48.6%	0.2%	-1.0	
ES	7.3%	48.6%	0.6%	-0.7	
SE	2.9%	48.4%	1.3%	0.0	
NO	2.8%	48.1%	2.8%	1.6	
TR	:	46.5%	2.0%	0.8	
HU	0.7%	46.5%	1.2%	-0.1	
MT	0.1%	46.2%	*10.8%*	9.5	
UK	14.3%	46.1%	0.9%	-0.3	
DE	19.2%	45.4%	2.0%	0.8	
DK	1.8%	45.3%	1.4%	0.1	
NL	4.5%	44.9%	2.4%	1.1	
Cluster 4					
EL	1.3%	43.9%	3.0%	1.8	
BE	2.7%	43.8%	2.5%	1.3	
FR	14.5%	43.4%	0.8%	-0.5	
CH	3.6%	43.2%	2.2%	1.0	
AT	2.2%	41.8%	-0.6%	-1.9	
CZ	1.1%	41.4%	2.7%	1.4	

Note: Estimated: EU-28 (2005–2012)
Exception to reference period: MT (2006–2012)
Data unavailable: ME, AL, RS, BA, IL, FO, MD, UA
(:) = missing data

Source: Computed by Science-Metrix using Eurostat data (online data codes: educ_grad5)

3.4.4 Additional policy highlights

Gender action plan / policy: A small number of RFOs within the ERA are promoting increased gender equality in research funding mechanisms through the implementation of financial and policy tools that include specific requirements in grant evaluation processes, provision of supplementary funding for absences (e.g. maternity and sometimes parental leave), implementation of quotas or targets in evaluation panels, as well as monitoring gender balance among research teams. For instance, RFOs in Austria, Luxembourg and Finland have established performance agreements with their respective governments; Norway has established a Committee for Gender Balance in Research (KIF) and created the Gender Equality Award (Research Council Norway); in Switzerland, the federal programme for equal opportunity of women and men at universities/Gender Studies (2013-2016) of the Swiss University Conference (SUC) has set targets for gender representation at several levels of the research career (Lipinsky, 2014).

Wage Gap: Based on the qualitative data, further efforts are needed to reduce the gender pay gap. For instance, new instruments designed to promote institutional flexibility in remuneration and benefits (e.g. endowment, flexible bonuses) have brought about the need to address gender inequalities that have arisen through the adoption and implementation of these new instruments. Policy measures aimed specifically at monitoring and addressing the gap in researcher wages have been implemented so far only in Austria, Cyprus and Finland. By contrast, other countries such as Luxembourg, Slovenia, Spain, the UK, Estonia and Iceland have opted for a less direct approach, including recommending that institutions adopt voluntary measures, or appoint advisory committees to monitor the situation and put forward suggested courses of action. Additional initiatives linked to plans to improve career prospects for female researchers include the Austrian Federal Government Equal Opportunity Act, which obligates universities to report yearly details on gender pay gaps (Lipinsky, 2014). Similarly, the Danish government implemented the EU directives on gender balance through the Act on Gender Equality and the Act on Equal Treatment of Men and Women (Grimpe and Mitchell, 2016).

Resources for career progression: Qualitative data documented diverse initiatives in support of career progression targeting both the individual and the institutional levels. At individual level, women are offered training to improve research proposal writing capabilities, skills improvement courses and preparatory courses for leadership positions (e.g. Germany), tailored workshops for career advancement (e.g. Switzerland), and mock professorship proceedings for qualified women to experience the appointment process (e.g. Norway). The WISE Programme in the Netherlands assists women to create their own research groups and be on tenure-track for full professorship. The Norwegian BALANSE programme (2013-2017) 'aims at stimulating the recruitment of female professors specifically in STEM [science, technology, engineering and mathematics] fields' (Lipinsky, 2014, p.25). The interview data also revealed a lively debate about the best way to enable gender mainstreaming between the use of quotas and the provision of career development tools. Women themselves have been promoting gender mainstreaming in research. For instance, in the Netherlands, the national network of female professors promotes increased representation of women in academia.

Incentives at the national level are also in place to encourage RPOs to implement gender equality measures. For instance, a special authorisation of the Danish Gender Equality Act allows the allocation of an additional professorship chair (off faculty plan) if a department reaches a certain number of female professor appointees. Norway financially rewards RPOs for gender equality leadership when they reach a certain standard of sustainability in this regard. Work-life balance is taken into account in heterogeneous ways ranging from grant extensions (e.g. in Denmark and Poland), or the guarantee of returning to the same position after extended leaves of absence (e.g. Slovenia, Spain and Estonia), to more advanced policies like the obligation for both parents to share parental leave, combined with a generous parental insurance, as found in Sweden.

In the particular case of some umbrella organisations, gender equality initiatives include the use of monitoring and evaluation practices, and/or the identification of specific units or personnel responsible for such activities. Gender balance is progressively included as a requirement in recruitment processes. For instance, 24 out of 42 respondents of a survey performed among CESAER members' universities declared having adopted a regulation for 'gender diversity in appointment committees' (CESAER, 2015b, p.71). Considering the importance of access to funding for the building of research careers, interview data documented that the Netherlands has introduced specific training to assist members of selection committees to avoid unconscious gender bias in the assignment of grants.

Gender balance in decision-making: The literature review revealed warnings that gender balance in decision-making presents a circular challenge as the low representation of women in decision-making bodies may affect the likelihood that gender-related topics can be addressed in future developments pertaining to research careers; moreover, female researchers remain insufficiently visible to encourage aspiring female researchers to follow in their footsteps (Widmer, 2008, p.5). Some documented measures implemented at the country level to promote more women to top-level academic positions fall into three overarching categories:

(1) Explicit targets and quotas are established to promote the push towards gender parity on boards (Lipinsky, 2014; Deloitte, 2014).

(2) Training and support programmes are put in place, targeting both the women working in the research community, and the research community itself to make it a more receptive professional environment for women. For instance, training is provided in Sweden and in the United Kingdom for managers and department heads to ensure awareness of potential biases and inequalities.

(3) Potential female candidates are identified for service on boards, committees and in other decision-making capacities in order to enhance transparency and gender balance in appointment procedures among other decisions; for instance, the Directory of Professional Women is maintained in Malta for such a purpose (Deloitte, 2014).

3.4.5 Composite indicator

The composite indicator developed by Science-Metrix for Priority 4 integrates the Headline and complementary EMM indicators, in addition to two others: the share of women amongst researchers and the share of women amongst heads of higher education institutions. In this way, the composite indicator captures valuable information along the full career path in research, from the entry level in tertiary education, through researchers' positions in general (in all sectors of the economy) as well as in the highest grade of academic research, and on to the most senior positions in decision-making in academia. Because it also captures the integration of the gender dimension in research, it offers a synthetic view of indicators pertaining to all of the core actions under Priority 4; that is, the core actions under Priority 4 aim to address gender inequalities in research institutions and decision-making bodies, as well as aim to promote the integration of the gender dimension in R&D policies, programmes and projects (ERAC Secretariat, 2015a). For details on the construction of the composite indicators, refer to Section 2.3.2.

The results of this composite indicator are presented numerically with full details in Table 32 (Annex 1). The top performing countries on the composite indicator are Serbia, Portugal, Lithuania, Iceland, Malta, Latvia and Croatia. The softest performances are from Germany, Luxembourg, Cyprus, the Netherlands, the Czech Republic and France.

The composite indicator for Priority 4, gender equality, shows, like all individual indicators presented above for Priority 4, a negative correlation with GDP. However, it is even slightly stronger in the case of the composite and could be qualified as being moderate (Pearson r of -0.41). Thus, smaller economies tend to fare slightly better than larger ones on this experimental composite. This correlation can be seen in assessing the number of countries in each cluster and the proportion of ERA GDP that they account for. Cluster 1 covers 7 countries (i.e. 21 % of those covered) and only 2 % of GDP, Cluster 2 covers 9 countries (27 %) and only 12 % of GDP, Cluster 3 covers 11 countries (33 %) and as much as 46 % of GDP, and Cluster 4 covers 6 countries (18 %) and as much as 40 % of GDP. Of the four largest economies in the ERA, those that account for more than 10 % of its GDP, two of them (France and Germany) fall in the bottom cluster, with the other two (Italy and the UK) falling in Cluster 3. The leaders on this composite indicator include Serbia, Portugal, Lithuania, Iceland, Malta, Latvia and Croatia. The followers include Germany, Luxembourg, Cyprus, the Netherlands, the Czech Republic and France. In general, Eastern European and Nordic countries tend to show the strongest performance.

With this broader set of indicators assessed here, using the composite, a broad picture of the state of affairs in gender equality can be outlined. In general, close to 50 % of PhD graduates in the EU-28 are women, with about 33 % of public-sector research positions occupied by women (meaning a 2:1 ratio of men to women), and only about 20 % each of Grade A research positions and heads of research institutions held by women (a 4:1 ratio of men to women). These numbers, with a greater representation of women in early career stages and fewer and fewer women in progressively later stages may suggest a generational shift towards greater parity, or it may suggest that there is important disparity in the attrition rates between men and women as they progress through their career stages.

Main findings

1. Gender balance policies are in place across most of Europe at the national or institutional levels, depending on local context. Basic monitoring tools are in place in a large number of these countries as well, although increased harmonisation and resolution of these tools would help to compare and share best practices across contexts, and ultimately to better target strategic action. Some policies include the application of gender quotas or the provision of capacity-building programmes, while monitoring tools sometimes include assessments of wage gaps.

2. Translating policies into actions is an additional step, and many RFOs have put in place specific incentives to address gender disparities, initiatives to attract young female talent into research careers, and training to raise awareness about unconscious biases. In general, a paradigm shift is still required to displace the responsibility from individual female researchers and onto the research community as a whole to address the disproportionate barriers facing women in research. These cultural shifts can benefit from integration with a broader conception of human resourcing and career progression in general, going beyond salary alone (Priority 3).

3. A glass ceiling still seems to be in effect, as the balance between men and women amongst doctoral graduates has been fairly even for the past decade, whereas women account for only one third of employed researchers, only about one fifth of Grade A researchers, and again only a fifth of heads of research institutions. Eastern European and Nordic countries are the closest to parity, for different cultural and historical reasons, but on average European research still has a long way to go before a gender balance is achieved and sustained.

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

3.5.1 Policy context

Sub-priority 5a

The ERA implementation process highlights the significant economic benefits that can be derived from the transfer, uptake and actual use of research findings. Transfer of the knowledge produced by RPOs to end-users is a fundamental step in addressing grand challenges and enhancing social prosperity. Europe faces the challenge, however, of tapping into the region's potential to capitalise on R&I investment in ways that create sustainable growth, while bridging the gap relative to the US and keeping ahead of some rapidly growing Asian economies (Debackere et al., 2014). Although a multitude of interaction patterns are shaping up and taking form across Europe, this study uncovered areas for continuous improvement in the breadth and the depth of interactions between Europe's knowledge institutes and industries. The drive toward open innovation and the tightening of exchanges within the knowledge triangle involving RPOs, government and the private sector put greater emphasis on R&I as collaborative activities (Debackere et al., 2014).

Efforts are ongoing to collect and consolidate EU-wide information on open innovation and knowledge transfer, with a specific focus on knowledge transfer activities undertaken by public research organisations and institutions in the higher education sector. These efforts aim to elucidate existing and emerging conduits for the transmission of knowledge, and to shine a light on factors that contribute to and detract from success (European Commission & Directorate-General for Research and Innovation, 2015c, p.70).

Progress in Sub-priority 5a requires additional efforts to address challenges related to mutual trust, language, the entrepreneurial orientation of RPOs and private sector partners, and legal and educational issues, with particular emphasis on better connecting RPOs and small and medium-size firms (SMEs) and enhancing available funding schemes for collaboration and knowledge transfer (Debackere et al., 2014). According to interviewees, beyond the traditional understanding of knowledge transfer as technology flows exchanged between RPOs and private firms, an additional dimension encompasses a broader range of processes and stakeholders involved in R&I. This draws attention to knowledge exchanges with civil society and the closer integration between hard and social sciences to address grand challenges.

Sub-priority 5b

Several ERA countries are putting in place or already have strategies regarding access to and dissemination of scientific information, including open access through an enhanced digital ERA. Both at national and organisational levels, open access approaches vary considerably; moreover, the European Commission has noted that Member States tend to 'choose soft law rather than hard law when implementing OA' (European Commission, 2014b, p.55). For instance, according to interview data, the Netherlands and France have set targets for the outputs of publicly funded research to be entirely open access by 2024 and 2020 respectively. Denmark is focused on having OA to all peer-reviewed research articles in all Danish RPOs by 2022. Depending on the country, the target may be measured in terms of green OA, gold OA or both ([34]). The harmonisation of copyright laws, including on topics related to text and data (content) mining

[34] Gold OA refers to 'papers made available for free by the publishers themselves, be it on their website […] or on the site of an aggregator' (Archambault et al., 2016). Green OA refers to 'papers made available for free by parties other than publishers, usually the authors themselves, who archive papers in institutional repositories, subject repositories such as arXiv, or commercial repositories such as ResearchGate' (Archambault et al., 2016).

(TDM), remains a challenge at the European level for technology transfer and OA, this issue is currently under discussion (Science Europe, 2015a) ([35]).

In regard to ERA Stakeholder Organisations, there is significant interest and activity around OA, from the bottom up, including the signing of memoranda of understanding with the Commission on the ERA, committing the organisations to promote OA within their membership (European Commission & Directorate-General for Research and Innovation, 2015c). Examples of concrete initiatives include the adoption of new principles on OA publisher services by Science Europe Member Organisations, which stipulate a minimum set of services from publishers applicable when providing payments/subsidies for OA: indexing, copyright and re-use, sustainable archiving and machine readability (Science Europe, 2015c). The European Universities Association (EUA), published a briefing paper on open access to research publications (Lourenço & Borrell-Damian, 2014), and has created a checklist for practical guidelines on open access implementation (EUA, 2015). LERU universities have deployed OA strategies and mechanisms to enable researchers' output to be held and available through discipline-based repositories (national and international). LERU has also started to engage with the EU on text and data mining and on copyright issues (Maes, 2014). Looking into CESAER's actions around OA, the organisation has formed a 'CESAER Open Access Task Force', mandated 'to prepare and support CESAER members in achieving the vision and mission through Open Science' (CESAER, 2015a, p.1).

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 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, the ERAC selected the share of product or process innovative firms cooperating with public research or higher education institutions as the Headline indicator for Sub-priority 5a. Because consolidated data was not available for these two categories together, the Headline has been split into two: the share of product or process innovative firms cooperating with research institutes (in the public or private sector), and the share of product or process innovative firms cooperating with higher education institutions.

Note that the indicator focusing on cooperation with research institutes does not only capture public research institutes in the latest year of available data (i.e. 2012), 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. This could potentially bias the analysis of growth since data for 2008 and 2010 only cover public research institutes. This issue has been properly flagged by adding a 'definition differs' note to Table 20. Also note that the above two indicators do not distinguish between large and small firms; however, the former are 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 2016 ERA Monitoring Handbook.

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[35] See also, http://ec.europa.eu/internal_market/consultations/2013/copyright-rules/index_en.htm; http://ec.europa.eu/internal_market/copyright/copyright-infso/index_en.htm

Share of product or process innovative firms cooperating with research institutes (in the public or private sector)

Full results for the indicator on the share of product or process innovative firms cooperating with research institutes (in the public or private sector) are detailed in Table 20, and are plotted on a map in Figure 5. The countries showing the strongest performance on this Headline indicator are Finland, which leads by a wide margin with nearly a quarter of innovative firms involved in collaborative research with research institutes in the public and private sectors, followed by Greece, Slovenia, Norway and Belgium. The softest performances are from Italy, Bulgaria, Malta and Serbia, each of which has less than 3 % of innovative firms collaborating with research institutes. Scores on this indicator are quite normally distributed, with only Cluster 3 slightly larger than expected (47 % of countries relative to an expectation of 34 % under a normal distribution of the data), and Cluster 2 slightly smaller (25 % instead of 34 %). This means that there is slight asymmetry in performance with slightly more than 50 % of countries below the ERA average. Relative to the EU-28 level, there is no such asymmetry, with 16 countries having a lead and 16 countries having a gap to the EU-28.

There is no correlation between performance and growth for this indicator, meaning that there is no leader group that is pulling away from the pack. A number of countries show strong growth, chief among them being Romania, which is increasing at a compound annual rate of over 20 %, and Austria, which is increasing at a compound annual rate of almost 15 %. Luxembourg and Slovakia are showing sharp declines, each at a compound annual rate of about -12 %.

Similarly, GDP shows no meaningful correlation with performance on this indicator, meaning that large and small economies have equal likelihood of being found in any performance cluster. The largest economies are spread out in their results. Furthermore, clusters 1 and 4 cover roughly the same share of countries (16 % and 13 %, respectively) as well as portions of the ERA GDP within a few percentage points of one another (9 % and 12 %, respectively). Clusters 2 and 3 account for the most countries as well as the bulk of the GDP, with a fairly even split between them. Still note that countries with a smaller share of large firms might be disadvantaged.

Share of product or process innovative firms cooperating with higher education institutions

Turning to the second component of the Headline indicator on the share of product or process innovative firms cooperating with higher education institutions (Table 21, Figure 6), the countries in which the highest percentage of innovative firms cooperate with the higher education sector are Finland, Slovenia, Austria, Greece, Lithuania and Belgium. In each of these countries, over 18 % of innovative firms are engaged in collaborative research with the higher education sector being at least 50 % ahead of the EU-28 score. The countries in which the smallest share of private firms cooperate with the higher education sector are Italy, Cyprus, Bulgaria, Romania, Malta and Serbia, each of which has a collaboration rate under 6 %, being at least 50 % behind the EU-28 score. Scores are quite evenly distributed, relative to expectation under the assumption of a normal distribution of the scores (see Footnote 5), without a standout group skewing the ERA average.

As with the first component of the Headline indicator, there is no correlation between performance and growth on this indicator, with stronger and weaker performers equally likely to be showing a positive trend in their collaboration rates over the 2008-2012 period. Some notably strong growth is registered from Spain, Lithuania and Estonia, each of which is increasing its collaborations at a compound annual rate of close to 10 %. Luxembourg and Latvia have declined notably over the reference period, each at a compound annual rate of approximately -10 %.

Size of economy seems to have no significant influence on performance on this indicator, and the proportion of GDP found in each cluster quite closely follows the share of countries each one covers; note there is a slightly greater representation of ERA GDP in Cluster 2 and a slight under-representation of ERA GDP in clusters 1 and 4. Cluster 1 has 19 % of countries and 8.4 % of ERA GDP, Cluster 2 has 28 % of countries and about 45 % of GDP, Cluster 3 has 34 % of countries and 33 % of GDP, and Cluster 4 has 19 % of countries and 13 % of GDP. The largest economies in the ERA are found in the middle clusters, with the exception of Italy, which sits just below the threshold between clusters 3 and 4. As with the first component of this Headline indicator, countries with a smaller share of large firms might be disadvantaged.

Table 20 Share of product or process innovative firms cooperating with public or private research institutions (2008-2012)

Country	Weight in GDP	Score (2012)	CAGR (2008-12)	Lead/Gap to EU-28 CAGR	Trendline (2008-12)
EU-28		**7.3%**	**3.5%**	**N/A**	
Cluster 1	8.7%	16.0%	0.4%	-3.1	
Cluster 2	30.1%	10.7%	5.1%	1.5	
Cluster 3	48.9%	6.3%	1.3%	-2.3	
Cluster 4	12.2%	1.7%	0.8%	-2.8	
Cluster 1					
FI	1.4%	23.0%	-0.1%	-3.6	
EL	1.4%	15.7%	:		
SI	0.3%	*14.3%*	:		
NO	2.9%	13.8%	0.8%	-2.7	
BE	2.8%	13.3%	0.4%	-3.1	
Cluster 2					
AT	2.3%	12.6%	14.7%	11.2	
DK	1.8%	10.9%	-7.2%	-10.7	
SE	3.1%	10.8%	8.9%	5.4	
LT	0.2%	10.7%	2.9%	-0.6	
ES	7.5%	10.6%	13.1%	9.6	
HR	0.3%	10.1%	-2.2%	-5.7	
UK	14.8%	10.0%	:		
IS	0.1%	*9.7%*	:		
Cluster 3					
FR	15.0%	8.0%	-1.6%	-5.2	
PL	2.8%	7.8%	-3.8%	-7.3	
LU	0.3%	7.7%	-12.0%	-15.5	
IE	1.3%	*7.1%*	:		
RO	1.0%	6.9%	22.9%	19.4	
LV	0.2%	6.8%	0.1%	-3.4	
NL	4.7%	*6.6%*	:		
PT	1.2%	6.5%	3.5%	-0.1	
DE	19.9%	*5.9%*	:		
HU	0.7%	5.9%	-2.6%	-6.1	
CZ	1.2%	5.7%	-2.3%	-5.8	
TR	:	5.4%	:		
SK	0.5%	5.3%	-11.5%	-15.0	
CY	0.1%	4.7%	11.2%	7.7	
EE	0.1%	4.4%	10.0%	6.5	
Cluster 4					
IT	11.6%	2.8%	12.2%	8.7	
BG	0.3%	2.6%	-9.3%	-12.8	
MT	0.1%	1.5%	-0.6%	-4.1	
RS	0.2%	*0.0%*	:		

Note: Definition differs (added by Science-Metrix): 2012 (EU-28, BE, BG, CZ, DK, DE, EE, IE, EL, ES, FR, HR, IT, CY, LV, LT, LU, HU, MT, NL, AT, PL, PT, RO, SI, SK, FI, SE, UK, NO, RS, TR)
Provisional: EU-28 (2008); DK (2008)

Low reliability: EU-28 (2008); SE (2008)
Eurostat country flags have been retained in the EU-28 aggregate
Missing countries in EU-28 aggregate: Growth (DE, IE, NL, SI)
Exception to reference year: 2010 (DE, IE, NL, SI, IS)
Data unavailable: CH, ME, MK, AL, BA, IL, FO, MD, UA
(:) = missing data

Source: Computed by Science-Metrix using Eurostat data (online data codes: inn_cis6_coop, inn_cis7_coop, inn_cis8_coop, inn_cis6_type, inn_cis7_type, inn_cis8_type)

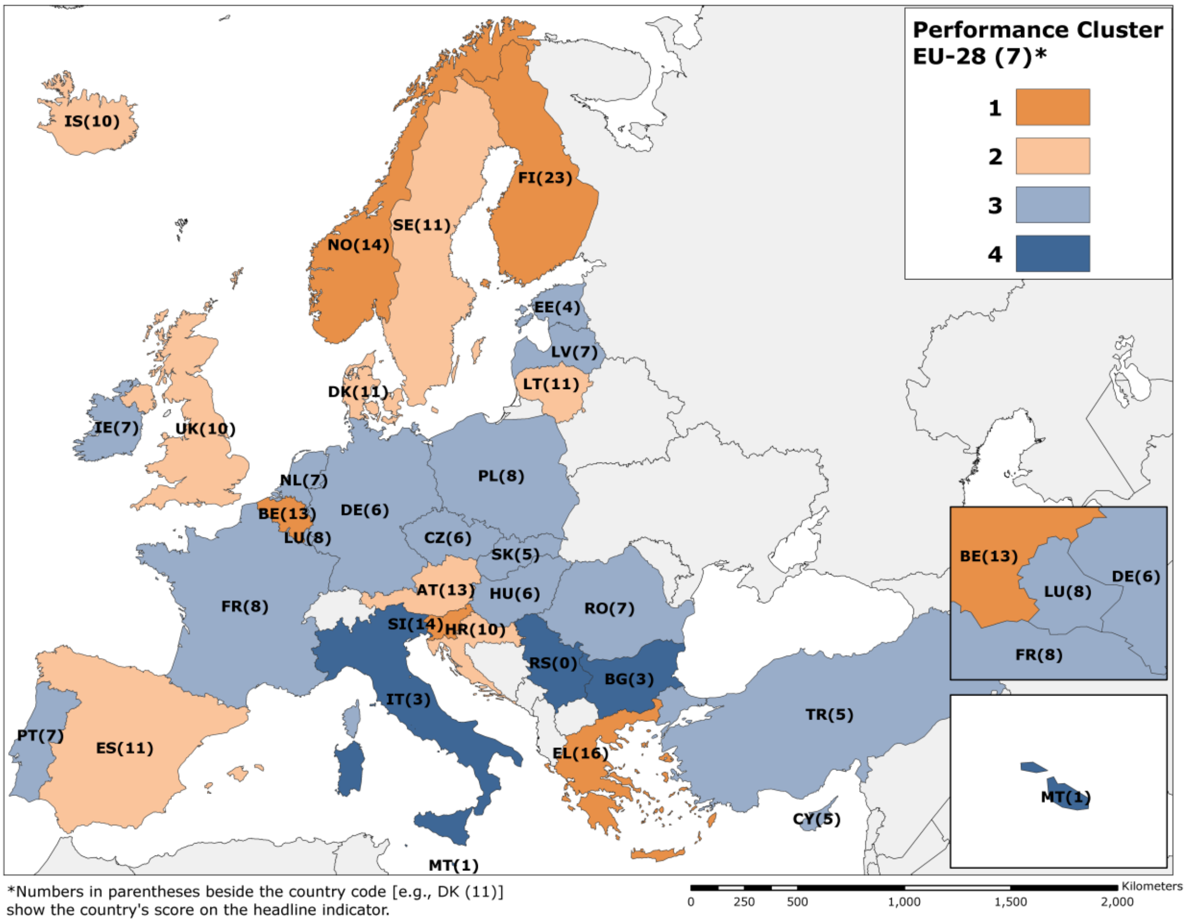

Figure 5 Map of the share of product or process innovative firms (in %) cooperating with public or private research institutions (2012)

Note: As per Table 20.

Source: Eurostat data (online data codes: inn_cis6_coop, inn_cis7_coop, inn_cis8_coop, inn_cis6_type, inn_cis7_type, inn_cis8_type)

Table 21 Share of product or process innovative firms cooperating with higher education institutions (2008-2012)

Country	Weight in GDP	Score (2012)	CAGR (2008-12)	Lead/Gap to EU-28 CAGR	Trendline (2008-12)
EU-28		**12.0%**	**1.3%**	**N/A**	
Cluster 1	8.4%	20.7%	2.1%	0.8	
Cluster 2	45.1%	14.7%	0.0%	-1.3	
Cluster 3	33.2%	8.8%	-0.9%	-2.2	
Cluster 4	13.3%	3.8%	-0.9%	-2.1	
Cluster 1					
FI	1.4%	26.2%	-1.5%	-2.8	
SI	0.3%	*22.0%*	:		
AT	2.3%	20.9%	1.7%	0.4	
EL	1.4%	18.6%	:		
LT	0.2%	18.1%	9.3%	8.0	
BE	2.8%	18.1%	-1.2%	-2.5	
Cluster 2					
SE	3.1%	17.1%	4.2%	3.0	
HU	0.7%	17.0%	-2.3%	-3.6	
UK	14.8%	15.9%	:		
DK	1.8%	14.7%	-4.6%	-5.9	
HR	0.3%	14.4%	-0.1%	-1.4	
CZ	1.2%	14.3%	2.3%	1.0	
DE	19.9%	*13.9%*	:		
NO	2.9%	12.8%	0.3%	-1.0	
SK	0.5%	12.6%	0.1%	-1.2	
Cluster 3					
FR	15.0%	11.0%	-2.9%	-4.2	
EE	0.1%	9.9%	8.8%	7.5	
IE	1.3%	*9.8%*	:		
PL	2.8%	9.4%	-3.0%	-4.3	
PT	1.2%	9.3%	1.2%	-0.1	
ES	7.5%	9.2%	11.9%	10.6	
IS	0.1%	*8.4%*	:		
NL	4.7%	*8.3%*	:		
LU	0.3%	7.0%	-12.3%	-13.6	
LV	0.2%	7.0%	-9.8%	-11.1	
TR	:	6.8%	:		
Cluster 4					
IT	11.6%	5.3%	0.2%	-1.1	
CY	0.1%	4.7%	-6.5%	-7.8	
BG	0.3%	4.4%	-1.7%	-3.0	
RO	1.0%	4.3%	-4.0%	-5.3	
MT	0.1%	4.1%	7.6%	6.4	
RS	0.2%	*0.0%*	:		

Note: Provisional: 2008 (EU-28, DK)
Eurostat country flags have been retained in the EU-28 aggregate
Missing countries in EU-28 aggregate: Growth (DE, IE, NL, SI)
Exception to reference year: 2010 (DE, IE, NL, SI, IS)
Data unavailable: CH, ME, MK, AL, BA, IL, FO, MD, UA
(:) = missing data

Source: Computed by Science-Metrix using Eurostat data (online data codes: inn_cis6_coop, inn_cis7_coop, inn_cis8_coop, inn_cis6_type, inn_cis7_type, inn_cis8_type)

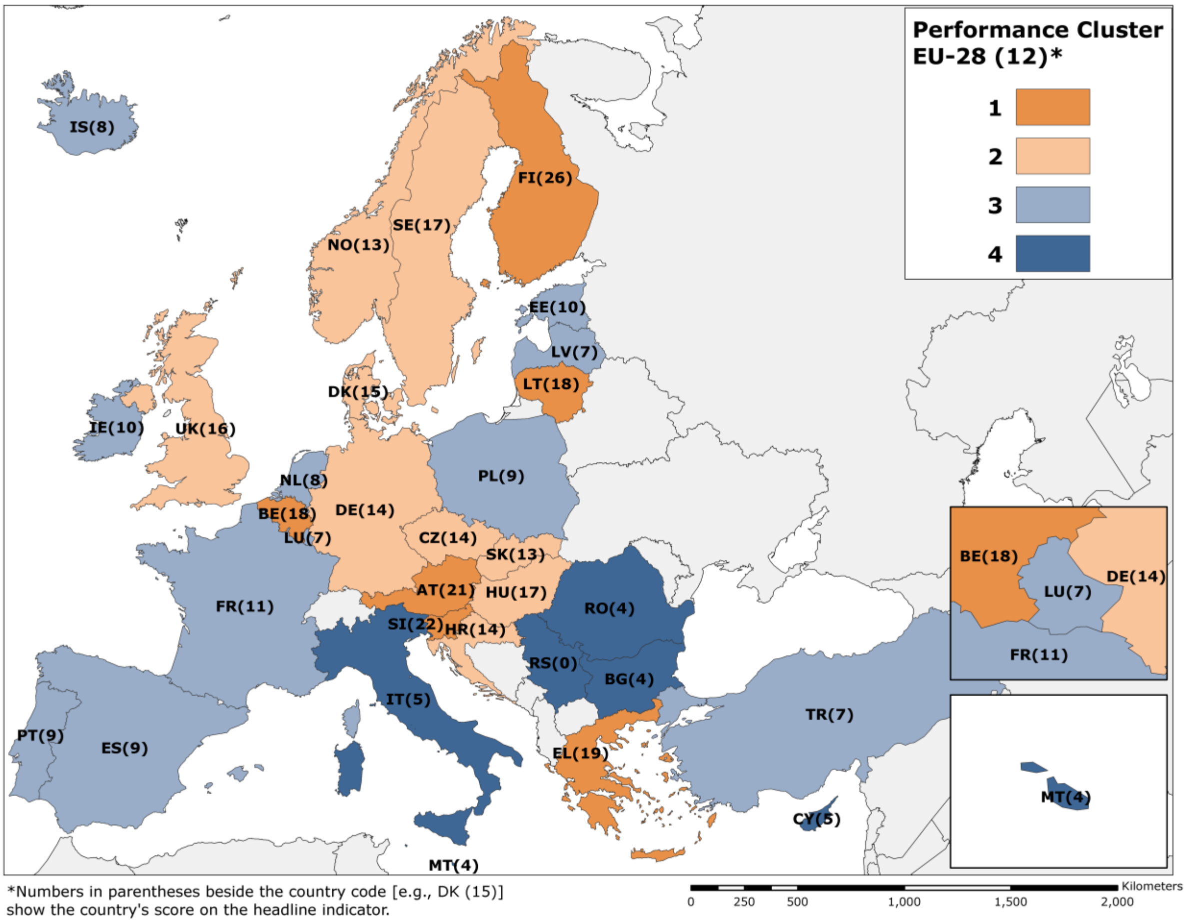

Figure 6 Map of the share of product or process innovative firms (in %) cooperating with higher education institutions (2012)

Note: As per Table 21.

Source: Eurostat data (online data codes: inn_cis6_coop, inn_cis7_coop, inn_cis8_coop, inn_cis6_type, inn_cis7_type, inn_cis8_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 private sector support, 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 the 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. Innovation vouchers are also starting to spread throughout the region. In addition, some countries already have in place dedicated funding agencies 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) — for example, 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 what share of publicly conducted research is actually financed by the private sector as a proxy for the extent of public-private cooperation in support of the promotion of open innovation and knowledge transfer between the public and private sectors.

In Europe, the private sector employs relatively few researchers. Young graduates have little experience outside academic circles and often lack the skills to pursue a career in the private sector (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. Note that 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 22.

The leaders on this indicator are Belgium, Lithuania, Latvia, Romania, the Netherlands and Germany, each with at least 12 % of publicly conducted R&D funded by private sector investments. Below the 3 % threshold, one finds Italy, Luxembourg, Portugal, Malta and Cyprus. In terms of distribution of countries, Cluster 3, which sits just below the ERA average, is slightly larger than expected (41 % of countries against an expected 34 % under a normal distribution of the scores), while Cluster 2, which sits just above the ERA average, is slightly smaller than expected (25 % against the expected 34 %). The top and least performing clusters (1 and 4) are of a size near expectations (19 % for the former and 16 % for the latter; each are expected to cover 16 % of countries under normality of the scores).

As for the Headline indicator, there is no correlation between performance and growth, meaning that there is no gap opening up between the leaders and the rest. Portugal has shown impressive growth over the 2009-2013 period, as have Luxembourg and Romania (while noting that Luxembourg's growth is calculated over the 2010-2013 period due to a lack of data for 2009). Also note that in more recent years, a decline is observed for both Luxembourg and Romania. Some notable declines are registered for Cyprus, which also turned in the weakest performance in the reference year, and for Slovakia.

Performance shows no correlation with GDP. Cluster 1 covers 19 % of countries and accounts for about 29 % of ERA GDP, Cluster 2 covers 25 % of countries and about 3 % of GDP, Cluster 3 covers 41 % of countries and over 50 % of GDP, and Cluster 4 covers 16 % of countries and 13 % of GDP. With the exception of Germany, which ranks in the top cluster, the four largest economies all fall below the ERA average performance (the UK and France are in Cluster 3, while Italy is in Cluster 4).

Number of public–private co-publications per million population

The second complementary EMM indicator for Sub-priority 5a is the number of public–private cooperative publications (or co-publications) produced per million population ([36]). It serves as a proxy to measure whether or not, and to which extent, public-private partnerships in R&I lead to fruitful outputs. However, note that it only captures one form of knowledge transfer; for example, it does not capture knowledge transfer leading to co-patenting. Also, 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 23.

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[36] Public–private co-publications are scientific papers that were co-authored by at least one author from each of those two sectors.

The strongest performances along this dimension are from Switzerland, Iceland, Denmark and Sweden, each of which published more than 100 public–private co-publications per million population in 2014. Scores on this indicator are positively skewed, with only 37 % of countries above the ERA average (i.e. in Clusters 1 and 2). Due to this asymmetric distribution, whereby few countries stand out above the ERA average, there are no countries more than one standard deviation below that average. Hence, there is no Cluster 4. The bulk of countries (63 %) are in Cluster 3, which can be viewed as a merge of the two least performing clusters (see Footnote 5 for details on the clustering method). Four countries produced fewer than one public–private co-publications per million inhabitants: FYR Macedonia, Latvia, Montenegro and Albania.

Performance and growth are weakly correlated in this instance (Pearson r of 0.30), meaning that countries in the leading groups are more often gaining ground than those in the bottom cluster. Looking at the colouration of the table, one notices that the very extreme changes have only come from the notable compound annual increase of the Republic of Moldova, of 9 %, and the notable decrease from Latvia, which registered almost no public–private co-publications in 2014, and therefore shows a decrease of almost 100 %. A large number of small countries (Estonia, Lithuania, Malta, Croatia and Romania) also show a consistent decline of at least 10 % year-on-year. Recall that countries with a small share of large firms can be disadvantaged on this indicator. Beyond these cases, changes over the 2008-2014 period have been much less pronounced, though the tendency for the EU-28 as a whole is towards a very slight decline in public–private partnerships, especially since 2011.

Looking at size of economy, one once again notices little correlation between GDP and scores on this complementary EMM indicator. Nevertheless, most of the largest economies fall in the top two clusters; for instance, Cluster 2 covers more of the ERA GDP (60 %) than would be expected based on the share of countries it includes (26 %). Three of the four largest economies in the ERA (i.e. Germany, the UK and France) fall in Cluster 2, above the ERA average. The remaining large economy, Italy, falls in the top of Cluster 3. Cluster 1 covers 11 % of countries and about 8 % of ERA GDP and Cluster 3 covers 63 % of countries and 29 % of GDP.

Comparing Headlines to complementary EMM indicators

Within Sub-priority 5a, there are some notable correlations among the Headline and complementary EMM indicators. Performance on the two components of the Headline indicator is strongly correlated (Pearson r around 0.80), which is perhaps unsurprising, although valuable to support with quantitative evidence: countries in which product or process innovative firms tend to collaborate most with public/private research institutions are predominantly the same countries in which such firms collaborate most with the higher education sector. When looking at growth, the correlation still holds, although it is considerably weaker (Pearson r of 0.34). Countries in which the rate of private–public collaboration is increasing are more likely to be the same countries in which private–higher education collaboration is also increasing, but only marginally more likely.

Let us turn now to examining the Headline indicators in relation to the complementary EMM indicators, starting with the first component of the Headline indicator. The share of innovative firms cooperating with public/private research institutes has a positive but weak correlation with the share of publicly conducted R&D that is financed by the private sector (Pearson r of 0.23), and a moderate but notable correlation (Pearson r of 0.33) with public–private co-publications per million inhabitants. Turning to the second Headline component, its correlations with the complementary EMM indicators are nearly identical: there is only a very tenuous connection with private funding for publicly conducted R&D (Pearson r of 0.19), and a moderate but notable connection to the number of public–private co-publications per million inhabitants (Pearson of 0.41).

Despite these 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.

Looking at the overall situation in Sub-priority 5a, about 7 % of product or process innovative firms collaborate with research institute partners, and 12 % do so with partners in the higher education sector at the EU-28 level; both of these shares are showing a gradual increase although it is quite small for the latter one. The private sector also contributes about 8 % of the funding for publicly conducted R&D, a figure that has been relatively stable in recent years. Performance has also remained relatively steady in the number of public–private co-publications produced per million population (34 % in 2014), although it has been declining for the EU-28 since 2011.

Table 22 Share of public research financed by the private sector (2009-2013)

Country	Weight in GDP	Score (2013)	CAGR (2009-13)	Lead/Gap to EU-28 CAGR	Trendline (2009-13)
EU-28		**8.1%**	**0.9%**	**N/A**	
Cluster 1	29.1%	14.5%	1.7%	0.8	
Cluster 2	3.4%	9.4%	-3.7%	-4.7	
Cluster 3	54.4%	5.4%	-2.3%	-3.2	
Cluster 4	13.2%	1.8%	-1.5%	-2.4	
Cluster 1					
BE	2.8%	18.6%	0.3%	-0.7	
LT	0.2%	16.4%	-0.5%	-1.4	
LV	0.2%	14.0%	:		
RO	1.0%	13.0%	7.8%	6.9	
NL	4.7%	12.5%	:		
DE	20.2%	12.3%	0.2%	-0.8	
Cluster 2					
TR	:	11.6%	-3.6%	-4.5	
SI	0.3%	10.2%	-2.7%	-3.6	
HU	0.7%	10.2%	-8.9%	-9.8	
RS	0.2%	9.6%	:		
HR	0.3%	9.5%	2.3%	1.4	
FI	1.5%	8.2%	-5.8%	-6.7	
IS	0.1%	7.9%	:		
BG	0.3%	7.7%	:		
Cluster 3					
UK	14.6%	7.4%	:		
ES	7.4%	6.7%	-4.5%	-5.5	
CZ	1.1%	6.7%	3.3%	2.3	
NO	2.8%	6.4%	-1.0%	-2.0	
AT	2.3%	6.0%	-0.6%	-1.5	
EL	1.3%	5.7%	:		
FR	15.1%	5.6%	5.2%	4.3	
EE	0.1%	5.0%	5.7%	4.8	
SK	0.5%	5.0%	-14.9%	-15.9	
SE	3.1%	4.5%	-4.6%	-5.6	
PL	2.8%	4.4%	*-5.3%*	-6.2	
DK	1.8%	3.8%	-5.2%	-6.1	
IE	1.3%	3.2%	-3.3%	-4.2	
Cluster 4					
IT	11.5%	2.7%	0.3%	-0.6	
LU	0.3%	2.3%	*8.9%*	8.0	
PT	1.2%	2.0%	14.0%	13.1	
MT	0.1%	1.1%	-9.2%	-10.1	
CY	0.1%	0.7%	-21.4%	-22.4	

Note: Break in time series: EU-28 (2010, 2011, 2012, 2013); BE (2012); EL (2011); FR (2010); PT (2013); RO (2011); SI (2011); IS (2013)
Definition differs: EU-28 (2009, 2010, 2011, 2012, 2013); HR (2012, 2013); HU (2009, 2010, 2011, 2012, 2013); PL (2009, 2010); SK (2009, 2010, 2011, 2012, 2013); UK (2011, 2012, 2013)
Estimated: EU-28 (2009, 2011, 2013); IE (2009, 2011, 2013); SE (2013)
Eurostat country flags have been retained in the EU-28 aggregate
Missing countries in EU-28 aggregate: DE, NL
Exception to reference year: BG (2012); PL (2012); RS (2011)
Exception to reference period: PL (2009-2012), LU (2010-2013)
Data unavailable: DE, NL, CH, ME, MK, AL, BA, IL, FO, MD, UA
(:) = missing data
The portions of R&D expenditures from the government and the higher education sectors financed by the foreign

business sector are missing for Germany, so they are not taken into account in the computation of the indicator. This may result in a slight underestimation in the score.
The portion of R&D expenditures from the higher education sectors financed by the foreign business sector is missing for the Netherlands. Moreover, the portion of R&D expenditures from the government sector financed by the foreign business sector for the Netherlands is only available for 2011-2013.

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

Table 23 Number of public–private co-publications per million population (2008-2014)

Country	Weight in GDP	Score (2014)	CAGR (2008-14)	Lead/Gap to EU-28 CAGR	Trendline (2008-14)
EU-28		**33.9**	**-0.1%**	**N/A**	
Cluster 1	8.3%	164.0	1.5%	1.7	
Cluster 2	62.8%	58.3	-0.2%	-0.1	
Cluster 3	29.0%	7.4	-7.6%	-7.4	
Cluster 4	N/A	N/A	N/A	N/A	
Cluster 1					
CH	3.5%	217.6	3.0%	3.1	
IS	0.1%	187.3	1.2%	1.3	
DK	1.7%	143.5	2.7%	2.8	
SE	2.9%	107.8	-0.7%	-0.6	
Cluster 2					
NL	4.4%	85.6	-0.1%	0.1	
FI	1.4%	69.9	-4.5%	-4.3	
BE	2.7%	68.5	-0.1%	0.0	
SI	0.2%	66.0	2.1%	2.2	
AT	2.2%	59.0	2.7%	2.9	
DE	19.5%	53.0	1.6%	1.8	
NO	2.5%	50.9	-4.9%	-4.8	
UK	15.1%	50.2	-1.0%	-0.9	
LU	0.3%	40.0	0.3%	0.4	
FR	14.3%	39.6	1.4%	1.5	
Cluster 3					
IE	1.3%	34.3	4.6%	4.7	
HU	0.7%	23.2	1.5%	1.6	
IT	10.8%	18.0	-3.1%	-3.0	
ES	7.0%	16.3	-0.2%	-0.1	
CZ	1.0%	13.8	-8.2%	-8.0	
HR	0.3%	10.6	-10.8%	-10.7	
EL	1.2%	9.9	-3.9%	-3.8	
SK	0.5%	8.1	-4.6%	-4.5	
PT	1.2%	7.1	-3.2%	-3.1	
CY	0.1%	7.0	1.4%	1.5	
EE	0.1%	6.8	-17.9%	-17.8	
RS	0.2%	6.2	1.7%	1.8	
PL	2.8%	3.7	3.4%	3.5	
RO	1.0%	2.6	-10.7%	-10.6	
MT	0.1%	2.4	*-13.5%*	-13.4	
BG	0.3%	2.1	-4.9%	-4.7	
LT	0.2%	1.7	-16.4%	-16.3	
TR	:	1.4	-4.2%	-4.1	
MD	:	1.4	9.0%	9.1	
BA	:	1.0	-8.9%	-8.7	
MK	0.1%	0.5	:		
LV	0.2%	0.0	-70.0%	-69.9	
ME	0.0%	0.0	:		
AL	:	0.0	:		

Note: Data unavailable: IL, FO, UA
(:) = missing data
Source: Computed by CWTS using WoS data (Thomson Reuters), Eurostat data and World Bank data

3.5.4 Additional policy highlights 5a

Industry-academia interactions: KT centres, TTOs, incubators: The literature review identified a large variety of organisations, including but not limited to RPOs, that promote knowledge transfer and uptake of scientific findings. According to a recent study, however, technology and innovation centres play a very important role in this process; there are nearly 200 such centres across Europe, 'including the German Fraunhofer Institutes, the French Carnot centres, the TNO centres in the Netherlands, the Finnish Technical Research Centre (VTT) and SHOK-TEKES centres, the Danish Advanced Technology Group GTS centres, the Norwegian SINTEF centre, [and] the Spanish Tecnalia centres', as well as the Catapult centres in the UK (Debackere et al., 2014, p.27). These organisations have a long tradition of matching industry needs with research activities, and in supporting the commercialisation of research. Interview data uncovered some interesting catch-up trends in Eastern Europe, despite the still low demand from local industries. Some examples include the Directorate for Innovation in Hungary, or the Open Desk Approach in Estonia. Enterprise Estonia has been developed to support the extension of innovation policy measures, as well as the collective implementation of unified rules on intellectual property in universities. Additionally, Structural Funds for R&I were used to support the TTO and KT centres in many Eastern European Member States (Srholec and Szkuta, 2016; Klincewicz and Szkuta, 2016; Udovič, Bučar, & Hristov, 2016; Baláž & Zifciakova, 2016). Regarding technology transfer offices (TTOs), LERU has expressed that 'the TTO Circle of the Joint Research Centre, a network of leading [TTOs], is … [a] potentially valuable vehicle and partnership to boost innovation' (Maes & Deketelaere, 2014, p.37). According to interview data, the effectiveness, efficiency and sustainability of these initiatives still need to be assessed.

Looking specifically at small and medium-sized enterprises (SMEs), a number of dedicated initiatives exist for the purpose of stimulating and supporting their partnerships with the academic sector, with the ultimate goal of ensuring that SMEs are in a position to reap the rewards of innovation. Some such initiatives include:

- 'PathogenCombat (EU) that provided useful contacts, up-to-date information and forums for interactions to SMEs;
- the Competitiveness and Innovation Framework Programme (EU) that supports SME innovation and provides financial and business support services;
- the Accelerator model (UK) where large firms act as intermediaries between universities and SMEs;
- Mini-KTPs (UK) where funding and other support are provided to SME–university collaborative projects' (Debackere et al, 2014, p.54)

The interview data suggested improving integration between the public and private sector by enhancing consistency in funding, starting from fundamental research and continuing all the way through the innovation chain. Currently, different funding channels operate depending on the stage of the research, while the access to the appropriate information is often not straightforward, especially for small institutions. In addition, the ERA design could expand its current focus on public sector actors to further include private or semi-private structures, such as those characteristic of RTOs. So far, the current monitoring approaches insufficiently capture RTOs' contribution to the European research landscape.

Building collaboration through training and career development: Some initiatives have been put in place in ERA countries with the goal of helping researchers — particularly those at the early stages of their careers — to learn about and gain experience with interactions involving research activities between the public and private sectors. For instance, Vitae is an organisation dedicated to professional development in research careers in the UK. It offers support for RPOs to develop researchers' exposure to non-academic environments through courses, placements, events and alumni meetings to change academics' perception about the intellectual challenges of working in other sectors, as well as academics' recognition of experience acquired outside of academia. In Germany, universities of applied sciences require applicants to have at least three years' experience in the private sector to be eligible for a professor position. Poland has put in place a programme to send 500 junior researchers to the US to receive training in commercialisation of research results, knowledge transfer and patenting in order to implement a major cultural change in the country. The UK, France and Denmark have a long-standing tradition of industrial PhDs, (see Hristov, Slavcheva, Jonkers & Szkuta, 2016, for further discussion on intersectoral mobility policies). Interviewees from Spain and Norway also mentioned that industrial PhD programmes have been developed in their countries. The Demola Finish project offers opportunities for students to undertake their final year project with a local company that commits to buying the most promising ideas or prototypes developed at project end ([37]). Norway also has in place a Public Sector PhD scheme (OFFPHD), in which PhD candidates spend some time in a public professional setting ([38]).

Dedicated events for industry-academia interactions are avenues being explored to bring together researchers and industry, and to facilitate knowledge transfer. For instance, in Finland, key account managers from various industry sectors act as a bridge between universities and businesses, by organising meetings to exchange information. The University of Delft (Netherlands) is organising research exhibitions where researchers present their findings and results to companies. Idea labs allow researchers and business stakeholders to meet for four to five days to workshop a research-based solution to a given problem and obtain joint funding together in order to develop this solution.

Regional development / smart specialisations: According to interview data, there are opportunities to tighten the connection between the ERA's focus on research that addresses grand challenges, the regional development dimension, and the benefits that research can bring to local challenges. The literature review revealed an international consortium of six universities, based in Germany, France, Belgium and Luxembourg, that work to facilitate 'greater specialisation, sharing of courses and improved knowledge transfer to businesses' (European Commission, 2014a, p.9).

The 'triple helix' approach aims to develop partnerships between regional government, universities/research institutes and local business communities to work together to share knowledge and develop strategies that will be jointly implemented ([39]). This approach can be found, for example, in Cardiff University, which has designed the project Innovation Campus to link the university to the city, or in the collaboration between the UK Government and the University of Cambridge to 'invest in growing the region's technology cluster' (European Commission, 2014a, p.9). Similarly, 18 EU regions in Spain, Austria, Germany, France, Belgium, and other countries, participate in the Vanguard initiative, which aims to 'to jointly implement smart specialisation strategies, mobilising public and private resources in favour of R&I around cluster initiatives for emerging and transforming technologies' (European Commission, 2014a, p.9). Interview participants suggested that there is room to build common ground between regional funds and H2020 funding. The need to build this common ground is supported by the JRC-led, Parliament-funded Stairway to Excellence initiative ([40]). Reinforced awareness of this initiative would probably be of benefit to it.

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

[37] http://www.demola.net/students

[38] http://www.forskningsradet.no/en/Funding/OFFPHD/1253996392808

[39] https://www.triplehelixassociation.org/helice/volume-1-2012/helice-issue-2/creating-knowledge-impact-triple-helix-approach

[40] http://s3platform.jrc.ec.europa.eu/stairway-to-excellence

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 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 publications, which has become an underlying principle in H2020. Furthermore, in H2020 an Open Research Data Pilot was launched and recently extended to cover all thematic areas of H2020, whilst ensuring opt-out possibilities for issues such as IPR concerns, privacy or national security concerns. In addition to this work, since the establishment of the ERA, both the Commission and the Council have issued notices and recommendations on the subject to Member States (ERAC Secretariat, 2016).

The main driver for OA is linked to RFOs' 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 remain implemented in a heterogeneous fashion. In some cases, in addition to financial incentives, RFOs proactively require funded publications to be OA. Interviewees identified such practices in Belgium, Croatia, Cyprus, Finland, Denmark, Germany, Portugal and Switzerland. Some interviewees endorsed the tightening of the financial consequences in cases of non-compliance with this requirement. In a more general approach, the UK has put in place block grants to RPOs to cover the costs of article processing charges (APCs) linked to OA.

The Headline indicator for Sub-priority 5b (Open Access) is the share of a country's publications available in OA as per Peter Suber's definition ([41]) of gratis OA. In addition to the proportion of total OA, the indicator is also produced for two sub-types of OA: gold and green. The former refers to

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

The latter refers 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).

In other words, 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; if the publisher is the one providing access, then the 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. 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. These figures all use the same units, each expressing how many of a country's total publications are available (in total OA, in gold and in green) as a share of their total 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

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

(in this case, the Web of Science [WoS] produced by Thomson Reuters). The numerator is obtained by performing an internet search for all 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 ([42]).

The share of publications available in OA can be provided by the publication year of the papers. However, a 2005 publication might only become available in OA years after its original publication date. This phenomenon, referred to as 'delayed OA', makes it impossible to study the growth in the share of OA publications using a single snapshot (e.g. Spring 2016 in the case of this study) of those papers in the WoS that are available in OA. Although an analysis of the trend in the share of papers available in OA based on their publication year shows a strong increase based on this study's 2016 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. This will only become possible as new snapshots of OA publications become available.

Thus, 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 striking drop in the share of OA papers in the most recent year (i.e. 2015, Figure 7). This drop is particularly pronounced for green OA and appears to be due to short-term delayed OA, which is mostly attributable to embargo periods. These embargoes are a period following publication, after which publishers release the copyright of traditional subscription-based journals, thereby either making their full content directly available to the public, or making the content partially available by allowing researchers to post their papers online on various archives or personal websites. 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.

Finally, note that the proportions of OA papers computed in this study are slightly underestimated since, like any other harvester, the 1science harvester does not capture 100 % of all OA papers. It is estimated that the recall achieved in this monitoring exercise is roughly equal to 75 %; in other words, about a quarter of WoS papers have erroneously been classified as being paywalled (Archambault et al., 2016). Thus, to obtain adjusted proportions, one simply has to multiply the proportions reported in this study by a correction factor (i.e. by 1/0.75 = 1.33); in this study, only the unadjusted figures are provided. Note that the most accurate adjustment might be one that varies across countries. Also note that while this indicator provides a simple yet robust measure of OA to scientific publications by country, it does not capture OA to scientific data. For further details on the methodology, refer to the 2016 ERA Monitoring Handbook and to Archambault and colleagues (2016).

[42] The OA index is produced by 1science (http://www.1science.com/).

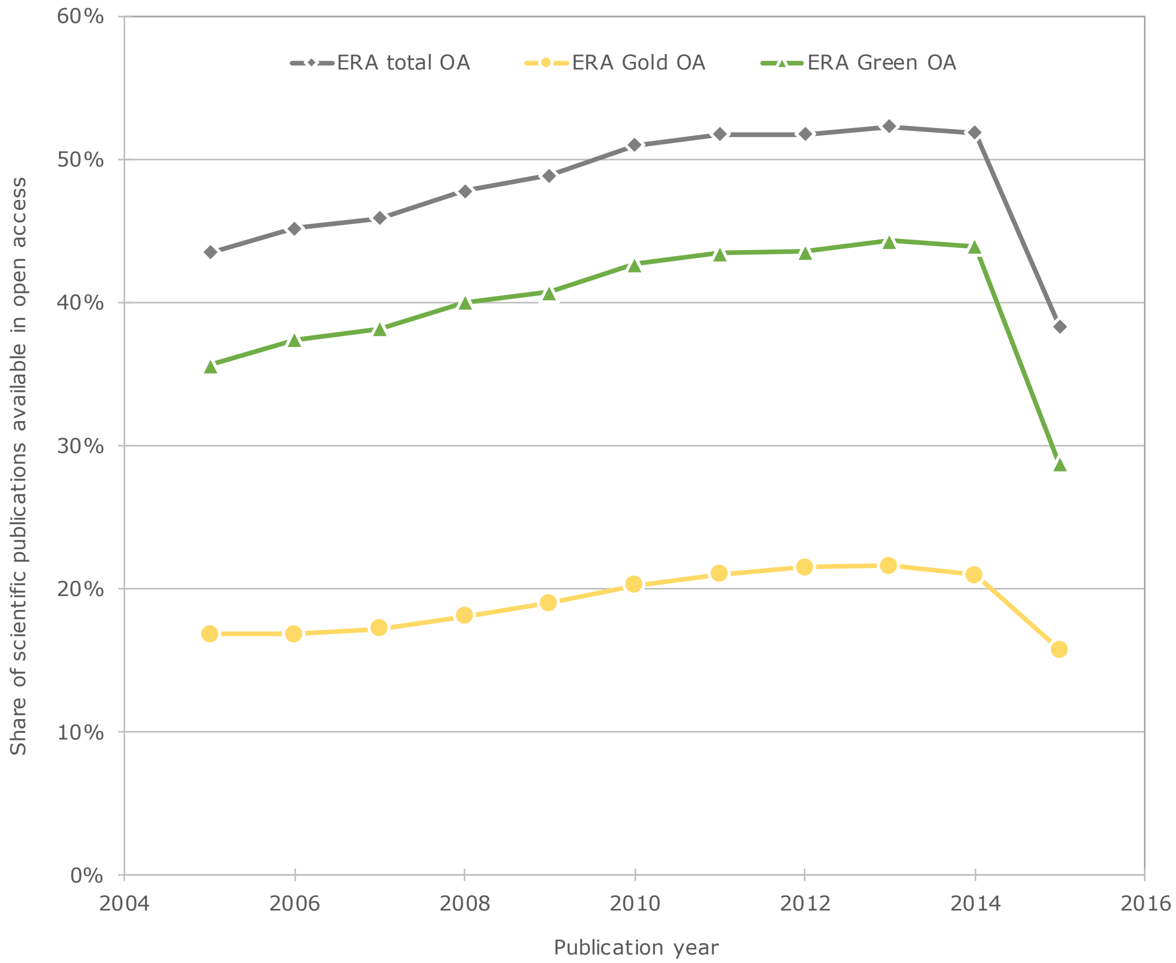

Figure 7 Trends in the share of scientific publications available in open access (total, green and gold) at the ERA-wide level (2005–2015)

Note: The trends are based on the publication year of papers instead of the production year of the data (see above text for explanation). Note that the trends are very similar for the EU-28.

Source: Computed by Science-Metrix using 1science data

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 2014 are presented in Table 24, covering total OA, gold OA and green OA.

It is worth noting that many publications are not available in OA immediately as of the date of publication, but become OA only later after an embargo period (during which the publisher maintains stricter controls on dissemination). Accordingly, while data is available for publication year 2015, these findings are still significantly affected by embargoes (which typically last 6-12 months), and therefore do not reflect the central tendency of research overall to be available in OA.

The leading countries in the share of research available in total OA are Montenegro, Luxembourg, Croatia and Serbia, with each having about 60 % to 65 % of their publications (from 2014) available in OA. The EU-28 average is about 52 %, having passed the 50 % 'tipping point' about two years ago (Archambault et al., 2014) ([43]). The countries with the smallest shares of publications available in OA are Latvia, Germany, the Republic of Moldova, Turkey, Malta, Ukraine and Albania, who all have proportions of 50 % or less.

Gold OA

Gold OA, recall, covers articles that are made available through the publishers. While subsets of total OA may be less relevant from a user's perspective, they can shed a 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, even if it is the product (i.e. the resulting accessibility of research) that is of primary interest to users.

The leading countries according to this measure are Montenegro, Bosnia and Herzegovina, Croatia and Serbia, each of which has more than 30 % of its publications available in gold OA. The lowest proportions, each below the 17 % threshold, are from Latvia, the Republic of Moldova and Ukraine. Scores on this indicator are slightly skewed in their distribution, with more countries than expected (based on the assumption of a normal distribution) sitting just below the ERA average. Performance on this indicator and size of economy show no notable correlation, with large and small economies having roughly equal likelihood to be among top performers for gold OA.

Green OA

Once again, this indicator is primarily of interest in the policy context to understand the underlying mechanisms that contribute to the eventual levels of accessibility to research, whereas the mechanisms themselves may be of relatively little interest to potential users, whose primary interest is the resulting accessibility to research itself.

The leading countries on this indicator are Luxembourg, Portugal, the Netherlands, Iceland, Estonia, Belgium and Hungary, each having over 51 % of their publications available in green OA. The lowest proportions, all below the 40 % threshold, are from the Republic of Moldova, Romania, Bosnia and Herzegovina, Montenegro, Turkey and Albania. Scores for green OA are quite normally distributed, with no notable skews in the distribution. Once again, GDP shows no meaningful correlation with performance, so the chances of strong performance are roughly equal for small and large economies.

Comparing across Headline indicators

Approximately 52 % of EU-28 publications are available in OA (for publication year 2014, as presently measured). Looking at the different avenues to OA, one sees that approximately 45 % of articles are available through the green route, which means third-party sources such as researcher websites, university repositories, and the like. By contrast, only about 21 % of articles are available through gold routes, which means that they are directly made available by the publisher. (Recall that, as an individual article can be made available through more than one site, some articles will be classified as both green and gold, meaning that the two routes cannot simply be added together to determine total OA.)

The conclusion to be drawn here is that green OA is making a substantially greater contribution to overall levels of accessibility than gold OA is. This is a welcome conclusion to discover, as a

[43] Because the EU-28 average is lower than the scores of most individual countries, it is possible that international collaborations may be more likely to be available in OA. As an example, if Italy and Slovenia collaborate on an article and it is published in OA, then this one paper will be counted once in Italy's share and once in Slovenia's, but when aggregating the EU-28 average, this paper will be counted once rather than twice (i.e. once for EU-28 as a whole rather than once each for the two partners). This finding suggests that a potentially interesting line of further study would be to assess the connections between OA and international collaboration.

recent study has demonstrated that articles in green OA tend to have a greater impact on the research community than do articles in gold OA, and articles that are protected behind paywalls (i.e. not in OA at all) make still less impact on the scientific discourse (Archambault et al., 2016). Accordingly, it is reassuring to find that European papers employ green OA routes — the highest impact strategy overall — more often than gold OA routes.

Along a slightly different line, some country-level variation across indicators is interesting to note here. In particular, Montenegro, Bosnia and Herzegovina, and Romania have among the highest proportions of papers available in gold OA (and total OA), but among the lowest in green OA. In fact, Montenegro and Bosnia and Herzegovina are the only two countries to have more papers available in gold OA than green OA.

In general, levels of open access are increasing, as can be seen by comparing levels of OA presented here with previous assessments (Archambault et al., 2014), and this increase can be seen across types of OA: green, gold and total. The number of adopted policies supporting OA data and OA publications has greatly increased since 2010, though the connection between these policies and the increases in OA levels are as yet unclear.

Table 24 Share of publications available in Open Access (2014)

Country	Weight in GDP	Total OA	Gold OA	Green OA
EU-28		**52.2%**	**21.0%**	**44.7%**
Cluster 1	0.9%	61.5%	32.8%	43.6%
Cluster 2	51.0%	57.6%	24.7%	48.4%
Cluster 3	28.4%	53.5%	21.4%	45.1%
Cluster 4	19.8%	47.4%	18.1%	39.2%
Cluster 1				
ME	0.0%	65.1%	43.2%	35.5%
LU	0.3%	61.0%	20.6%	57.2%
HR	0.3%	60.4%	34.6%	41.3%
RS	0.2%	59.7%	32.6%	40.3%
Cluster 2				
HU	0.7%	59.2%	25.8%	51.1%
BA	:	59.2%	37.3%	36.1%
PT	1.2%	59.0%	19.6%	52.4%
BG	0.3%	59.0%	19.2%	50.0%
FO	:	58.7%	:	:
NL	4.4%	58.7%	25.3%	51.8%
MK	0.1%	58.5%	28.5%	45.0%
CH	3.5%	58.0%	25.0%	50.6%
BE	2.7%	57.9%	22.5%	51.3%
EE	0.1%	57.7%	22.5%	51.7%
LT	0.2%	57.6%	24.3%	47.4%
NO	2.5%	57.4%	26.2%	50.0%
SE	2.9%	57.0%	25.6%	50.4%
IS	0.1%	56.4%	21.7%	51.7%
CY	0.1%	56.4%	20.9%	48.3%
UK	15.1%	56.4%	26.7%	48.5%
RO	1.0%	56.0%	29.3%	36.6%
DK	1.7%	55.9%	26.5%	47.2%
FR	14.3%	55.8%	18.0%	50.3%
Cluster 3				
PL	2.8%	55.1%	26.8%	40.6%
IE	1.3%	54.6%	22.0%	48.5%
FI	1.4%	54.1%	22.0%	47.1%
IT	10.8%	53.5%	18.7%	47.3%
IL	:	53.4%	19.7%	46.6%
AT	2.2%	53.3%	23.6%	45.9%
SI	0.2%	53.2%	23.7%	43.0%
SK	0.5%	53.2%	20.6%	42.5%
CZ	1.0%	53.2%	21.2%	43.8%
ES	7.0%	53.0%	19.6%	46.4%
EL	1.2%	52.0%	17.8%	44.6%
Cluster 4				
LV	0.2%	50.0%	16.7%	43.2%
DE	19.5%	49.8%	20.5%	43.0%
MD	:	47.3%	15.4%	39.7%
TR	:	47.2%	19.9%	35.1%
MT	0.1%	46.6%	19.5%	40.3%
UA	:	46.5%	10.8%	41.3%
AL	:	44.6%	23.6%	32.0%

Note: The clusters are based on total OA
(:) = missing data

Source: Computed by Science-Metrix using 1science data

3.5.6 Complementary EMM indicators

The 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 scientific data. 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 National Action Plans (NAPs). For the first two indicators, regarding RFOs and RPOs, no data was available. For the indicator on the presence or absence of a national OA policy or policies in NAPs, a preliminary analysis of NAPs revealed that it would not be feasible to adequately characterise these policies — that is, 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. Additionally, 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. Consequently, this indicator was constructed relying on the identification of national policies on OA in the RIO policy repositories ([44]). Note that by fostering OA to scientific publications and data, such policies can ultimately lead to more efficient science.

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 regional or institutional 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. Also, there is no time series (only 2016 data was available). Full results for the presence or absence of national OA policies in the RIO policy repositories are presented in Table 25.

Data was available for the 28 Member States. Only four countries, Latvia, Malta, Romania and Slovakia, had no OA policies adopted for either research data or scientific publications. Cyprus had no OA policies adopted for scientific publications only, while Hungary and Sweden had no such policies for research data only. Thus, the clear majority of countries have policies in place for both data and publications. This suggests that countries that are taking action on one of these two fronts are usually also taking action on the other. The majority of these policies have been adopted since 2012, although some countries that adopted policies particularly early on have bolstered these early actions with additional complements in recent years.

Unfortunately, and as previously mentioned, the presence of policies on its own can convey nothing about their strength or their scope; accordingly, a given country may have one very comprehensive and expansive policy that has a great impact, while another country takes a more piecemeal approach, and thus has a higher raw number of policies, but not necessarily a more impactful policy mix overall as a result.

[44] https://rio.jrc.ec.europa.eu/

Table 25 Presence or absence of national OA policies in RIO policy repositories (2016)

Country	Weight in GDP (2014)	Natl. OA Policies for research data		Natl. OA Policies for research publications	
		Presence (Yes/No)	Policy adoption years	Presence (Yes/No)	Policy adoption years
BE	2.9%	Yes	Unknown	Yes	Unknown (2); 2007
BG	0.3%	Yes	2013	Yes	2006 ; 2010 ; 2011 (2)
CZ	1.1%	Yes	Unknown (3)	Yes	Unknown; 2010
DK	1.9%	Yes	2012	Yes	2012
DE	20.9%	Yes	2014	Yes	2013
EE	0.1%	Yes	2004 (new 2012); 2013; 2014	Yes	1996; 2002 (new 2012); 2009; 2011
IE	1.4%	Yes	2014	Yes	2012
EL	1.3%	Yes	2013	Yes	2014
ES	7.5%	Yes	2011	Yes	2011
FR	15.3%	Yes	2013	Yes	2013
HR	0.3%	Yes	2015 (2)	Yes	2006 (3)
IT	11.5%	Yes	2013	Yes	2013
CY	0.1%	Yes	2013	*No*	
LV	0.2%	*No*		*No*	
LT	0.3%	Yes	2012	Yes	2012
LU	0.4%	Yes	2013	Yes	2013
HU	0.7%	*No*		Yes	2012
MT	0.1%	*No*		*No*	
NL	4.7%	Yes	2013	Yes	2012
AT	2.4%	Yes	2012 (2)	Yes	2012 (2)
PL	2.9%	Yes	2000; 2014; 2015 (2)	Yes	Unknown; 2000; 2006; 2009; 2010 (3); 2011 (2); 2012; 2014; 2015
PT	1.2%	Yes	2014	Yes	2014
RO	1.1%	*No*		*No*	
SI	0.3%	Yes	2011	Yes	2011
SK	0.5%	*No*		*No*	
FI	1.5%	Yes	2014	Yes	2014
SE	3.1%	*No*		Yes	2010
UK	16.2%	Yes	1967 ; 2013	Yes	2012

Note: Countries are sorted according to protocol order. If more than one policy is present, the year of adoption is specified for each policy. The number in parentheses indicates the number of policies in a given year or the year in which a policy was updated.
Data unavailable: IS, NO, CH, ME, MK, AL, RS, TR, BA, IL, FO, MD, UA

Source: Research and Innovation Observatory (RIO) policy repositories

Comparing Headline to complementary EMM indicators

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 average, and median, share of publications available in OA (total) is slightly larger for countries having national OA policies in place for research publications (average: 52 % with policies and 56 % without policies; median: 53 % and 56 %). Note, however, that the no policy group only includes 5 out of 28 countries. Thus these numbers should be interpreted cautiously.

Clearly, a more in-depth approach to assessing the mix of OA policies must be developed if one is to successfully measure the influence that these policies are having on the eventual levels of OA.

Some approaches for this more in-depth evaluation are currently in development, and preliminary quantitative assessments of their effectiveness are available (Vincent-Lamarre et al., 2016).

3.5.7 Additional policy highlights 5b

Financial issues and negotiation with publishers: The variety of financial incentives made available by RFOs across the ERA raises questions around the global cost of publishing under the OA model, as compared to the more traditional model, as well as on the sharing of costs between the scientific community and the end-users. While the cost mainly relied on the end-users in the former model, OA is transferring a larger burden onto the research teams themselves, or the authors in the case of 'Author pays' OA journals (a widespread option). The most vulnerable are researchers in countries with limited financial resources or performing in less developed R&I systems. A complex process of negotiation is ongoing between RPOs or networks of RPOs (e.g. rectors' conferences) where critical mass has become a major determinant of bargaining power vis-à-vis the publishers. The inclusiveness of the OA model was expressed as a major concern for some interviewees.

Legal aspects: Copyright laws are still heterogeneous across Europe, and while European copyright reform is ongoing, researchers interviewed in the context of this monitoring expressed need for guidance regarding the legal aspects, mainly regarding going the green OA route during the transitional phase. These concerns about copyright infringement resonate with the findings from a survey of EUA members on OA (EUA, 2015).

Implications for the private sector: Interview participants highlighted an issue they viewed as still insufficiently addressed in the move toward OA: open access to the results of research activities that involve partnerships with the private sector, particularly industrial applications, may affect the private sector's competitive advantage. A clear distinction was made between purely academic research projects and projects involving the private sector in terms of the feasibility of OA publishing. Mandatory OA publishing requirements could be a disincentive for the private sector to collaborate with the academic sector. OA may therefore have implications for some other ERA priorities around knowledge transfer and incentives for the private sector to engage in research collaboration, and should be addressed at the European level.

OA awareness and HR resources: Several ERA countries are organising events aimed at educating people and raising awareness about OA at different levels. Seminars are in place in several countries to inform researchers about OA publishing but human resources are needed to support researchers in this transition. For instance, in the Netherlands, workshops are organised to bring together chairs of RFOs, RPOs and publishers to set national targets; in Germany, the Max Planck Digital Library is meant to support researchers and their institutes.

Repositories and e-infrastructures: An intensive investment has already been made in OA infrastructures by individual governments, universities, research institutes, research libraries and funders. According to the literature review, more than 1 000 European repositories are registered in OpenDOAR, with at least one registry from every European country (Science Europe, 2015c). In addition, several countries have developed national OA portals granting access to records from institutional repositories and other more selective, subject-specific and specialised types of content — for example, DART Europe or Europe PubMed Central (Science Europe, 2015c).

EUA confirms some of these trends, indicating that 82 % of its member universities reported having an institutional or shared repository online to provide access to their research, while 79.3 % were using gold or green routes (or both) to make their peer-reviewed articles available in OA (EUA, 2015, p.21). The challenge is that lack of coordination and fragmentation of publicly run repositories and similar initiatives often goes against the goal of facilitating access to research outputs (Science Europe, 2015c).

Interviewees highlighted the need for coordinating access to repositories at the EU level to ensure truly efficient access to research content. The OpenAIRE network and OpenDOAR directory ([45]) aim to fulfil such a need by offering the possibility of searching all the affiliated repositories at the same time.

OA for data: The discussion around OA for publications has progressed to the consideration of the ways to transition to new models for knowledge circulation and dissemination. In contrast, OA for data is a relatively new development to be built with a rationale more grounded on the reproducibility of research results. OA for data involves different technical and legal challenges. Interview data seem to conclude that the willingness to share data is growing but the technical challenges in terms of e-infrastructures and human resources, as well as the required data literacy for the would-be users, remain to be addressed. LERU has identified these challenges as well and has made recommendations to embed data literacy within postgraduate education, so it becomes a core academic competency; workshops dedicated to big data management and the development of virtual access are starting to be developed (LERU, 2014). A recent ERAC Opinion on Open Research Data assessed accessibility of research data, through the lenses of both sharing and reuse, and formulated 11 recommendations as a result. Four categories of recommendations emerged: Training of stakeholders and awareness raising; Data quality and management; Sustainability and funding; and Legal issues (ERAC Secretariat, 2016, p.2).

3.5.8 Composite indicator

The composite indicator developed by Science-Metrix aims to provide a synthetic view of the performance of countries in Priority 5 (Optimal circulation, access to and transfer of scientific knowledge) by integrating the relevant dimensions of sub-priorities 5a and 5b. It covers five indicators: the share of innovative firms cooperating with public/private research institutions, the share of product or process innovative firms cooperating with partners in the higher education sector, the share of private funding provided in support for publicly conducted R&D, the number of public–private co-publications per million population, and the share of a country's publications available in OA (covering both gold and green routes) ([46]). For details on the construction of the composite indicators, refer to Section 2.3.2. Full results are presented in Table 34 (Annex 1).

The strongest countries according to the composite indicator are Switzerland, Belgium, the Netherlands, Croatia and Hungary, which stand out markedly in comparison to the rest of the group. Note, however, that the score of Switzerland is based on only 2 of the 5 indicators included in the composite. The softer performances come from Latvia, Turkey and Malta, which fall more than one standard deviation below the average score for the ERA countries. The distribution is only slightly skewed, with Cluster 2 having more countries than expected, and Cluster 4 having slightly fewer than expectation assuming a normal distribution of the score (see Footnote 5 for details on the clustering method).

There is no correlation between GDP and performance, indicating that size of economy plays no meaningful role in determining outcomes. Cluster 1 covers 15 % of countries and over 12 % of ERA GDP, Cluster 2 covers 42 % countries and almost 30 % of GDP, Cluster 3 covers 33 % of countries and almost 50 % of GDP, and Cluster 4 covers 9 % of countries and accounts for 11 % of GDP. Both Germany and Italy, two of the four largest economies, fall in the bottom half of the table, with the UK and France performing above the ERA average.

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[45] https://www.openaire.eu/supporting-open-science; http://www.opendoar.org

[46] For Priority 5, a differential weighting approach was used to ensure that the sub-priorities 5a and 5b, although they differ in number of indicators, contribute, in as much as is possible, equally to the composite for Priority 5.

Main findings

Sub-priority 5a

1. Knowledge transfer is extremely diverse across Europe. Funding at each link along the chain from the lab bench to the market needs to be more integrated, and the work of research transfer organisations in their mediating role needs to be more effectively measured.
2. Several options were identified for consideration as potential catalysts to develop new intersectoral connections and strengthen existing ones; these include joint industry–academic events, joint industry–RPO calls for applications, and training and career development initiatives integrating doctoral students with private industry. Such initiatives can develop trust between RPOs and the private sector, and valorise non-academic experience among the ranks of graduate students, where each of these items is critical to intensify public–private collaboration and promote intersectoral researcher mobility (linked to Priority 3).
3. Knowledge transfer across various boundaries can create benefits for various communities, although these mechanisms are only poorly understood at present. More effective monitoring of the societal impacts of science (especially beyond just patents), and improved science education and public science literacy, can help to communicate the value derived from R&I investments. Additionally, integrating the natural with the social sciences and the humanities can help to track and address grand societal challenges, as well as more specifically regional topics.

Sub-priority 5b

1. The open access (OA) movement has evolved very rapidly, from a predominantly subscription-based model to articles available in OA passing the 50 % 'tipping point' in recent years. Green OA (i.e. self-archiving) makes a much larger contribution than gold OA (i.e. archiving by the publisher) to overall levels of accessibility, and an increasing number of OA repositories are developing across Europe.
2. The policy landscape for OA is very diverse, sometime implemented at the national level, sometimes at the RFO level, sometimes at the RPO level, and sometimes combinations of two or even all three of these. These policies sometimes take a 'hard', legislative approach, and at other times a softer approach. Ongoing challenges to further progress include the cost of gold OA, diversity of copyright laws across national contexts, opacity of the legal aspects of rights ownership, private-sector worries about sacrificing a competitive advantage if they collaborate with the public or academic sectors (and are therefore required to publish in OA), and researcher concerns about the impact of OA on publication requirements and therefore career progression.
3. Turning from OA to research publications towards OA to research data, one once again finds a great diversity of approaches across national contexts, including the institutional level of policy implementation. Additionally, there are important financial and technical challenges relating to the storage and usable formatting of data made available in OA, as well as low levels of literacy in the wider population of potential users. Private-sector worries about competitive advantage apply here as well.

3.6 Priority 6 – International cooperation

3.6.1 Policy context

The literature stresses the international nature of science; however, two forces pull in opposing directions here, producing an interesting tension. On the one hand, science is growing more globally interconnected as the accelerated expansion of research, notably in countries such as China and Brazil, increases the pool of world-class researchers and research organisations. This enlarged global research community not only has more members, but that membership is also increasing in areas of the world that were previously under-represented (Witze, 2016). Governments are increasingly aware of this international dimension and are developing internationalisation strategies in response.

On the other hand, scientific exploration is growing increasingly specialised, calling for effective divisions of labour to accommodate this degree of specialisation in an efficient manner. Importantly, centres of excellence in a given research area must be interconnected, often across national, cultural and linguistic boundary lines. Thus, while the international dimension urges greater integration, the specialisation dimension urges strategic divisions, while also requiring that these divided clusters retain an appropriate degree of contact, so as not to become disconnected siloes. This tension must be sustained, and appropriately managed to ensure that the appropriate degrees of interconnection do not undermine necessary divisions, or vice versa (Daimer et al., 2015, p.9).

The Strategic Forum for International Scientific & Technological Cooperation (SFIC), in its revised mandate ([47]) in April 2016, has been designated as the ERA-related group for Priority 6 (International S&T cooperation) and has also been made responsible for ERA Roadmap Priority 6 on international cooperation. SFIC aims at developing common principles in international cooperation and to make it easier for third countries (i.e. non-ERA countries) to collaborate with Europe.

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). As scientific publications remain the main channel through which scientific discoveries are disseminated in most scientific fields, they offer a useful source of information to capture the outcome of S&T strategies on international cooperation in a simple and robust manner. Indeed, research partners usually co-author their scientific publications. Using fractional counting, it is thus possible to count the number publications of an ERA country involving at least another co-author from a non-ERA country. The ERAC selected this indicator as the Headline for Priority 6 using the number of researchers in the public sector as a denominator to account 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 are more impactful 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.

There are a number of downsides to this indicator. Firstly, the volume of papers published by individual researchers, as well as the propensity for international cooperation, varies across fields.

[47] Revised mandate for SFIC (Strategic Forum for International S&T Cooperation), as approved by the Council at its 3459th meeting held on 11 April 2016.

Consequently, the specialisation patterns of countries will impact this indicator. For example, a country specialised in mathematics — where researchers publish fewer papers relative to biomedical research — will likely be disadvantaged relative to a country specialised in biomedical research. Similarly, a country specialised in particle physics — where international cooperation is the norm — will likely be advantaged relative to a country 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 former issue (this alternative was used in place of this Headline in the composite indicator for Priority 6; note that data is available for more countries in that case). To account for both of these issues, a more complex measures compensating for differences in the specialisation patterns of countries could be developed in a similar manner as was done for the GDRC indicator (see Section 3.4.3). This indicator can also 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 Headline indicator. Additionally, countries at the periphery of the 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 26 and shown on a map in Figure 8.

The strongest performers on this indicator are Switzerland, Ireland, the Netherlands, Cyprus and Sweden, who lead by a wide margin as the only countries with more than 85 co-publications with partners beyond the ERA, per 1 000 public sector researchers within their own country. Note that Switzerland — because it is 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 Headline figure. Denmark rounds out the leader group, as the only other country with a score over 70. The weakest performers on this indicator, each of whom had fewer than 20 co-publications with non-ERA partners per 1 000 researchers in 2014, were Poland, Serbia, Lithuania, Bulgaria, Slovakia, FYR Macedonia and Latvia.

Performance and growth on this indicator are not correlated with strong growth observed both among the leaders and followers. In fact, the leading group does not generally appear to be pulling further ahead of the pack. Notable increases were observed for Malta, Luxembourg and Portugal ([48]), each of which posted a CAGR of over 10 %, which is well ahead of the EU-28 average of 4.1 %. None of the presented countries had a negative CAGR on this indicator, although the trend column shows a slight decrease for Greece, as well as a stronger decrease for FYR Macedonia in recent years. The global increase in scientific co-publications is in great part accounted for by upcoming scientific powers, such as China, Brazil and India, which are rapidly expanding the number of partnership opportunities for other countries given the rapid growth in the size of their scientific output (Witze, 2016).

Size of economy seems to be a minimal factor in determining outcomes here, as GDP showed only a moderate correlation with the number of co-publications with non-ERA partners per 1 000 researchers in the public sector (Pearson r of 0.32). Clusters 1 and 2 combined include half of the countries assessed, but account for just under 90 % of the ERA GDP. The four largest economies are all found in Cluster 2.

[48] Note that due to a break in time series, the CAGR for Portugal was calculated over the 2008-2014 period, though 2005-2007 data are still presented in the trendline.

Table 26 Co-publications with non-ERA partners per 1 000 researchers in the public sector (2005-2014)

Country	Weight in GDP	Score (2014)	CAGR (2005-14)	Lead/Gap to EU-28 CAGR	Trendline
EU-28		**50.7**	**4.1%**	**N/A**	
Cluster 1	13.1%	85.8	4.8%	0.6	
Cluster 2	75.9%	55.1	6.0%	1.9	
Cluster 3	5.8%	27.4	7.7%	3.5	
Cluster 4	4.2%	11.7	3.2%	-1.0	
Cluster 1					
CH	3.5%	*96.6*	*1.4%*	-2.7	
IE	1.3%	87.5	6.2%	2.1	
NL	4.4%	87.1	5.4%	1.2	
CY	0.1%	86.5	8.4%	4.2	
SE	2.9%	85.1	3.8%	-0.4	
DK	1.7%	72.2	3.5%	-0.6	
Cluster 2					
BE	2.7%	62.8	3.0%	-1.1	
UK	15.1%	62.8	5.7%	1.6	
IS	0.1%	62.2	9.9%	5.8	
FR	14.3%	59.7	4.2%	0.0	
AT	2.2%	57.7	2.9%	-1.2	
NO	2.5%	55.3	6.0%	1.9	
IT	10.8%	51.4	2.9%	-1.3	
FI	1.4%	50.5	8.9%	4.8	
DE	19.5%	49.6	0.0%	-4.2	
ES	7.0%	48.7	9.1%	5.0	
LU	0.3%	44.7	13.8%	9.7	
Cluster 3					
SI	0.2%	37.2	5.3%	1.2	
CZ	1.0%	34.3	6.3%	2.2	
HU	0.7%	33.2	3.0%	-1.2	
PT	1.2%	32.2	11.1%	6.9	
MT	0.1%	28.4	16.4%	12.2	
ME	0.0%	27.0	:		
EE	0.1%	24.6	8.4%	4.3	
TR	:	21.4	3.8%	-0.3	
EL	1.2%	21.2	:		
RO	1.0%	20.9	8.6%	4.5	
HR	0.3%	*20.8*	6.3%	2.1	
Cluster 4					
PL	2.8%	16.8	3.0%	-1.1	
RS	0.2%	16.3	*4.6%*	0.5	
LT	0.2%	10.6	7.7%	3.5	
BG	0.3%	10.5	1.4%	-2.7	
SK	0.5%	10.5	1.6%	-2.5	
MK	0.1%	9.2	2.4%	-1.7	
LV	0.2%	8.1	1.6%	-2.6	

Note: Break in time series: BE (2012); 2005 (CZ, IT, UK); 2007 (DK, NO); DE (2006); 2011 (EL, RO, SI, FI); FR (2010); PT (2005-2008, 2013); SE (2005, 2007, 2011, 2013); IS (2011, 2013); RS (2014)
Definition differs: FR (2005-2009); HR (2012-2014); NL (2005-2014); SK (2005-2014); SE (2005-2007); NO (2005-2009); CH (2006, 2008, 2010, 2012)
Estimated: EU-28 (2008-2010); 2014 (BE, DK, DE); IE (2007, 2014); EL (2006, 2007); LU (2007, 2014); AT (2005, 2008, 2010, 2012, 2014); SE (2005-2014); UK (2005-2008, 2014)
Provisional: 2014 (EU-28, BE, CZ, DK, DE, FR, IT, CY, LV, LU, MT, NL, AT, PT, SI, UK)
Eurostat estimate: PT (2005)
Exception to reference period: CH (2006-2012); RS (2008-2014)
Data unavailable: AL, BA, IL, FO, MD, UA
(:) = missing data

Source: Computed by Science-Metrix using WoS data (Thomson Reuters) and Eurostat data (online data code: rd_p_persocc)

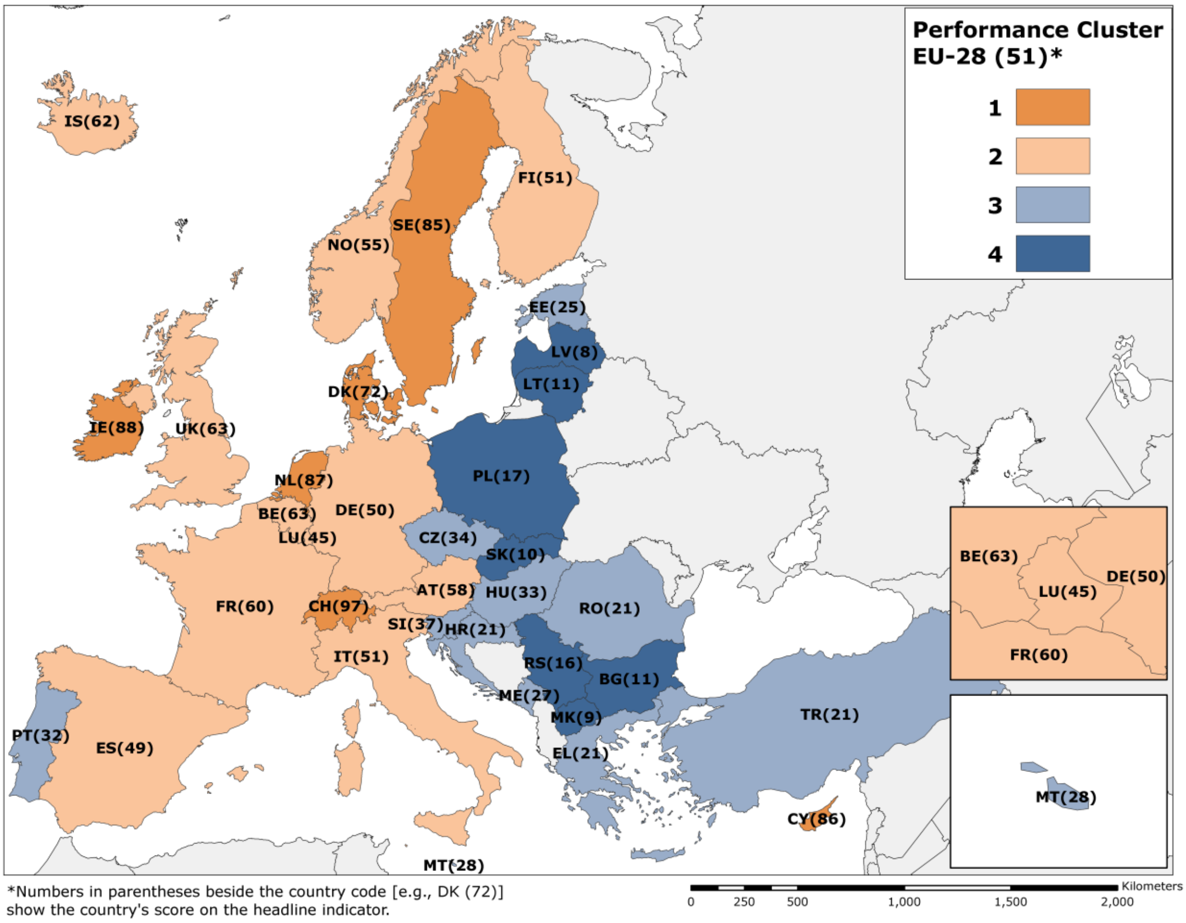

Figure 8 Co-publications with non-ERA partners per 1 000 researchers in the public sector (2014)

Note: As per Table 26.
Source: Computed by Science-Metrix using WoS data (Thomson Reuters) and Eurostat data (online data code: rd_p_persocc)

3.6.3 Complementary EMM indicators

The two complementary EMM indicators identified by the ERAC to track progress towards achieving the ERA on Priority 6 are the number of non-EU doctorate students as a share of all doctorate students, and the licence and patent revenue from abroad as a share of GDP.

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

By attracting outstanding researchers from international locations, the ERA will improve its capacity to address grand challenges and increase its competitiveness. Enrolling international students represents the first step toward this goal. However, approaches to increasing international collaboration vary from MS to MS and are uncoordinated. As such, it is 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 the ERAC for Priority 6 shows the percentage of a country’s doctoral students who come from a country outside the EU. One limiting factor here is that due to the lack of suitable data the indicator does not only focus on students from third countries; it also covers students coming from Associated Countries within the ERA. 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 27.

The strongest performers along this indicator are Switzerland, France, Norway and the UK, countries in which more than 30 % of doctoral students hail from outside the EU. Switzerland is especially strong, as the only country above the 50 % threshold, whereas no other country is close to 40 %. Again, this is not surprising given the presence of international research organisations in Switzerland (e.g. the CERN). The softer performance, well below the 1 % threshold, comes from Lithuania, the only country in Cluster 4. Scores on this indicator are severely skewed, as a small number of very strong countries pull up the ERA average, leaving a large group of countries with single-digit performances below that average. Cluster 3 includes close to 60 % of countries, whereas one would expect it to contain 34 % assuming a normal distribution of the scores (see Footnote 5). All of the other clusters are smaller than expected as a result.

Performance and growth on this indicator show no meaningful correlation. A strong performer and a weaker performer are equally likely to be showing a positive trend, and there is generally no growing gap between the leader group and the others. Note, however, that the strongest CAGRs are observed in Cluster 3. For instance, standout increases are noted for Latvia, Cyprus and Estonia, each of which posted an annual year-over-year increase of more than 25 % between 2005 and 2012. Note that the high growth for Latvia is attributable to a drastic increase in the last year only. This might be an outlier. As such, this important increase will have to be validated in the coming years once more recent data becomes available. Several countries showed year-over-year decreases on average for this period, with Lithuania showing a CAGR of almost -10 %.

Here again, size of economy showed a moderate correlation with the performance scores on this indicator (Pearson r of 0.41), with larger economies more likely to be the ones posting higher performance scores. Cluster 1 covers 12 % of countries and accounts for more than 35 % of ERA GDP, Cluster 2 covers 26 % of countries and 22 % of GDP, Cluster 3 covers 60 % of countries and only 43 % of GDP, and Cluster 4 includes covers 3 % of countries and less than 1 % of GDP (only one country in this case). Two of the four largest economies (France and the UK) in the ERA are in Cluster 1, with the remaining two sitting atop Cluster 3. Recall the possible role of an historical bias in this regard. For example, both France and the UK, two former colonial powers, might still profit from a larger flow of international students coming from their former colonies.

Licence and patent revenue from abroad as a share of GDP

Patents provide formal protection under the law for original inventions. Owners of patents are therefore entitled to royalties when their inventions are commercially marketed by other parties. As such, patents are a source of revenue originating from funding investments in research and development. The royalties and licences paid by foreign actors indicate that those actors use the technology developed by a European country. This can be seen as a proxy to monitor how much a country makes its technology available to the rest of the world and — indirectly — how open it is to international cooperation. It can also be viewed as a proxy for the strength of European R&I systems. Accordingly, the ERAC selected the share of GDP attributed to licence and patent revenue from abroad as the second complementary EMM indicator for Priority 6.

Note that the following biases can affect this indicator: economic structure bias and bias from taxation differentials. For example, countries with a high share of manufacturing industry tend to have a higher propensity to patent inventions than countries with a lower share of manufacturing. Countries that host the headquarters of large companies tend to have a higher level of patenting that than countries that do not. Countries with a high share of pharma, biotech, ICT, software and electrical machinery companies tend to have more patents than countries without such industries. In turn, such countries could earn proportionately more licence and patent revenues from abroad. Finally, another bias can emerge from differentials in taxation across countries. Full results are presented in Table 28.

The leading countries on this indicator are the Netherlands ([49]), Switzerland and Ireland, who lead the rest of the pack by a wide margin. Note that the economic structure bias might be playing a role here for the Netherlands, and that the differential taxation bias might have been profitable to Ireland. The differential taxation bias might also be at play for Luxembourg who ranks not far behind in Cluster 2. As the ERA average is very low and the standard deviation quite large, there is no Cluster 4 for this indicator (see Footnote 5). There are 13 countries that did not collect any licence or patent revenue from abroad in 2013, the reference year for this indicator; those countries are Bulgaria, Estonia, Greece, Croatia, Cyprus, Latvia, Lithuania, Malta, Portugal, Slovenia, Slovakia, Montenegro and FYR Macedonia.

Performance and growth on this indicator show a moderate correlation (Pearson r of 0.36), with strong performers also slightly more likely to be trending upwards as well, opening the gap between the leaders and the rest of the ERA countries. Ireland is showing prodigious growth, with about a 25 % average annual increase over the 2005-2013 period; again the differential taxation bias might be at play. Other countries growing notably include the Netherlands (see Footnote 49), Germany ([50]) and Italy.

Size of economy does not appear to play a meaningful role in determining outcomes on this indicator. Cluster 1 covers 9 % countries and accounts for 6.5 % of ERA GDP, Cluster 2 covers 24 % of countries and accounts for more than roughly 30 % of GDP, and Cluster 3 covers 67 % of countries and 61 % of GDP. Of the four largest economies in the ERA, only Germany is above the ERA average score for this indicator.

Comparing Headline to complementary EMM indicators

The Headline indicator shows a notable, positive correlation with each of the complementary EMM indicators for Priority 6. A greater number of co-publications with non-ERA partners (per 1 000 researchers) is connected with a larger share of doctoral students from outside the EU (Pearson r of 0.73), and with greater licence and patent revenues from abroad (Pearson r of 0.70).

Given the degree of interdependence between these indicators, it seems more justifiable in the case of Priority 6 to use a single Headline indicator to assess behaviour, whereas some other priorities show a greater independence between their various facets; in such cases, multiple indicators (potentially integrated into a composite, in order to facilitate a comprehensive view) are particularly important to assure that a well-rounded picture of performance is obtained. Additionally, even with correlations as strong as those observed for this priority, 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.

Overall, EU-28 countries publish about 50 papers with non-ERA partners per 1 000 researchers in the public sector, and are increasing that level of output (though scientific research worldwide is growing generally more international, an important piece of context in interpreting these data). This average output with third countries is mostly reflective of the central tendencies across national contexts. By contrast, the share of doctoral students coming from non-EU countries and the share of GDP constituted by patent and licence revenue from abroad are strongly clustered in

[49] The performance score for the Netherlands was for 2012, as the data for 2013 was a clear outlier relative to their previous performance and the direction of its trend. It will be interesting to see whether future updates of this data validate that this outlier is in fact correct, or whether indeed it was an error as seems to be the case.

[50] Germany's performance in 2013, which is used to compute its CAGR, is a statistical outlier, and may ultimately prove to be erroneous. In the case of the Netherlands, the discrepancy was very large between its score and a reasonable expectation based on past performance, leading to the use of 2012 data as an exception to the reference year. In the case of Germany, the discrepancy was smaller, and so its 2013 score was conserved, though once again it will be important to check in future updates of this data to see whether this sudden change is validated or corrected as erroneous.

a small group of countries (though not always the same countries for these two indicators), and therefore the averages are less reflective of the central tendencies across national contexts. In interactions with third countries, a small group of ERA countries leads the way, with the rest of the ERA at some length behind. That distance is closing on some indicators, less so on others.

Table 27 Non-EU doctorate students as a share of all doctorate students (2005-2012)

Country	Weight in GDP	Score (2012)	CAGR (2005-12)	Lead/Gap to EU-28 CAGR	Trendline (2005-12)
EU-28		**25.5%**	**3.5%**	**N/A**	
Cluster 1	35.5%	37.5%	3.4%	-0.1	
Cluster 2	21.6%	20.6%	4.9%	1.4	
Cluster 3	42.7%	4.4%	7.2%	3.7	
Cluster 4	0.2%	0.1%	-9.7%	-13.2	
Cluster 1					
CH	3.5%	50.2%	2.1%	-1.3	
FR	14.3%	35.4%	3.5%	0.0	
NO	2.5%	33.5%	6.3%	2.8	
UK	15.1%	30.8%	1.6%	-1.9	
Cluster 2					
NL	4.4%	24.5%	2.3%	-1.2	
SE	2.9%	24.0%	8.8%	5.3	
IS	0.1%	23.9%	9.5%	6.0	
BE	2.7%	22.0%	2.4%	-1.1	
ES	7.0%	20.4%	4.8%	1.3	
LU	0.3%	20.3%	-0.1%	-3.6	
DK	1.7%	18.4%	6.2%	2.7	
IE	1.3%	18.4%	-2.6%	-6.1	
PT	1.2%	13.7%	13.0%	9.5	
Cluster 3					
DE	19.5%	11.3%	0.1%	-3.4	
IT	10.8%	9.0%	19.1%	15.6	
AT	2.2%	9.0%	3.6%	0.1	
FI	1.4%	7.9%	10.4%	6.9	
RS	0.2%	7.1%	-2.5%	-6.0	
SI	0.3%	6.1%	11.3%	7.8	
EE	0.1%	4.7%	25.8%	22.3	
CZ	1.0%	4.4%	4.3%	0.8	
MK	0.1%	3.9%	2.3%	-1.2	
BG	0.3%	3.1%	-5.6%	-9.1	
HU	0.7%	3.0%	-1.1%	-4.6	
HR	0.3%	2.7%	8.1%	4.7	
MT	0.1%	2.6%	4.7%	1.2	
TR	:	2.5%	-1.9%	-5.4	
CY	0.1%	2.3%	28.1%	24.6	
RO	1.0%	2.0%	-5.1%	-8.6	
PL	2.8%	1.9%	-4.4%	-7.9	
SK	0.5%	1.5%	14.4%	10.9	
LV	0.2%	1.5%	32.0%	28.5	
EL	1.2%	1.0%	0.0%	-3.5	
Cluster 4					
LT	0.2%	0.1%	-9.7%	-13.2	

Note: Data unavailable: ME, AL, BA, IL, FO, MD, UA
(:) = missing data

Source: Eurostat data (online data codes: educ_uoe_mobs02 and educ_uoe_enrt01)

Table 28 Licence and patent revenue from abroad as a share of GDP (2006-2013)

Country	Weight in GDP	Score (2013)	CAGR (2006-13)	Lead/Gap to EU-28 CAGR	Trendline (2006-13)
EU-28		**0.64%**	**9.6%**	**N/A**	
Cluster 1	9.3%	3.01%	18.3%	12.5	
Cluster 2	29.5%	0.96%	9.0%	3.3	
Cluster 3	61.2%	0.08%	-17.6%	-23.4	
Cluster 4	N/A	N/A	N/A	N/A	
Cluster 1					
NL	4.5%	*3.72%*	*17.5%*	7.8	
CH	3.6%	*3.07%*	*8.6%*	-1.0	
IE	1.2%	2.23%	28.8%	19.2	
Cluster 2					
FI	1.4%	1.38%	16.8%	7.2	
LU	0.3%	1.29%	5.3%	-4.3	
SE	3.0%	1.08%	1.7%	-7.9	
IS	0.1%	*0.90%*	:		
HU	0.7%	0.89%	10.6%	1.0	
DE	19.5%	0.77%	18.6%	9.0	
DK	1.8%	0.71%	1.8%	-7.8	
BE	2.7%	0.64%	8.2%	-1.5	
Cluster 3					
UK	14.1%	0.46%	-3.0%	-12.6	
FR	14.6%	0.43%	6.7%	-2.9	
AT	2.2%	0.25%	7.4%	-2.2	
IT	11.1%	0.19%	18.2%	8.5	
CZ	1.1%	0.13%	*17.3%*	7.6	
NO	2.7%	0.08%	-11.7%	-21.3	
RO	1.0%	0.07%	*-13.2%*	-22.8	
ES	7.1%	0.07%	-0.3%	-10.0	
PL	2.7%	0.05%	8.0%	-1.6	
EL	1.2%	0.00%	-100.0%	-109.6	
MT	0.1%	0.00%	-100.0%	-109.6	
PT	1.2%	0.00%	-100.0%	-109.6	
SK	0.5%	0.00%	-100.0%	-109.6	
BG	0.3%	0.00%	0.0%	-9.6	
EE	0.1%	0.00%	0.0%	-9.6	
HR	0.3%	0.00%	0.0%	-9.6	
CY	0.1%	0.00%	0.0%	-9.6	
LV	0.2%	0.00%	0.0%	-9.6	
LT	0.2%	0.00%	0.0%	-9.6	
SI	0.2%	0.00%	0.0%	-9.6	
ME	0.0%	0.00%	:		
MK	0.1%	0.00%	0.0%	-9.6	

Note: Provisional: EU-28 (2011-2013); 2013 (BE, BG, CZ, DK, DE, EE, IE, FR, HR, IT, CY, LV, LT, LU, HU, MT, NL, AT, PL, PT, RO, SI, SK, FI, SE, UK, NO, ME, MK); EL (2011-2013); ES (2012, 2013)
Potential outlier: 2013 (DE, NL)
Eurostat country flags have been retained in the EU-28 aggregate
Exception to reference year: 2012 (NL, IS, CH)
Exception to reference period: 2006-2012 (NL, CH); CZ (2009-2013); RO (2008-2013)
Data unavailable: AL, RS, TR, BA, IL, FO, MD, UA
(:) = missing data

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

3.6.4 Additional policy highlights

International cooperation landscape: Since 2012, the context for international research collaboration has been strengthened by the following, among others:

(1) 'Improving the framework conditions for research and innovation cooperation across the world through policy dialogues with the EU's partners, as well as through the involvement of the EU and Member States in global fora such as the Global Research Council.

(2) The preparation of multi-annual roadmaps for key countries and regions with the involvement of Member States through the Strategic Forum for International Science and Technology Cooperation (SFIC).

(3) The development and testing of methodologies in the context of SFIC to identify common priorities and implement joint actions through a number of geographic initiatives for the USA, China, Brazil and Russia.

(4) Support for policy dialogues and/or joint research and innovation activities between EU/Member States and selected international partner countries and regions have been undertaken through a series of FP7 and Horizon 2020 policy support projects with activities supporting bilateral and bi-regional policy dialogues, networking and twinning events, support to National Contact Points, awareness raising and training' (European Commission & Directorate-General for Research and Innovation, 2015c, p.88).

Progress has been made in the development of common principles conducive to research cooperation at the global level through enhanced involvement of the EU and Member States in global fora such as the Global Research Council (GRC), the Belmont Forum, and the OECD Global Science Forum, among others (European Commission & Directorate-General for Research and Innovation, 2015c). In addition, Horizon 2020 is fully open to participation from international partner countries (European Parliament & Council of the European Union, 2013).

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), Korea (2007), Egypt (2008), New Zealand (2009), Japan, (2011), Jordan (2011), and Algeria (2013). The European Research Council also developed 'implementing arrangements' to increase international scientific exchange offering opportunities for young researchers supported by non-European funding agencies to join a research team funded by ERC. To date, arrangements have been signed with the United States (2012), South Korea (2013), Argentina (2015), Japan (2015), China (2015), South Africa (2015) and Mexico (2015). A large number of specific agreements have also been signed on nuclear research in the same period ([51]).

Bilateral agreements between ERA countries and third countries: Even if an exhaustive presentation of the bilateral agreements between Member States or Associated Countries with third countries is not possible, the interview data reveals a strong concentration of the bilateral agreements with the US, China, Brazil, India, Russia, Japan and South Korea. The eastern countries continue to maintain strong scientific cooperation with former Soviet countries. Several interviewees indicated that using European instruments to convince partners from third countries to collaborate is much more effective than using just national instruments.

Some countries have established innovation centres in third countries as it is the case for Denmark and Germany in the countries cited above. They are used for knowledge transfer as well as developing scientific partnerships and researcher exchange. Some countries in Western Europe also have privileged relationships with former colonies. The most proactive country in terms of international cooperation seems to be Switzerland, with six offices in the BRICS acting as points of contact and promoters of Swiss scientific endeavours, and 20 scientific counsellors stationed in embassies.

[51] The European Union bi-lateral S&T agreements up to June 2016, http://ec.europa.eu/research/iscp/index.cfm?pg=countries.

Researcher mobility: The instruments developed for researchers' mobility at national and European level may generally be useful for collaboration both with other ERA countries and with third countries. For instance, the Mobilitas Pluss programme carried out by the Estonian Research Council since December 2015, and mainly funded by the European Regional Development Fund, is a great enabler for mobility going in and out of Estonia, for collaboration with ERA and non-ERA countries, and for collaboration with the public and private sectors. The Marie Skłodowska-Curie Actions are also great enablers for mobility across the ERA and with third countries.

The Destination Europe programme has been developed to attract talented minds to Europe through promoting the European research environment and opportunities. Since 2012, Destination Europe events have mainly been organised in North America, and have started to open up to South America with a first South American event in Sao Paulo in 2015.

Major challenges for international cooperation: Several challenges were identified in the interviews. For example, there is a lack of financial or human resources dedicated to international cooperation at the national level in some countries. The administrative burden in developing such cooperation, as well as the HR requirements for bringing in researchers from third countries, may be limiting some ERA countries from fully exploring the potential benefits of international cooperation. Finally, understanding the complexity of European programmes for third-country partners and the administrative requirements to be complied with may also be a significant obstacle for countries' participation (in ERA-NETS, for example). Some interviewees also recommended a more bottom-up approach for developing European international cooperation by consulting more extensively with the ERA countries.

No clear evidence has emerged from the qualitative data about a real impact from Horizon 2020 (which had been in place for only 18 months at the time of writing this report) on the increased integration of third countries into the European research landscape.

3.6.5 Composite indicator

The composite indicator developed by Science-Metrix to produce an integrated snapshot of performance across dimensions for Priority 6 covers the following indicators: co-publication rate with non-ERA partners, licence & patent revenue from abroad as a share of GDP, the co-patenting rate with invention partners outside of the ERA, and the share of doctoral students in a given country coming from outside the EU. For details on the construction of the composite indicators, refer to Section 2.3.2. Full results for this composite indicator are presented in Table 35 (Annex 1).

The strongest countries on this composite indicator are Switzerland and Ireland, who have a significant lead on the rest of the countries, followed by the Netherlands, Iceland, the UK and Belgium. The softer performances on this indicator are from Malta, Slovenia, Latvia, Slovakia, Turkey, Croatia and Lithuania.

Size of economy shows only a negligible correlation with performance on the composite indicator (Pearson r of 0.21). In fact, large and small economies are both found among the leading cluster. Cluster 1 covers 18 % of countries and accounts for 27 % of the ERA GDP, while Cluster 2 covers 33 % of countries and 44 % of GDP, Cluster 3 covers 27 % of countries and 27 % of GDP and Cluster 4 covers 21 % of countries and about 1.5 % of GDP. Of the four largest economies in the ERA, the UK is in Cluster 1, France and Germany are in Cluster 2, and Italy is in Cluster 3.

Main findings

1. International cooperation is developing around the pole of addressing shared grand societal challenges, with centres of excellence emerging to tackle specific issues requiring an interdisciplinary approach. Western European countries tend to be leading the way in these collaborations with third countries, with multi-annual roadmaps being designed for various national and regional contexts. These third-country collaborations have an important interface to make with international collaboration within the ERA (Sub-priority 2a).

2. Bilateral and multilateral agreements are developing and in place with many fast-rising nations worldwide, notably Brazil, Russia, India and China (the BRICs). However, a gap is opening between the research leaders of Europe and other ERA countries, as the leaders have moved far ahead in arranging and implementing these international agreements.

3. The ERA is proving to be an attractive market for the talented minds of the world, although the attraction seems to have greater force in drawing these candidates to Western Europe than to the Eastern European countries. The same group of countries leads in co-publications with third-country partners, attraction of PhD students from beyond the EU, and patent revenues from abroad. The research environment, included but not limited to salary considerations, plays an important role in attracting researchers from abroad, while the financial and administrative support required to install and maintain international partnerships is insufficient in many national contexts.

4 OVERALL RESULTS ACROSS PRIORITIES

In order to assess progress of countries towards achieving the ERA, overall across indicators, Science-Metrix computed two additional, experimental composite indicators. The first type of composite — the Headline composite — aims to give a balanced reflection of performance across the eight Headline indicators selected by ERAC as being the most relevant in monitoring progress in achieving the ERA. Thus, the sub-priorities 2a and 2b are represented separately, as are sub-priorities 5a and 5b. The second type of composite — the Meta-composite — aims to provide a comprehensive overview of performance towards achieving each of the six ERA priorities' relevant dimensions by integrating multiple indicators within each priority (sub-priorities are merged within priorities 2 and 5). These quantitative findings can help to offer a comprehensive overview of country-level performance. However, as with all such comprehensive approaches, this integrated assessment conceals important underlying variation, and is made to be used in concert with the detailed results discussed in Section 3, not in place of these detailed results.

4.1 Composite indicator of Headline indicators (Headline composite)

The Headline composite integrates the following indicators ([52]): the Adjusted Research Excellence score, the GBARD allocated to transnational collaboration per researcher in the public sector, the share of ESFRI Landmark projects in which a country participates, the number of EURAXESS job ads posted per 1 000 researchers in the public sector, the share of women amongst Grade A researchers in the higher education sector, the share of private innovative firms cooperating with public/private research institutions as well as the share cooperating with higher education institutions, the share of publications available in open access (including both green and gold), and finally the number of publications co-authored with non-ERA partners per 1 000 researchers in the public sector. The full results are detailed in tables below. As there are so many component indicators integrated into this composite, the total score and the scores for the Headlines for priorities 1 to 3 are shown in Table 36, while the total scores are presented again along with the Headlines for priorities 4 to 6 in Table 37.

The strongest performers on the Headline composite are Sweden, Switzerland, the Netherlands, Belgium, Norway and the UK. The countries lagging the most in this integrated snapshot are Lithuania, Latvia, Slovakia, Serbia and Malta. Scores are quite normally distributed, meaning that the leader group is not exceptionally far ahead of the pack, nor is the least performing group substantially back from the rest of the ERA.

Looking at size of economy, one finds a moderate correlation between performance on the Headline composite and GDP figures (Pearson r of 0.28): larger economies are somewhat more likely to be found among the strongest performers on this indicator, though only marginally so.

[52] The Headline composite integrates nine individual indicators. The selection is meant to give a balanced reflection of performance across the eight Headline indicators (one per priority/sub-priority) selected by ERAC as being the most relevant in monitoring progress in achieving the ERA: each priority/sub-priority is represented with a single indicator, sub-priorities 2a and 2b are represented separately, as are sub-priorities 5a and 5b. As Priority 2 and 5 are each split into two parts, one would expect a total of eight indicators. However, recall that for sub-priority 5a, the desired Headline indicator would measure the share of innovative firms cooperating in research with public/private and higher education sector partners; as consolidated data was not available for these two sectors, the Headline was split into two, one tracking private–public collaboration and the other tracking private–higher education collaboration. Accordingly, both of these Headline indicators have been included here in the Headline composite. Note that the two indicators for sub-priority 5a individually carry less weight than any other indicator in the composite as they are highly correlated; they each received a weight of about 0.5. The other indicators were weighted equally, yet accounting for redundancy in the dataset. Also note that for the Headline indicator for sub-priority 2b (i.e. availability of national roadmaps with identified ESFRI projects and corresponding investment needs) has been substituted with the complementary EMM indicator on ESFRI landmarks since it could not be included in this study's composite (it is a qualitative indicator). ESFRI landmarks were chosen over ESFRI projects since they represent successful ESFRI projects (i.e. operational).

Cluster 1 covers 19 % of countries and accounts for about 30 % of ERA GDP, while Cluster 2 covers 31 % of countries and about 34 % of GDP, Cluster 3 covers 34 % of countries and again about 34 % of GDP, and Cluster 4 covers 16 % of countries and around 1 % of GDP. The notable discrepancy here is that clusters 1 and 4 cover about the same number of countries, but the strongest performing group has a combined GDP about 30 times higher than their counterparts in the least performing group. The leader group’s combined GDP is obviously driven by the huge portion represented by the UK, but even looking beyond this single large economy, Cluster 1 GDP scores are still an order of magnitude (about 10 times) larger than the economies of countries in Cluster 4, reinforcing the interpretation that larger economies do tend to perform somewhat better on this indicator.

4.2 Composite indicator of Priority composites (Meta-composite)

The Meta-composite has been constructed using a bottom-up approach, whereby intermediate priority composites were first constructed to synthesise performance within each priority. Since the number of relevant dimensions, and of available indicators to measure them, varies across priorities, this approach carries two benefits: it provides a synthetic view of progress towards achieving the ERA both within (the intermediate priority composites) and across (the Meta-composite) priorities, and it equalises the contribution of each priority to the Meta-composite. Each priority is represented by a single intermediate composite (i.e. one for 1, 2a&b, 3, 4, 5a&b and 6) in the Meta-composite. These were weighted equally so that each intermediate priority composite contributes equally to the final scores of the Meta-composite indicator ([53]), yet accounts for redundancy in the dataset (see Section 2.3.2 for details on the construction of composite indicators). Altogether, the six intermediate composite indicators cover a total of 27 indicators across priorities (see Table 3). Full results are presented numerically in Table 38.

The leading countries on this indicator are Switzerland, Sweden, Iceland, Belgium, Denmark, the Netherlands, Norway and the UK. The lagging countries are Latvia, Bulgaria, Malta, Slovakia and Turkey. As for the Headline composite, the scores on this indicator roughly follow a normal distribution with slightly less than half of the countries above the ERA average in clusters 1 and 2. However, the distribution of countries that are above the ERA average (for the covered countries) unexpectedly appear to be concentrated in Cluster 1 (i.e. the top performing cluster) instead of Cluster 2. Thus, relatively few of the countries with a lead relative to the EU-28 and ERA average have a small lead.

Looking at size of economy, GDP shows no correlation whatsoever with scores on the Meta-composite indicator, indicating that large and small economies are both found among the strong performers using this measure. Cluster 1 covers 24 % of countries and approximately 35 % of ERA GDP, Cluster 2 covers 18 % of countries and roughly 5 % of GDP, Cluster 3 covers 42 % countries and about 60 % of GDP, while Cluster 4 covers 15 % of countries and 1 % of GDP (noting that GDP figures for Turkey are not available). Of the four largest economies in the ERA, three are below average performance, with only the UK found in Cluster 1.

4.3 Comparing Headline composite to Meta-composite indicators

The Headline composite and the Meta-composite offer two different lenses through which to view performance overall across priorities, so the present section will offer some analysis of the similarities and differences between these two views. While the Headline composite integrates only the indicators identified as the most salient by the ERAC, the Meta-composite integrates a

[53] For Priority 2, a differential weighting approach was used to ensure that the sub-priorities 2a and 2b, although they differ in number of indicators, contribute, in as much as is possible, equally to the intermediate composite for Priority 2. The same applies for the sub-priorities 5a and 5b of Priority 5.

broader evidential base (which includes, where possible, the Headline indicators but also a considerable number of others as well).

The results from the Headline composite and Meta-composite are quite strongly correlated (Pearson r: 0.83 for country scores, 0.84 for ranks, and 0.82 for clusters, data not shown). In fact, looking at these two composite indicators, Belgium, the Netherlands, Sweden, the UK, Norway and Switzerland are clearly among the leader group, figuring among top performers (i.e. in Cluster 1) for both metrics. Another similarity between these two composite indicators is that, in both cases, the gender dimension (Priority 4) is weakly correlated with overall performance; in fact, it is even slightly negative in both cases (Pearson r of -0.30 for the Headline composite and -0.11 for the Meta-composite). Countries leading the way in most other priorities tend to be those who fare less well in progress towards gender parity specifically, while Eastern European countries that have lower scores overall tend to perform well along the gender dimension. Nordic countries seem to have strong scores overall while also showing leadership on the gender front.

That being said, there are some striking differences in the performance of some countries between these two composites. For instance, some countries come out much stronger on the Headline composite than on the Meta-composite, most notably France, Croatia, Italy and the Netherlands. Contrarily, certain countries show a remarkably stronger performance on the Meta-composite than the Headline composite, most notably Serbia and Iceland. Again, such differences highlight the importance of relying on a broad set of indicators to adequately capture all the relevant nuances in the performance of individual countries even if the Headline figures, once aggregated, provide an adequate overview of the whole ERA. Indeed, the Headline composite might overlook important variations on a country-by-country level across some other relevant dimensions that cannot be fully captured solely on the basis of the Headline figures.

4.4 Additional overall policy highlights

Integration of ERA and *Open Innovation, Open Science, Open to the World* (3Os) visions: Overall, interviewees recognised that progress has been made to identify the relevant priorities and to put in place a framework to address them. Nonetheless, they also stressed that there is a long way to go to achieve a satisfactory situation regarding the different priorities and that the necessary reforms to do so would be long term.

Since June 2015, the shift from an ERA-focused to a 3Os-focused vision[54] has caused some confusion among the European research community regarding the Commission's priorities. This confusion is not creating favourable conditions for a greater commitment to the ERA. Many interviewees were left with the impression that the ERA is not a Commission priority anymore and would prefer to see a better integration between the ERA and the 3Os vision instead of a substitution of one for the other.

Additionally, interviewees identified a need for better integrating the European Higher Education Area (EHEA) with the ERA through European policies and funding programmes to strongly link education, research and innovation.

Sharing good practices, reducing fragmentation and catching-up policy: Some efforts have been made in terms of sharing good practices among ERA countries regarding the different priorities through the JPIs, the stockholders' organisations and other mechanisms such as Coimbra ([55]). Nonetheless, European research remains fragmented and regional harmonisation of practices among the funding agencies, for example, remain limited to small subgroups of

[54] See http://europa.eu/rapid/press-release_SPEECH-15-5243_en.htm

[55] http://www.coimbra-group.eu/

countries. Nonetheless, interviewees agreed on the crucial need to reduce fragmentation and to be able to speak with one voice to represent Europe in the global landscape. Depending on the nature of challenges present in each priority, top-down and bottom-up approaches may be adopted to find an adequate balance between alignment and taking advantage of European diversity. The creation of a unified European ranking system has been suggested, as well as a long-term mechanism to steer European universities in the directions desired for ERA development.

A major source of fragmentation pointed out by some interviewees is, on the one hand, the challenges that newcomers may face in the integration process in terms of their ability to be heard by the Commission and, on the other hand, their lack of commitment in return that prevents closing the research gap among ERA countries. Trust-building among the different European regions seems to be long and sometimes frustrating process. The imbalanced participation in Horizon 2020 is symptomatic of this divide. In this context, powerful catching-up policies are needed at the European level in order to spread excellence across Europe and make it more competitive in the global context. Further high-level partnership development between European institutions, governments and stakeholder organisations is strongly desired as part of the capacity-building process.

Performance measurement and accountability and long-term vision: The explicit formulation of ‘addressing grand challenges’ as an ERA priority has raised the need for building a virtuous cycle between citizens’ trust in and support for research and the results-oriented research itself (accountability).The recurrent lack of funding (to different extents) highlighted in almost all ERA countries cannot be solved without developing the public’s interest in research activities by showing the actual and potential benefits for the population in order to garner its support for policymaking. This virtuous cycle has been initiated among the leading countries but remains to be developed in the majority of ERA countries. Nonetheless, the need for performance measuring and accountability has raised concerns regarding a bias toward supporting short-term outcomes research that would be detrimental in the long run.

Main findings

1. The sharing of best practices across the ERA must continue, and indeed increase. This requires open channels of communication, as well as robust assessment tools, where these tools are crucial in determining which practices work best in which situations, and for providing to the various ERA partners a language in which to frame their discussions of best practice. This homogeneity must be counter-balanced with the acknowledged and celebrated diversity across Europe.
2. In addition to measurement tools, targets would provide a useful focus for the ongoing action of installing and solidifying a truly unified European Research Area. Instead of framing these targets as a finish line, after which the ERA would be said to be successfully implemented and the process complete, such targets could be framed as milestones to achieve along the way. Such targets would of course have to account for diversity across national contexts, meaning that targets for a given action should likely vary across countries. In being put into practice, principles such as the freedoms of people, goods, services and capital are always faced with the challenges of reality; these are endemic to the implementation of idealised principles, such that one never finishes overcoming these challenges. Nevertheless, to acknowledge that this process never concludes does not require that one renounce the possibility of having a tangible orientation or making progress; establishing milestones could be greatly beneficial in establishing such an orientation and detailing this progress, all while accepting that beyond these milestones will always lie further milestones rather than a definitive conclusion, or an arrival at the final destination.
3. Just as assessment tools, targets and best practices must negotiate an appropriate balance between homogeneity and diversity across national contexts, so too must the ERA project as a whole be placed in an appropriate balance with the emerging Triple Open strategy. A clear picture must be provided for how a predominantly internal focus on integration within the ERA can be complemented by a primarily external focus in the Triple Open project: an integrated European Research Area as the pole star within a research constellation spanning the globe.

5 CONCLUSION

The present monitoring report has aimed to assess the current state of affairs as well as trajectories in recent years in the process of achieving the European Research Area (ERA). This assessment has covered the individual countries participating in the ERA project, as well as the performance of the ERA as a whole. The study assesses progress and achievements in the six priorities identified in the 2015 ERA Roadmap, and the primary indicators used have been the Headline indicators selected by the ERAC, as well as the complementary ERA Monitoring Mechanism (EMM) indicators.

Additionally, further indicators of potential relevance have been identified and computed by Science-Metrix, who have also devised a series of composite indicators — experimental tools that can offer an integrated overview of performance across indicators — for consideration by the ERAC. Extensive qualitative information has also been gathered through literature reviews and interviews with key stakeholders in European research performing organisations (RPOs) and research funding organisations (RFOs), in an effort to provide additional context to the quantitative findings, ease their interpretation, and provide insight from multiple perspectives on progress towards achieving the ERA.

An acknowledged obstacle in assessing progress to date, and in assessing the path ahead, is that benchmarks and targets for the individual indicators have not been established, raising the question of exactly what it means to 'achieve the ERA' (see the 'Main findings' box, page 118. Moving forward, the addition of further detail to the definition of the objective to be achieved would indicate a clearer direction for action, while also pointing to additional informative facets or performance to be assessed.

Priority 1

The first priority is to establish more effective national research systems, primarily providing consistent and predictable funding for research, and also making the allocation processes more competitive and transparent for researchers and institutions to attain that funding. The underlying assumption is that an increase in competitiveness will achieve an increase in the quality of research funded.

On average across the EU, about 0.7 % of GDP is dedicated to government budget allocations for research & development (GBARD), although this figure has shown a gradual annual decrease since the Financial Crisis in 2008. However, individual governments have adopted divergent strategies since the Crisis, with some cutting back their research budgets in the context of broader fiscal consolidation measures, and others increasing their research budgets in an effort to use research and innovation as the engine to drive their economies forward. Note, however, that some countries have used indirect fiscal measures, which are not captured in GBARD, to complement or substitute for the loss in direct funding for R&D. In such cases, the trends based on GBARD can erroneously suggest a decline in public funding of R&D. As noted in the report *Science, research and innovation performance of the EU* (European Commission & Directorate-General for Research and Innovation, 2016b, p.143), this is particularly striking for the Netherlands, Portugal, Ireland, France, Belgium and the UK. Private-sector investment has also generally decreased, creating additional lines of divergence. These divergences threaten the long-term predictability of research funding systems, which has been identified by stakeholders as a crucial component in effective strategic planning and the performance of research.

While competition for funding is acknowledged as an important driver of quality, some stakeholders have also identified potential negative effects that can follow from a funding process in which competition is too intense (see Section 3.1.4 for further details), suggesting that an optimal system is one where competitiveness is increased but not without limit. Additionally, diversity in the implementation of funding schemes across countries makes it difficult to assess exactly what proportion of a nation's funding is allocated on a competitive basis, and to compare how competitive one funding context is relative to another.

Looking across indicators for Priority 1, the strong performers are generally the same when assessing countries using the Adjusted Research Excellence indicator computed by the Joint Research Centre (JRC) (the Headline indicator for this priority), the GBARD as a proportion of GDP, and the European Innovation Scoreboard (EIS) Summary Innovation Index (SII); more so between the Headline and SII. While the gap between the leader group and the rest of the ERA participants is closing according to the EIS composite (with some variation across countries), the other two indicators show that the leaders are pulling further ahead (again with some variation across countries).

Sub-priority 2a

Priority 2 was divided into two components; the first component, Sub-priority 2a, focuses on ERA countries' efforts to jointly address grand challenges. Two facets are relevant here: transnational cooperation, and the focus on a set of highlighted research topics of acute socioeconomic importance. Together, these two facets aim to increase efficiency in addressing these grand challenges, primarily by leveraging increased funding through a larger partnership and by capitalising on the benefits of cross-border collaboration. Additionally, the EU established ERA-NETs funding as a mechanism to increase the reserve of funding for these joint initiatives.

Joint calls between ERA countries experienced an upswing in 2014-15, with over 30 joint calls open and over 10 Joint Programming Initiatives (JPIs) already operational. Total funding for these cross-border collaborations is expected to exceed EUR 600 million in 2016. On average, about EUR 2 000 per 1 000 researchers in the public sector are allocated to transnational collaborations at the EU-28 level (based on GBARD data), with a slight annual increase over recent years. Looking at public-to-public research collaborations (including ERA-NETs, Article 185, and Joint Programming Initiatives), investment per researcher in the public sector has been increasing sharply in recent years.

The impact that these JPIs will have on different research contexts is not yet clear, as stakeholders wait to see how they will affect funding structures, priority-setting exercises, and other features of the various national research ecosystems across Europe. During interviews, stakeholders highlighted tensions that sometimes arise between grand challenges — which address shared needs across the European context — and more local topics that also require research. Similarly, disparities in the level of commitment across countries and across levels of government prove to be a challenge, widening the gap between the leaders on these projects and the rest of their ERA partners. Some catch-up measures are in place to help to close these gaps, but stakeholders urge the implementation of further measures, highlighting especially the value of increased alignment between levels of government (see Section 3.2.4 for more details).

Another facet of this evolving transnational research landscape is the rate of co-publication with partners in other ERA countries, used as an assessment of the outputs of these collaborative initiatives. In 2014, about 66 publications per 1 000 researchers in the public sector were co-published with a partner in another ERA country at the EU-28 level, a figure that has been increasing steadily over the last decade. The future evolution of this pattern may provide some insight into the level of integration achieved within the ERA.

Sub-priority 2b

The second component of Priority 2, Sub-priority 2b, focuses specifically on research infrastructures, and especially the European Strategy Forum for Research Infrastructures (ESFRI), which aims to provide the high-quality infrastructure required to support cross-border research collaborations. The majority of ERA countries (close to 65 %) have national ESFRI roadmaps in place, with nearly 85 % of these roadmaps including the identification of specific ESFRI projects in which the countries intend to participate, and about half of these roadmaps identifying the financial resources necessary for their participation in these projects.

On average, EU-28 countries participate in about 21 % of the ESFRI projects in development, although digging deeper one finds that in fact there is a small group of leading countries that participate in most ESFRI projects, with the rest of the countries showing a much lower rate of participation. In fact, slightly more than half of ERA countries score below the ERA average across the covered countries. Similarly, average participation in the operational ESFRI Landmarks is around 30 % at the EU-28 level, but once again this average is pulled up by a small group of standout leaders, who are mostly the same as the leaders for the projects in the developmental phase. France, Italy, the Netherlands and the UK are in the top six countries for both indicators.

Key stakeholders have identified that low levels of coordination between the public and private sectors in ESFRI projects are a barrier to progress, as is a low level of coordination between levels of government. Increased coordination across both of these barriers — between sectors, and between levels of government — would help to more effectively address cross-cutting issues. Furthermore, the selection of locations for infrastructure projects presents some accessibility barriers, while stakeholders noted that the European Charter for Access could provide a valuable tool to address this issue.

Priority 3

Priority 3 focuses on the mobility of knowledge workers, aiming to promote an open labour market for researchers. Measures to increase this mobility include making research grants portable so that they follow the researcher and their projects, opening up national restrictions on funding programmes, and breaking down barriers that divide the public, private and higher education sectors and insulate them from one another. A wide range of policy and programme initiatives are in place, but success has been disparate across national contexts. Key stakeholders also noted that there is sometimes a disconnect between the optimistic view of progress on this front from the policy circle and the perceptions of researchers who are themselves most directly affected by these measures.

The EURAXESS portal was designed to provide a single window for job postings and professional support for researchers in Europe (as well as researchers from abroad looking to pursue their careers in Europe). On average, EU-28 countries post about 47 job ads to EURAXESS per 1 000 public-sector researchers, a figure that is growing by about 8 % per year. A small group of countries lead the way on this indicator and are slowly pulling away from the rest of the group. Key stakeholders perceive EURAXESS is still in its initial stages, with awareness and adoption increasing, but they also register a need for continued promotion in order for awareness to continue growing. They also note that many legal barriers to researcher mobility have been handled effectively, but that administrative and linguistic barriers persist in many cases. Support for and implementation of the Human Resources Strategy for Researchers (HRS4R) continue to grow.

A survey asking researchers across the ERA whether they felt that hiring processes in their institution were open, transparent and based on merit showed that in a handful of countries the confidence in the hiring processes is very strong; however, in the majority of countries, less than half of respondents expressed confidence in their institution's hiring processes. Poland and Ireland are two countries where EURAXESS is used very often and where more than half of researchers express confidence in their hiring processes.

An important facet of Priority 3 pertains to early career mobility and professional development. Stakeholders report that early career researchers seem to be deriving considerable benefit from the mobility initiatives in place, as recruitment in earlier career stages seems to be based more on merit, whereas hiring processes for later-stage research positions prove to still draw on established networks rather than on a predominantly meritocratic approach. Mobility for PhD students was also covered in the analysis, which demonstrated that about 7 % of doctoral candidates in the EU-28 hold citizenship in a Member State other than the one in which they are studying. Switzerland has put substantial effort into recruitment of international candidates from

Member States for their PhD programmes, and leads the way with over 35 % of their students coming from abroad, while no other country passed the 20 % threshold.

Priority 4

The fourth priority pertains to gender equality within the research community, including recruitment and career progression of women in research, gender balance in decision-making, and integration of the gender dimension into the content of research. There is considerable diversity of approaches, monitoring programmes and results across national contexts; for instance, some countries are using legislative tools to compel their research institutions to do more on this front, whereas other countries are taking a softer approach. The Helsinki Group on Gender in Research and Innovation leads discussions around three areas of best practice: gender equality plans for RFOs, resources to promote the inclusion of a gender dimension in research content for RPOs, and strategies to address biases, including unconscious biases, in funding and recruitment.

A generational shift may be underway: on average across the EU, women account for nearly 50 % of PhD graduates, about 33 % of actively working researchers (in the public sector), but only about 20 % of Grade A researchers (in the higher education sector) and again only about 20 % of heads of higher education institutions. However, this optimistic interpretation is challenged by the fact that the representation of women amongst PhD candidates and active researchers shows no evidence of substantial change over the last decade, while gender parity amongst Grade A researchers is still several decades away at present annual growth rates.

When looking at the integration of the gender dimension in research content, it is included in EU-28 research articles about as often as the world average, which is between 0.0 % and 0.2 % for the natural and agricultural sciences as well as engineering & technology publications, and between 3.5 % and 7.5 % for publications in the medical and social sciences as well as the humanities. However, while European research is increasing its integration of the gender dimension in research content, this increase is slightly below the global average increase.

There are some interesting regional differences to note, however, as Eastern European nations and Nordic countries seem to be leading the way in addressing gender disparities in professional advancement within the research community. The inclusion of the gender dimension in research content shows no clear regional pattern.

Challenges that extend far beyond the research community are also relevant in this context, as the wage gap, work-life balance difficulties, and under-representation among decision-makers all affect women disproportionately. Stakeholders acknowledge that a variety of measures are in place to address these issues, from soft recommendations to formulate a plan of action, all the way to making funding arrangements being made contingent on meeting exacting criteria. However, while progress has been made, gender parity is still yet to be realised.

Sub-priority 5a

As in the case of Priority 2, Priority 5 has been divided into two components. The first component, Sub-priority 5a, concerns knowledge transfer. In many contexts, knowledge flow is conceived as technology transfer from public-sector or higher education-sector researchers in the ‘hard’ sciences to commercial applications in the private sector to improve economic competitiveness. However, the relevant definition in the context of the ERA is broader, including RPOs, the private sector and government partners in a knowledge triangle; moving towards a conception of knowledge exchange rather than simply a one-way transfer; broadening the scope to include social sciences and humanities within this system; and the consideration of social, environmental and other non-economic outcomes as relevant results. Such a broadened conception requires measures suited to address the structure, practice and culture surrounding knowledge transfer.

Just over 7 % of product or process innovative firms in Europe are cooperating on research projects with public/private research institutes, and 12 % are cooperating with higher education institutions. While rates of firms collaborating with public/private research institutes are lower than rates of collaboration with higher education institutions, the rates are increasing faster for the former, closing the gap between current rates. The private sector also provides about 8 % of the funding for publicly conducted research, a share that has remained mostly stable in recent years. In terms of scientific output, EU-28 countries produce, on average, 34 public–private collaboration publications per million population, though the leader group is strong, and performance has remained steady over recent years.

Various funding instruments have been implemented to promote public–private collaboration, at both the country and EU levels; additional EU-level measures are also under consideration. Technology and innovation centres in the individual countries often play a crucial intermediary role; and training, career development and professional networking opportunities that span sectorial divides also provide some important conduits for knowledge flow. Commercialisation of research — providing researchers with the support needed to develop their discoveries into a market-ready format — remains underdeveloped in most countries and at the EU level, according to key stakeholders.

Private-sector interviewees noted that public–private integration is a two-sided issue, but that the European Commission's focus on addressing this issue approaches it primarily from one side: that of the public sector. These interviewees highlighted the potential value of including the private sector in programme design, to approach this issue from both sides at once rather than primarily from only one.

Sub-priority 5b

Priority 5 treats the circulation of knowledge, but whereas Sub-priority 5a pertains to knowledge transfer between sectors, Sub-priority 5b pertains to the accessibility of research data and publications. Most ERA countries have open access (OA) policies in place to promote accessibility of publications and research data. Many RFOs are making OA publication a condition of funding, and many are providing funds to cover the costs associated with publishing in certain OA venues. RPOs are also, individually and in groups, negotiating new arrangements with publishers, moving from a reader-pays to a researcher-pays model; while this emerging model is addressing some disparities of access that exist under the system they are replacing, the emerging model is introducing new disparities that also need to be addressed.

The OA movement has been accelerating worldwide in recent years, passing the 50 % tipping point in 2014 (Archambault et al., 2014), and with papers in OA showing a distinct citation advantage over articles behind paywalls (Archambault et al., 2016). On average across ERA countries, about 55 % of each country's publications are available in OA, with about 24 % available in gold OA (made available through the publisher) and about 45 % available in green OA (made available through a third party's website, such as the website of a researcher or university). As some articles are available through multiple channels, the total OA is not simply the sum of the green and gold portions. OA is increasing in each category, which we see by comparing the present findings to a previous report on the topic of open access published by the European Commission (Archambault et al., 2014).

The diversity of copyright laws across European jurisdictions proves to be a legal hurdle to the free circulation of knowledge, as are the awareness of and support for researchers in their interactions with publishers in the context of these laws. Digital repositories are an important piece of infrastructure for providing access to research publications and data, but efforts to consolidate the huge number and variety of repositories into a single searchable, and therefore user-friendly, interface are still in the early stages of development. Recent developments in the provision of such tools are ongoing in the private sector.

An additional facet to consider is the intersection between the movement towards increasingly open access and increasingly intersectoral collaboration: private sector involvement in research can complicate matters when OA conflicts with the need to protect competitive commercial advantage. Accordingly, OA mandates can act as deterrents for potential partners in the private sector if they perceive these mandates as being too broad to provide the necessary space to protect competitive advantage.

Career advancement for researchers also exists in a complex relationship to the OA movement, as tenure and promotion processes for individual researchers often integrate the impact profile of the researchers' publications as well as the journals in which they publish. Papers published in OA enjoy a citation advantage over paywalled papers, on average, which prima facie creates an incentive to publish in OA. However, the older, more prestigious, and typically higher-impact journals are not OA, creating a counteracting incentive.

Open access to data is an emerging phenomenon, relative to OA for publications, and aims more to promote the repeatability (and thus reliability) of scientific research, as well as to facilitate the reuse of data in new experimental contexts. The challenges in this instance revolve more around technical challenges and skills development for users, whereas publications face hurdles primarily along legal and financial lines. Data OA and big data are salient topics in science policy discussions worldwide, and the ERAC has recently put forward a set of recommendations covering four categories: Training of stakeholders and awareness raising, Data quality and management, Sustainability and funding, and Legal issues.

Priority 6

The sixth and final priority treats international cooperation, aiming to enhance collaboration with countries outside the ERA. The ERA has been involving itself more and more in international research cooperative programmes with third countries, such as the Global Research Council (GRC), the Belmont Forum, and the OECD Global Science Forum, amongst others. Arrangements have been signed with more than 20 third countries to promote cooperation in research as well as researcher training. Individual ERA countries also have a number of bilateral agreements in place with third countries, and interviewees noted that participation in European programmes is a valuable incentive for ERA countries in attracting and developing partnerships with third countries.

Challenges impeding further partnerships with third countries include lack of financial and human resources dedicated to the establishment and maintenance of such partnerships, the administrative burden that establishing and managing these formal partnerships entails, and the complexity of European programmes for including third countries. Interviewees noted that a bottom-up approach to facilitating these partnerships might provide invaluable input into the design of a streamlined process that better aligns with the needs of actual users.

Annually, EU-28 countries publish on average about 50 papers with non-ERA partners per 1 000 researchers in the public sector, a figure that has been increasing steadily over recent years. About a quarter of doctoral students in the EU-28 come from outside the EU ([56]), while about half of one per cent of GDP comes from patent and licensing revenue from abroad. In the cases of both foreign doctoral students and patent and licensing revenue from abroad, a small group of countries leads the way; however, while the gap is closing between leaders and the rest in terms of attracting PhD students from abroad, the leaders are pulling further ahead in patent and licensing revenue from beyond the ERA. Recruitment may be evening out, but the knowledge export economy is not yet following suit.

Overall findings across priorities

Looking at the Headline composite and Meta-composite indicators, Belgium, the Netherlands, Sweden, the UK, Norway and Switzerland are clearly among the leader group, figuring among top

[56] Note that international doctoral candidates from within the EU are discussed in Sub-priority 2a.

performers for both composites across priorities. In the case of both of these overall composites, the gender dimension (Priority 4) is weakly correlated with overall performance; in fact, it is even slightly negative in both cases. Countries leading the way in overall progress towards achieving the ERA tend to be those who fare less well in progress towards gender parity specifically, while Eastern European countries that have lower scores overall tend to perform well along the gender dimension. Nordic countries seem to have strong scores overall while also showing leadership on the gender front.

While progress towards achieving an integrated ERA is tangible, stakeholders still report the sentiment that substantial room exists within the ERA for convergence between national contexts, and that many of the transnational interactions are re-inscribing pre-existing connections rather than establishing primarily new bonds between subsets of the broader European community.

Top-down and bottom-up approaches must be balanced if European unity and diversity are each to be able to deliver their unique values and advantages. Trust between community members, including both established ERA countries and those who have more recently joined, must continue to build and even accelerate. Differential rates of participation in Horizon 2020 are an exemplary symptom of the need for catch-up policies to be pushed further.

Public trust must also be developed, to secure the continued and stable support necessary for research to really deliver its benefit of improving social and economic conditions for all members of the European community. These two vectors of trust, both trust within the research community and trust in the value of research among the broader public, must be supported by transparent and effective assessments of the ERA, to provide the evidential bases necessary to demonstrate the progress that has been made. A focus on short-term objectives and measurement can be valuable, as the show of trust in this process must be met with a demonstration that that trust was well placed and should be sustained. However, this acknowledgment of short-term goals must not be allowed to displace the long-term focus of the ERA.

Lastly, some discussion has been developing since mid-2015; with the launch of the 'Triple Open: Open Innovation, Open Science, Open to the World' strategy ([57]), some in the research community are wondering whether the priority of the European Commission has shifted from a primarily inward focus on the ERA as an integrated and cohesive unit (albeit with an outward-facing component) to a primarily outward focus on integration with third countries. They wonder how the ERA and Triple Open (3O) priorities are meant to interface with one another, searching for a vision according to which the ERA and the 3O priorities are complementary, reinforcing each other rather than pulling in opposite directions — a vision of European diversity working harmoniously as the centrepiece of a global research community.

[57] https://ec.europa.eu/digital-single-market/en/news/open-innovation-open-science-open-world-vision-europe

Main findings

Priority 1

1. Further policy alignment is encouraged across jurisdictions and across policy documents within individual jurisdictions, to promote integration.
2. Further streamlining of funding application processes would help reduce existing fragmentation, increasing the return on research funding while facilitating collaboration across national borders and across sectors.
3. Research assessment tools need to balance the diversity required to effectively measure diverse national contexts with the consistent approach required to compare across these contexts.
4. A more holistic approach is urged for the process of assessing the contributions of individual researchers.
5. National R&I funding commitments need to be clear and explicit, and be laid out long term, to provide the environment of predictability sought by the private sector, in addition to facilitating clear expectations with respect to collaboration across national borders within the ERA.

Sub-priority 2a

1. National and international funding arrangements would benefit from further harmonisation, which can also facilitate international researcher mobility.
2. Joint Programming Initiatives (JPIs) addressing grand challenges could benefit from being more explicitly linked to the smart specialisation strategies of the partners involved, and vice versa.
3. The societal benefits of research need to be more robustly assessed to facilitate improved research management as well as to better communicate the value of research to the public, demonstrating return on investment.

Sub-priority 2b

1. ESFRI roadmaps, in place in most countries, would benefit from more explicitly outlining the financial requirements to reach the operational phase, and to sustain the operational phase once initiated.
2. Regional disparities in research capacity could be (partially) addressed through the selection of locations for research infrastructures.
3. Smaller-scale research infrastructures could benefit from similar strategies that have been successfully applied to larger installations: comprehensive national inventories to promote awareness, and time-sharing arrangements to promote efficient usage.
4. Including the private sector in the conception, development and operation of research infrastructures could help to catalyse private-sector involvement in R&I more broadly. A similar approach could be taken with third-country partners to increase international collaboration.

Priority 3

1. The optimism of the policy community about implementing open, transparent and merit-based hiring processes is out of phase with the views of individuals working within the research community itself. This move towards improved hiring processes has led to improvements in early career stages, but in later career stages other criteria still seem to carry important weight in hiring decisions.
2. Improving the access of foreign researchers to national granting programmes, and increasing the portability of the research funds granted, could both greatly improve international researcher mobility. Implementation is still in early phases in each case.
3. A broader conception of human resourcing — beyond salary alone — is urged in order to improve recruitment as well as working conditions. Pension right transferability and language competency for teaching requirements are flagged as salient topics here.

Priority 4

1. Tools to monitor gender balance and assess progress towards policy objectives are in place across most of Europe, but greater harmonisation of those tools would help to promote the sharing of best practices.
2. At a cultural level, an important paradigm shift is still required to move the burden from one of individual responsibility on the part of female researchers to a collective responsibility within the research community to address the barriers that disproportionately affect women in the profession.
3. A glass ceiling still seems to be in effect, as gender parity amongst doctoral graduates was achieved a decade ago and yet disparities are more and more accentuated as one assesses more senior ranks within the research world.

Sub-priority 5a

1. Funding structures to support the progression from lab bench to marketplace still show important gaps. Research transfer organisations appear to be playing an important mediating role, but that role is not yet well understood or effectively measured.
2. Additional opportunities to foster intersectoral collaboration are recommended, to increase familiarity and trust between the academic and private sectors, thereby paving the way for increased exchange between them.
3. Further integration of the natural and social sciences along with the humanities is recommended as offering better potential solutions to societal challenges — both regional challenges and shared grand challenges.

Sub-priority 5b

1. The transition towards open access to research publications has progressed in great strides in recent years, but copyright issues, researcher concerns about career progression, and private-sector concerns about competitive advantage are still acknowledged barriers.
2. Open access to research data has developed relatively less quickly, and important technical and financial barriers impede a transition to effective storage and hosting of data, while low levels of data literacy in the general populace are a barrier to uptake.

Priority 6

1. International collaborations with third countries are developing, although Western European nations are leading the way and a gap is opening with the rest of the ERA.
2. International recruitment is advancing as well, although once again Western Europe is leading the charge on this front, and pulling away from the rest. A broader conception of

human resourcing will be important to address the disparities in the research environment that have given Western Europe its present advantage.

Across priorities

1. Sharing of best practices across the ERA needs to continue to grow, supported by effective measurement tools.
2. Establishing targets related to these indicators — framed as milestones rather than finish lines — would help to orient action and demonstrate progress.
3. A bold vision is required to harmonise the focus on an integrated European Research Area that is also growing more integrated with the wider world under the new Triple Open Strategy.
4. International cooperation is developing around the pole of addressing shared grand societal challenges, with centres of excellence emerging to tackle specific issues requiring an interdisciplinary approach. Western European countries tend to be leading the way in these collaborations with third countries, with multi-annual roadmaps being designed for various national and regional contexts. These third-country collaborations have an important interface to make with international collaboration within the ERA (Sub-priority 2a).
5. Bilateral and multilateral agreements are developing and in place with many fast-rising nations worldwide, notably Brazil, Russia, India and China (the BRICs). However, a gap is opening between the research leaders of Europe and other ERA countries, as the leaders have moved far ahead in arranging and implementing these international agreements.
6. The ERA is proving to be an attractive market for the talented minds of the world, although the attraction seems to have greater force in drawing these candidates to Western Europe than to the Eastern European countries. The same group of countries leads in co-publications with third-country partners, attraction of PhD students from beyond the EU, and patent revenues from abroad. The research environment, included but not limited to salary considerations, plays an important role in attracting researchers from abroad, while the financial and administrative support required to install and maintain international partnerships is insufficient in many national contexts.

ANNEX 1: ADDITIONAL TABLES

Table 29 Performance of countries in ERA Roadmap Priority 1 based on composite indicator

Country	Weight in GDP	Score	Component indicators: REI (2013)	GBARD/GDP (2014)	Res/1000 pop (2014)	Paper/1000 res (2014)
EU-28		**50**	**44.4**	**0.671%**	**7.40**	**481**
Cluster 1	14.0%	76	71.8	0.892%	11.81	683
Cluster 2	70.4%	55	45.1	0.676%	8.41	552
Cluster 3	13.1%	33	24.9	0.526%	5.28	423
Cluster 4	2.5%	15	17.9	0.286%	4.34	268
Cluster 1						
DK	1.7%	83	70.2	1.021%	14.36	632
SE	2.9%	79	66.6	0.839%	13.32	707
CH	3.5%	78	97.5	0.888%	*8.07*	*771*
FI	1.4%	74	54.5	0.975%	14.63	488
NL	4.4%	73	70.1	0.735%	8.71	817
Cluster 2						
NO	2.5%	65	56.5	0.854%	11.11	505
IS	0.1%	63	40.2	0.969%	*11.14*	458
AT	2.2%	62	48.6	0.804%	9.59	567
BE	2.7%	60	57.2	0.681%	9.53	548
DE	19.6%	58	49.9	0.870%	8.62	455
IE	1.3%	58	47.3	0.384%	8.32	789
FR	14.3%	54	46.5	0.695%	9.25	470
UK	15.1%	53	72.5	0.560%	8.68	434
CY	0.1%	49	36.6	0.356%	2.04	938
LU	0.3%	49	44.6	0.719%	9.88	326
SI	0.3%	49	26.3	0.433%	8.65	685
IT	10.8%	46	33.0	0.524%	4.79	665
PT	1.2%	46	27.0	0.937%	7.73	336
Cluster 3						
ES	7.0%	42	33.9	0.555%	5.36	526
CZ	1.0%	41	23.4	0.640%	6.92	464
EE	0.1%	41	29.7	0.711%	6.67	368
HR	0.3%	30	17.8	0.625%	3.27	447
HU	0.7%	30	29.7	0.283%	5.94	419
EL	1.2%	29	28.7	0.440%	6.29	289
TR	:	25	17.8	:	3.19	500
PL	2.8%	24	18.2	0.430%	4.58	368
Cluster 4						
MT	0.1%	23	22.8	0.236%	4.71	397
RS	0.2%	20	14.3	0.415%	:	338
LT	0.2%	18	16.4	0.346%	5.97	239
SK	0.5%	17	18.6	0.383%	5.45	192
RO	1.0%	14	15.7	0.213%	2.04	427
BG	0.3%	8	17.2	0.247%	3.99	146
LV	0.2%	7	20.1	0.162%	3.88	136

Note: This composite indicator integrates four components: the adjusted Research Excellence Indicator (acronym: REI; data source: DG Joint Research Centre, Competence Centre on Composite Indicators), government budget appropriations or outlays for R&D as a percentage of GDP (GBARD/GDP; Eurostat), the number of researchers per 1 000 population (Res/1000 pop; Eurostat), the number of publications per 1 000 researchers in the public sector (Paper/1 000 res; Science-Metrix using Web of Science).
Missing indicators: GBARD/GDP (TR); Res/1000 pop (RS)
Exception to reference year: Res/1000 pop (2013: IS; 2012: CH); Paper/1000 res (2012: CH)

Data unavailable: ME, MK, AL, BA, IL, FO, MD, UA

Source Calculations by Science-Metrix; for details on the methodology, please refer to Section 2.3.2 of this report or to the 2016 ERA Monitoring Handbook

Table 30 Performance of countries in ERA Roadmap Priority 2 based on composite indicator

Country	Weight in GDP	Score	Component indicators					
			GBARD transnat (2014)	P-to-P part (2014)	Co-pub w/ERA (2015)	Co-invention w/ERA (2011-13)	ESFRI Landmarks (2016)	ESFRI Projects (2016)
EU-28		**50**	**3 511**	**512**	**39.5%**	**13.0%**	**30.2%**	**20.7%**
Cluster 1	24.7%	67	5 580	1 356	51.9%	28.1%	48.3%	33.3%
Cluster 2	66.2%	59	6 067	1 126	48.1%	18.5%	41.1%	24.6%
Cluster 3	8.4%	46	1 517	542	46.5%	20.6%	16.4%	16.3%
Cluster 4	0.8%	29	497	133	35.4%	16.8%	6.2%	2.9%
Cluster 1								
BE	2.7%	70	9 251	1 064	53.1%	31.0%	48.3%	33.3%
LU	0.3%	66	3 387	2 836	71.5%	55.2%	3.4%	0.0%
NL	4.4%	65	4 101	1 087	45.7%	13.9%	58.6%	38.1%
FR	14.3%	65	:	439	37.3%	12.3%	82.8%	61.9%
Cluster 2								
SE	2.9%	63	6 067	2 046	47.5%	12.5%	55.2%	19.0%
CH	3.5%	62	*27 941*	:	55.7%	31.0%	24.1%	19.0%
FI	1.4%	60	3 795	983	46.7%	13.5%	44.8%	33.3%
DK	1.7%	60	2 787	1 358	47.4%	15.6%	44.8%	19.0%
IT	10.8%	60	8 395	255	37.2%	10.2%	65.5%	52.4%
AT	2.2%	60	6 958	1 610	55.9%	23.6%	27.6%	0.0%
CY	0.1%	60	3 018	3 625	65.5%	28.7%	3.4%	0.0%
UK	15.1%	59	2 561	345	34.7%	11.8%	55.2%	66.7%
DE	19.6%	59	*4 686*	571	37.5%	10.2%	69.0%	28.6%
NO	2.5%	56	4 414	:	49.4%	14.2%	34.5%	28.6%
CZ	1.0%	55	1 245	104	42.9%	28.2%	48.3%	28.6%
EE	0.1%	52	939	367	56.9%	23.1%	20.7%	0.0%
Cluster 3								
ES	7.0%	50	2 385	312	35.2%	11.9%	31.0%	52.4%
RO	1.0%	49	1 191	927	35.4%	30.0%	13.8%	19.0%
PT	1.2%	49	749	224	43.1%	19.0%	31.0%	19.0%
IE	1.3%	49	2 951	739	46.0%	20.8%	6.9%	14.3%
IS	0.1%	48	*6 927*	:	64.7%	11.8%	0.0%	4.8%
PL	2.8%	46	678	253	27.4%	25.3%	31.0%	33.3%
EL	1.2%	46	1 098	18	44.9%	19.4%	34.5%	33.3%
SI	0.3%	46	955	769	46.7%	10.2%	20.7%	4.8%
HU	0.7%	44	194	199	47.0%	27.2%	13.8%	4.8%
SK	0.5%	44	52	142	51.9%	41.1%	6.9%	9.5%
LV	0.2%	43	1 030	1 334	51.9%	9.5%	0.0%	0.0%
MT	0.1%	41	0	1 047	63.8%	:	6.9%	0.0%
Cluster 4								
BG	0.3%	37	97	103	49.0%	14.5%	6.9%	9.5%
HR	0.3%	37	1 569	133	43.9%	14.3%	3.4%	0.0%
RS	0.2%	35	101	:	34.9%	36.2%	6.9%	0.0%
LT	0.2%	34	220	163	37.3%	14.4%	10.3%	0.0%
TR	:	2	:	:	12.0%	4.4%	3.4%	4.8%

Note: This composite indicator integrates six components: National GBARD (EUR) allocated to Europe-wide, bilateral or multilateral transnational public R&D programmes per FTE researcher in the public sector (acronym: GBARD transnat; data source: Eurostat), Member State participation (EUR) in Public-to-Public collaborations per FTE researcher in the public sector (P-to-P part; Eurostat and 1st ERA-Learn 2020 Annual Report on P2P Partnerships), International co-publication rate with ERA partners (Co-pub w/ERA; Science-Metrix using Web of Science), International co-invention rate with ERA partners (Co-invention w/ERA; Science-Metrix using PATSTAT data on PCT applications), Percentage of ESFRI Landmarks in which a Member State/Associated Country is a partner (ESFRI Landmarks; ESFRI data), and Percentage of ESFRI Projects in which a Member State/Associated Country participates (ESFRI Landmarks; ESFRI data). Note that a differential weighting approach was used to ensure that the sub-priorities 2a and 2b, although they differ in number of indicators, contribute, in as much as is possible, equally to the composite for Priority 2.

Missing indicators: TR has less than 75 % of indicators covered (GBARD Transnat and P-to-P part are missing); P-to-P part (IS, NO, CH, RS, TR); Co-invention w/ERA (MT); GBARD transnat (FR)

Missing countries in EU-28 aggregate: GBARD transnat (FR)
Exception to reference year: GBARD transnat (2013: DE, IS; 2012: CH)
Data unavailable: ME, MK, AL, BA, IL, FO, MD, UA

Source: Calculations by Science-Metrix; for details on the methodology, please refer to Section 2.3.2 of this report or to the 2016 ERA Monitoring Handbook

Table 31 Performance of countries in ERA Roadmap Priority 3 based on composite indicator

Country	Weight in GDP	Score	Component indicators: EURAXESS postings (2014)	Share of PhDs from other EU MS (2013)	Open, Trans, Merit Hiring (2012)
EU-28		**63**	**47.0**	**7.4%**	**49.0%**
Cluster 1	27.6%	77	91.2	18.7%	58.2%
Cluster 2	29.1%	62	83.7	9.0%	45.3%
Cluster 3	41.9%	44	11.9	4.9%	37.9%
Cluster 4	1.5%	23	1.1	3.0%	32.8%
Cluster 1					
UK	15.1%	82	63.8	13.2%	72.5%
LU	0.3%	79	73.7	:	63.4%
NL	4.4%	78	98.7	19.8%	54.1%
IE	1.3%	77	139.1	12.6%	56.1%
SE	2.9%	73	156.1	10.2%	49.1%
CH	3.5%	72	*16.1*	37.6%	54.1%
Cluster 2					
NO	2.5%	69	69.1	8.7%	53.7%
AT	2.2%	67	71.3	19.6%	38.2%
BE	2.7%	66	51.9	11.8%	47.1%
DK	1.7%	66	17.8	17.3%	51.8%
IS	0.1%	66	42.6	11.5%	49.0%
EE	0.1%	60	21.8	5.0%	56.1%
PL	2.8%	59	146.7	1.0%	58.0%
EL	1.2%	58	78.8	:	35.8%
FR	14.3%	58	49.8	8.0%	37.4%
CY	0.1%	58	81.7	3.7%	42.4%
HR	0.3%	56	362.0	2.4%	29.8%
CZ	1.0%	55	11.4	10.4%	44.1%
Cluster 3					
MT	0.1%	53	:	5.1%	45.4%
ES	7.0%	48	13.0	4.2%	43.0%
SI	0.3%	48	28.0	6.4%	28.5%
FI	1.4%	46	5.4	7.2%	40.0%
LV	0.2%	45	2.7	4.1%	53.8%
DE	19.6%	43	5.5	3.8%	44.3%
PT	1.2%	41	7.3	4.3%	35.3%
RO	1.0%	40	17.0	1.7%	37.6%
IT	10.8%	37	26.4	4.2%	14.0%
SK	0.5%	37	1.4	7.6%	37.3%
Cluster 4					
HU	0.7%	31	1.0	5.7%	34.0%
LT	0.2%	26	1.7	2.6%	31.1%
RS	0.2%	22	0.6	*4.1%*	:
BG	0.3%	21	1.4	2.0%	27.4%
TR	:	14	0.7	*0.6%*	38.9%

Note: This composite indicator integrates three components: Number of researcher postings advertised through the EURAXESS job portal per 1 000 researchers in the public sector (acronym: EURAXESS postings; data source:

EURAXESS historical data and Eurostat); Share of doctoral candidates with a citizenship of another EU Member State (Share of PhDs from other EU MS; Eurostat); Share of researchers expressing satisfaction that the hiring procedures in their institution are Open, Transparent and Merit-based (Open, Trans, Merit Hiring; MORE2 Survey).

Missing indicators: Less than 75 % of indicators are covered for: MT (EURAXESS postings missing); LU and EL (Share of PhDs from other EU MS); Open, Trans, Merit Hiring (RS)

Missing countries in EU-28 aggregate: GBARD transnat (FR)

Exception to reference year: EURAXESS postings (2012: CH); Share of PhDs from other EU MS (2014: RS, TK)

Data unavailable: ME, MK, AL, BA, IL, FO, MD, UA

Source: Calculations by Science-Metrix; for details on the methodology, please refer to Section 2.3.2 of this report or to the 2016 ERA Monitoring Handbook

Table 32 Performance of countries in ERA Roadmap Priority 4 based on composite indicator

Country	Weight in GDP	Score	Component indicators				
			Women Grade A (2013)	Gen Dim Res Cont (2011-15)	Women PhD (2012)	Women Res (2013)	Women Inst Heads (2014)
EU-28		**46**	**20.9%**	**0.97**	**47.3%**	**33.2%**	**20.1%**
Cluster 1	2.2%	73	30.5%	1.62	54.4%	45.7%	32.8%
Cluster 2	11.6%	59	25.7%	1.41	50.4%	38.9%	26.2%
Cluster 3	46.4%	46	20.3%	1.07	46.0%	35.4%	20.5%
Cluster 4	39.8%	28	15.5%	0.74	46.0%	28.5%	13.6%
Cluster 1							
RS	0.2%	87	:	1.59	:	*49.3%*	*53.8%*
PT	1.2%	74	*25.0%*	1.92	56.3%	45.4%	29.8%
LT	0.2%	71	*14.4%*	2.62	57.0%	51.2%	27.1%
IS	0.1%	71	*26.3%*	1.25	52.5%	44.4%	40.0%
MT	0.1%	70	*44.5%*	2.27	46.2%	29.8%	:
LV	0.2%	69	34.4%	0.65	59.9%	52.0%	25.0%
HR	0.3%	68	*38.0%*	1.03	54.6%	47.8%	21.2%
Cluster 2							
SE	2.9%	64	23.8%	1.37	48.4%	33.3%	50.0%
TR	:	63	:	1.88	46.5%	36.2%	:
SK	0.5%	62	23.7%	2.88	48.7%	42.7%	13.9%
NO	2.5%	62	25.2%	1.14	48.1%	36.9%	39.1%
SI	0.3%	60	22.5%	1.36	50.4%	36.0%	*30.5%*
FI	1.4%	57	26.6%	1.32	50.9%	31.5%	24.4%
PL	2.8%	56	22.6%	1.34	53.2%	37.8%	18.2%
RO	1.0%	56	29.7%	1.05	55.3%	45.7%	*11.1%*
BG	0.3%	53	31.7%	0.34	51.7%	49.7%	*22.4%*
Cluster 3							
DK	1.7%	51	19.2%	1.10	45.3%	34.5%	32.7%
ES	7.0%	51	20.9%	0.85	48.6%	39.3%	:
IT	10.8%	51	21.1%	0.80	*53.2%*	35.7%	23.2%
IE	1.3%	48	*28.2%*	0.84	49.2%	32.3%	18.5%
HU	0.7%	48	24.1%	1.53	46.5%	30.3%	16.7%
UK	15.1%	48	*17.5%*	1.12	46.1%	38.1%	:
EE	0.1%	44	*17.2%*	0.69	50.5%	44.4%	15.4%
EL	1.2%	43	*19.6%*	1.80	*38.2%*	39.4%	13.5%
BE	2.7%	42	15.6%	1.12	43.8%	33.4%	*23.8%*
AT	2.2%	40	*20.3%*	0.98	41.8%	29.6%	23.5%
CH	3.5%	39	19.3%	0.98	43.2%	*32.4%*	17.5%
Cluster 4							
DE	19.6%	32	17.3%	0.76	45.4%	27.9%	16.5%
LU	0.3%	30	16.5%	0.47	50.9%	27.3%	:
CY	0.1%	29	*10.8%*	0.67	50.0%	38.3%	*10.9%*
NL	4.4%	29	16.2%	1.07	44.9%	23.6%	*13.6%*
CZ	1.0%	27	*13.1%*	0.85	41.4%	28.3%	*16.9%*
FR	14.3%	22	*19.3%*	0.64	43.4%	25.5%	*10.2%*

Note: This composite indicator integrates five components: Share of women in Grade A academic positions in the Higher Education Sector (acronym: Women Grade A; data source: Women in Science database, DG Research and Innovation), Gender dimension in research content (Gen Dim Res Cont; Science-Metrix using Web of Science), Share of women heads of institutions in the higher education sector (Women Inst Heads; Women in Science database, DG Research and Innovation), Proportion of female PhD graduates (Women PhD; Eurostat), Share of women researchers (Women Res; Eurostat).
Missing indicators: Less than 75 % of indicators covered (Women Grade A and Women PhD are missing for RS; Women Grade A and Women Inst Heads are missing for TK); Women Inst Heads (ES, LU, MT, UK)

Exception to reference year: Women Grade A (2014: HR, MT; 2012: CY, EL, IE, FR, PT, IS; 2011: AT; 2008: CZ; 2007: LT; 2006: UK; 2004: EE); Women Inst Heads (2013: BE, BG, CZ, CY, NL, RO, SI, RS; 2012: FR); Women PhD (2011: EL, IT); Women Res (2011: RS; 2012; CH)
Data unavailable: ME, MK, AL, BA, IL, FO, MD, UA

Source: Calculations by Science-Metrix; for details on the methodology, please refer to Section 2.3.2 of this report or to the 2016 ERA Monitoring Handbook

Table 33 Share of women in Grade A positions in the Higher Education Sector (2015)

Share of women in Grade A positions in the Higher Education Sector (2015)

Country	Score
BG	34.0%
CZ	14.6%
EE	24.3%
EL	21.5%
FR	23.2%
LT	34.4%
HU	19.6%
NL	18.1%
PL	23.2%
PT	25.1%
SK	25.7%
SE	25.4%
NO	26.9%
IL	15.3%

Note: Exception to reference year: PT (2014).
Source: Women in Science database, DG Research and Innovation

Table 34 Performance of countries in ERA Roadmap Priority 5 based on composite indicator

Country	Weight in GDP	Score	Component indicators				
			Res Inst-private co-op (2012)	Higher educ-private co-op (2012)	Priv fund Pub R&D (2013)	Pub-Priv co-pub (2014)	Total OA Pubs (2014)
EU-28		**41**	**7.3%**	**12.0%**	**8.1%**	**33.9**	**52.2%**
Cluster 1	11.7%	76	9.0%	14.5%	12.7%	81.1	58.8%
Cluster 2	41.6%	57	9.6%	12.2%	7.5%	55.3	57.0%
Cluster 3	46.6%	40	7.5%	11.7%	5.3%	20.9	53.8%
Cluster 4	0.2%	15	4.6%	6.0%	8.9%	1.3	47.9%
Cluster 1							
CH	3.5%	90	:	:	:	217.6	58.0%
BE	2.7%	81	13.3%	18.1%	18.6%	68.5	57.9%
NL	4.4%	71	*6.6%*	*8.3%*	12.5%	85.6	58.7%
HR	0.3%	69	10.1%	14.4%	9.5%	10.6	60.4%
HU	0.7%	68	5.9%	17.0%	10.2%	23.2	59.2%
Cluster 2							
LT	0.2%	65	10.7%	18.1%	16.4%	1.7	57.6%
LU	0.3%	63	7.7%	7.0%	2.3%	40.0	61.0%
IS	0.1%	61	*9.7%*	*8.4%*	7.9%	187.3	56.4%
NO	2.5%	60	13.8%	12.8%	6.4%	50.9	57.4%
SE	2.9%	59	10.8%	17.1%	4.5%	107.8	57.0%
FI	1.4%	58	23.0%	26.2%	8.2%	69.9	54.1%
UK	15.1%	58	10.0%	15.9%	7.4%	50.2	56.4%
RS	0.2%	58	0.0%	0.0%	*9.6%*	6.2	59.7%
SI	0.3%	55	*14.3%*	*22.0%*	10.2%	66.0	53.2%
DK	1.7%	55	10.9%	14.7%	3.8%	143.5	55.9%
BG	0.3%	52	2.6%	4.4%	*7.7%*	2.1	59.0%
RO	1.0%	51	6.9%	4.3%	13.0%	2.6	56.0%
FR	14.3%	51	8.0%	11.0%	5.6%	39.6	55.8%
PT	1.2%	51	6.5%	9.3%	2.0%	7.1	59.0%
Cluster 3							
EE	0.1%	49	4.4%	9.9%	5.0%	6.8	57.7%
AT	2.2%	48	12.6%	20.9%	6.0%	59.0	53.3%
IE	1.3%	42	*7.1%*	*9.8%*	3.2%	34.3	54.6%
ES	7.0%	40	10.6%	9.2%	6.7%	16.3	53.0%
CZ	1.0%	40	5.7%	14.3%	6.7%	13.8	53.2%
DE	19.6%	40	*5.9%*	*13.9%*	12.3%	53.0	49.8%
PL	2.8%	39	7.8%	9.4%	*4.4%*	3.7	55.1%
CY	0.1%	38	4.7%	4.7%	0.7%	7.0	56.4%
EL	1.2%	37	15.7%	18.6%	5.7%	9.9	52.0%
SK	0.5%	35	5.3%	12.6%	5.0%	8.1	53.2%
IT	10.8%	33	2.8%	5.3%	2.7%	18.0	53.5%
Cluster 4							
LV	0.2%	28	6.8%	7.0%	14.0%	0.0	50.0%
TR	:	17	5.4%	6.8%	11.6%	1.4	47.2%
MT	0.1%	0	1.5%	4.1%	1.1%	2.4	46.6%

Note: This composite indicator integrates five components: Share of product or process innovative firms cooperating with public or private research institutions (acronym: Res Inst–private co-op; data source: Eurostat), Share of product or process innovative firms cooperating with higher education institutions (Higher educ–private co-op; Eurostat), Share of public research financed by the private sector (Priv fund Pub R&D; Eurostat), Number of public–private co-publications per million population (Pub–Priv co-pub; CWTS), Share of publications available in (Green and/or Gold) Open Access (Total OA Pubs; 1science & Science-Metrix). Note that a differential weighting approach was used to ensure that the sub-priorities 5a and 5b, although they differ in number of indicators, contribute, in as much as is possible, equally to the composite for Priority 5.
Missing indicators: CH has less than 75 % of indicators covered (Res Inst–private co-op, Higher educ–private co-op, and Priv fund Pub R&D are missing); Priv fund Pub R&D (DE, NL)
Missing countries in EU-28 aggregate: Priv fund Pub R&D (DE, NL)

Exception to reference year: Res Inst–private co-op & Higher educ–private co-op (2010: DE, IE, NL, SI, IS); Priv fund Pub R&D (2012: BG, PL; 2011: RS)
Data unavailable: ME, MK, AL, BA, IL, FO, MD, UA

Source: Calculations by Science-Metrix; for details on the methodology, please refer to Section 2.3.2 of this report or to the 2016 ERA Monitoring Handbook

Table 35 Performance of countries in ERA Roadmap Priority 6 based on composite indicator

Country	Weight in GDP	Score	Component indicators			
			Co-pub w/non-ERA (2015)	Non-EU PhD (2012)	Lic & Pat revenue (2013)	Co-invention w/non-ERA (2011-13)
EU-28		**55**	**32.6%**	**25.5%**	**0.64%**	**9.8%**
Cluster 1	27.2%	77	37.6%	28.3%	1.84%	16.1%
Cluster 2	44.1%	57	32.3%	15.3%	0.66%	11.3%
Cluster 3	27.3%	40	27.0%	7.1%	0.08%	10.1%
Cluster 4	1.5%	22	21.7%	2.5%	0.00%	5.7%
Cluster 1						
CH	3.5%	85	37.7%	50.2%	*3.07%*	14.3%
IE	1.3%	84	35.0%	18.4%	2.23%	22.1%
NL	4.4%	76	34.6%	24.5%	*3.72%*	10.0%
IS	0.1%	76	43.2%	23.9%	*0.90%*	15.0%
UK	15.1%	72	39.3%	30.8%	0.46%	17.4%
BE	2.7%	71	35.5%	22.0%	0.64%	18.0%
Cluster 2						
LU	0.3%	67	35.6%	20.3%	1.29%	11.6%
SE	2.9%	66	36.3%	24.0%	1.08%	10.8%
DK	1.7%	61	36.6%	18.4%	0.71%	10.5%
FI	1.4%	61	33.5%	7.9%	1.38%	10.3%
FR	14.3%	57	36.7%	35.4%	0.43%	8.4%
RS	0.2%	55	20.2%	7.1%	:	13.3%
HU	0.7%	53	29.2%	3.0%	0.89%	11.8%
NO	2.5%	52	33.9%	33.5%	0.08%	9.4%
EE	0.1%	51	32.2%	4.7%	0.00%	14.8%
DE	19.6%	50	32.3%	11.3%	0.77%	7.4%
BG	0.3%	49	29.3%	3.1%	0.00%	15.5%
Cluster 3						
PT	1.2%	44	29.7%	13.7%	0.00%	9.0%
CZ	1.0%	43	26.6%	4.4%	0.13%	10.9%
ES	7.0%	43	29.9%	20.4%	0.07%	7.5%
AT	2.2%	43	32.7%	9.0%	0.25%	6.9%
EL	1.2%	42	26.8%	1.0%	0.00%	15.2%
RO	1.0%	40	20.0%	2.0%	0.07%	14.9%
IT	10.8%	38	27.0%	9.0%	0.19%	6.8%
CY	0.1%	37	32.3%	2.3%	0.00%	7.9%
PL	2.8%	34	18.1%	1.9%	0.05%	12.0%
Cluster 4						
MT	0.1%	27	22.6%	2.6%	0.00%	:
SI	0.3%	27	23.1%	6.1%	0.00%	5.7%
LV	0.2%	25	24.6%	1.5%	0.00%	6.0%
SK	0.5%	24	23.6%	1.5%	0.00%	6.0%
TR	:	18	15.5%	2.5%	:	4.5%
HR	0.3%	17	21.3%	2.7%	0.00%	4.2%
LT	0.2%	15	21.1%	0.1%	0.00%	7.6%

Note: This composite indicator integrates four components: International co-publication rate with non-ERA partners (acronym: Co-pub w/non-ERA; data source: Science-Metrix using Web of Science), non-EU doctorate students as

	a share of all doctorate students (Non-EU PhD; Eurostat), Licence and patent revenue from abroad as a share of GDP (Lic & Pat revenue; Eurostat), International co-invention rate with non-ERA partners (Co-invention w/non-ERA; Science-Metrix using PATSTAT data on PCT applications). **Missing indicators:** Lic & Pat revenue (RS, TR); Co-invention w/non-ERA (MT) **Exception to reference year:** Lic & Pat revenue (2012: NL, IS, CH) **Data unavailable:** ME, MK, AL, BA, IL, FO, MD, UA
Source:	Calculations by Science-Metrix; for details on the methodology, please refer to Section 2.3.2 of this report or to the 2016 ERA Monitoring Handbook

Table 36 Performance of countries across ERA Priorities based on composite of Headline indicators, part 1

Country	Weight in GDP	Score	JRC Res Excellence (2013)	GBARD transnat (2014)	Part ESFRI Landmarks (2014)	EURAXESS job postings (2014)
			Component indicators			
EU-28		**50**	**44.4**	**3 511**	**30.2%**	**47.0**
Cluster 1	31.2%	66	70.1	9 056	46.0%	75.9
Cluster 2	33.6%	58	43.0	4 169	31.0%	79.5
Cluster 3	34.0%	46	28.1	1 499	26.6%	36.9
Cluster 4	1.2%	31	18.5	280	6.2%	1.6
Cluster 1						
SE	2.9%	72	66.6	6 067	55.2%	156.1
CH	3.5%	67	97.5	*27 941*	24.1%	*16.1*
NL	4.4%	67	70.1	4 101	58.6%	98.7
BE	2.7%	64	57.2	9 251	48.3%	51.9
NO	2.5%	64	56.5	4 414	34.5%	69.1
UK	15.1%	63	72.5	2 561	55.2%	63.8
Cluster 2						
FR	14.3%	62	46.5	:	82.8%	49.8
HR	0.3%	62	17.8	1 569	3.4%	362.0
FI	1.4%	61	54.5	3 795	44.8%	5.4
DK	1.7%	60	70.2	2 787	44.8%	17.8
IE	1.3%	58	47.3	2 951	6.9%	139.1
AT	2.2%	56	48.6	6 958	27.6%	71.3
LU	0.3%	56	44.6	3 387	3.4%	73.7
IS	0.1%	55	40.2	*6 927*	0.0%	42.6
IT	10.8%	53	33.0	8 395	65.5%	26.4
PT	1.2%	52	27.0	749	31.0%	7.3
Cluster 3						
SI	0.3%	49	26.3	955	20.7%	28.0
EL	1.2%	48	28.7	1 098	34.5%	78.8
PL	2.8%	48	18.2	678	31.0%	146.7
ES	7.0%	47	33.9	2 385	31.0%	13.0
DE	19.6%	47	49.9	*4 686*	69.0%	5.5
HU	0.7%	47	29.7	194	13.8%	1.0
CY	0.1%	46	36.6	3 018	3.4%	81.7
EE	0.1%	46	29.7	939	20.7%	21.8
RO	1.0%	45	15.7	1 191	13.8%	17.0
CZ	1.0%	41	23.4	1 245	48.3%	11.4
BG	0.3%	40	17.2	97	6.9%	1.4
Cluster 4						
LT	0.2%	36	16.4	220	10.3%	1.7
LV	0.2%	31	20.1	1 030	0.0%	2.7
SK	0.5%	31	18.6	52	6.9%	1.4
RS	0.2%	30	14.3	101	6.9%	0.6
MT	0.1%	25	22.8	0	6.9%	:

Note: This composite indicator integrates nine Headline indicators; i.e. one per priority/sub-priority (1, 2a, 2b, 3, 4, 5a, 5b, 6) with the exception of 5a for which the Headline indicator had to be split into two indicators due to the lack of raw data at the firm level, which would lead to double counting of some firms when merging data on firms cooperating with public/private research institutions with data on firms cooperating with higher education institutions. Note that the two indicators for Sub-priority 5a individually carry less weight than any other indicator in the composite as they are highly correlated; they each received a weight of about 0.5. The note continues in Table 37.

Source: Calculations by Science-Metrix, for details on the methodology, please refer to Section 2.3.2 of this report or to the 2016 ERA Monitoring Handbook

Table 37 Performance of countries across ERA Priorities based on composite of Headline indicators, part 2

Country	Weight in GDP	Score	Component indicators: Women Grade A (2013)	Res Inst-private co-op (2012)	Higher educ-private co-op (2012)	Total OA pubs (2014)	Non-ERA pubs per 1000 res (2014)
EU-28		**50**	**20.9%**	**7.3%**	**12.0%**	**52.2%**	**50.7**
Cluster 1	31.2%	66	19.6%	10.9%	14.4%	57.5%	75.0
Cluster 2	33.6%	58	24.1%	9.8%	12.7%	56.4%	53.9
Cluster 3	34.0%	46	20.9%	7.7%	11.6%	55.0%	34.9
Cluster 4	1.2%	31	29.3%	4.9%	8.4%	53.4%	14.8
Cluster 1							
SE	2.9%	72	23.8%	10.8%	17.1%	57.0%	85.1
CH	3.5%	67	19.3%	:	:	58.0%	*96.6*
NL	4.4%	67	16.2%	*6.6%*	*8.3%*	58.7%	87.1
BE	2.7%	64	15.6%	13.3%	18.1%	57.9%	62.8
NO	2.5%	64	25.2%	13.8%	12.8%	57.4%	55.3
UK	15.1%	63	*17.5%*	10.0%	15.9%	56.4%	62.8
Cluster 2							
FR	14.3%	62	*19.3%*	8.0%	11.0%	55.8%	59.7
HR	0.3%	62	*38.0%*	10.1%	14.4%	60.4%	20.8
FI	1.4%	61	26.6%	23.0%	26.2%	54.1%	50.5
DK	1.7%	60	19.2%	10.9%	14.7%	55.9%	72.2
IE	1.3%	58	*28.2%*	*7.1%*	*9.8%*	54.6%	87.5
AT	2.2%	56	*20.3%*	12.6%	20.9%	53.3%	57.7
LU	0.3%	56	16.5%	7.7%	7.0%	61.0%	44.7
IS	0.1%	55	*26.3%*	*9.7%*	*8.4%*	56.4%	62.2
IT	10.8%	53	21.1%	2.8%	5.3%	53.5%	51.4
PT	1.2%	52	*25.0%*	6.5%	9.3%	59.0%	32.2
Cluster 3							
SI	0.3%	49	22.5%	*14.3%*	*22.0%*	53.2%	37.2
EL	1.2%	48	*19.6%*	15.7%	18.6%	52.0%	21.2
PL	2.8%	48	22.6%	7.8%	9.4%	55.1%	16.8
ES	7.0%	47	20.9%	10.6%	9.2%	53.0%	48.7
DE	19.6%	47	17.3%	*5.9%*	*13.9%*	49.8%	49.6
HU	0.7%	47	24.1%	5.9%	17.0%	59.2%	33.2
CY	0.1%	46	*10.8%*	4.7%	4.7%	56.4%	86.5
EE	0.1%	46	*17.2%*	4.4%	9.9%	57.7%	24.6
RO	1.0%	45	29.7%	6.9%	4.3%	56.0%	20.9
CZ	1.0%	41	*13.1%*	5.7%	14.3%	53.2%	34.3
BG	0.3%	40	31.7%	2.6%	4.4%	59.0%	10.5
Cluster 4							
LT	0.2%	36	*14.4%*	10.7%	18.1%	57.6%	10.6
LV	0.2%	31	34.4%	6.8%	7.0%	50.0%	8.1
SK	0.5%	31	23.7%	5.3%	12.6%	53.2%	10.5
RS	0.2%	30	:	0.0%	0.0%	59.7%	16.3
MT	0.1%	25	*44.5%*	1.5%	4.1%	46.6%	28.4

Note: The other indicators were weighted equally, yet accounting for redundancy in the dataset. Additionally, the Headline for Sub-priority 2b (i.e. availability of national roadmaps with identified ESFRI projects and corresponding investment needs) has been substituted with the complementary EMM indicator on ESFRI landmarks since it could not be included in this study's composite (it is a qualitative indicator). ESFRI landmarks were chosen over ESFRI projects since they represent successful ESFRI projects (i.e. operational).
Missing indicators: Sub-priority 2a-GBARD transnat (FR); Priority 3-EURAXESS job postings (MT); Priority 4-Women Grade A (RS); Sub-priority 5a-Res Inst–private co-op & Higher Educ–private co-op (CH)
Missing countries in EU-28 aggregate: GBARD transnat (FR); EURAXESS job postings (MT);
Exception to reference year: GBARD transnat (2013: DE, IS; 2012: CH); EURAXESS job postings (2012: CH); Women Grade A (2014: HR, MT; 2012: CY, EL, IE, FR, PT, IS; 2011: AT; 2008: CZ; 2007: LT; 2006: UK; 2004: EE); Res Inst–private co-op & Higher educ–private co-op (2010: DE, IE, NL, SI, IS); Non-ERA pubs per 1 000 res (CH: 2012)
Data unavailable: ME, MK, AL, TR, BA, IL, FO, MD, UA

Source: Calculations by Science-Metrix; for details on the methodology, please refer to Section 2.3.2 of this report or to the 2016 ERA Monitoring Handbook

Table 38 Performance of countries across ERA Priorities based on the Meta-composite indicator

Country	Weight in GDP	Score	Composite indicators for individual priorities					
			Priority 1	Priority 2 (a & b)	Priority 3	Priority 4	Priority 5 (a & b)	Priority 6
EU-28		**54**	**50**	**50**	**63**	**46**	**41**	**55**
Cluster 1	33.1%	73	69	60	72	51	67	70
Cluster 2	6.6%	61	52	53	55	56	53	59
Cluster 3	59.4%	47	38	50	48	47	48	39
Cluster 4	1.0%	35	16	33	34	63	26	29
Cluster 1								
CH	3.5%	79	78	62	*72*	39	90	85
SE	2.9%	77	79	63	73	65	59	66
IS	0.1%	74	63	48	66	71	61	76
BE	2.7%	73	60	70	66	43	*81*	71
DK	1.7%	70	83	*60*	66	52	55	61
NL	4.4%	70	73	65	78	29	70	76
NO	2.5%	69	65	56	69	62	60	52
UK	15.1%	69	53	59	82	48	58	72
Cluster 2								
FI	1.4%	66	74	60	46	57	58	61
IE	1.3%	65	58	49	77	48	42	84
LU	0.3%	63	49	66	79	30	63	67
PT	1.2%	58	46	49	41	74	51	44
AT	2.2%	57	62	60	67	41	48	43
RS	0.2%	54	20	35	22	87	58	55
Cluster 3								
HR	0.3%	53	30	37	*56*	68	69	17
EE	0.1%	52	41	52	60	43	49	51
FR	14.3%	52	54	65	58	22	51	57
SI	0.3%	52	49	46	48	60	55	27
HU	0.7%	49	30	44	31	48	68	53
ES	7.0%	48	42	50	48	51	40	43
DE	19.6%	47	58	59	43	32	39	50
IT	10.8%	46	46	60	37	51	33	38
PL	2.8%	46	24	46	*59*	56	39	34
CY	0.1%	45	49	60	58	28	38	37
RO	1.0%	45	14	49	40	56	51	40
CZ	1.0%	43	41	55	55	27	40	43
EL	1.2%	43	29	46	58	42	37	42
LT	0.2%	43	18	34	26	71	65	15
Cluster 4								
LV	0.2%	39	7	43	*45*	*69*	28	25
BG	0.3%	38	8	37	21	52	52	49
MT	0.1%	38	23	41	53	70	0	27
SK	0.5%	38	17	44	37	61	35	24
TR	:	22	25	*2*	14	*63*	17	18

Note: This composite indicator integrates the six priority composite indicators; i.e. one per priority or sub-priority (1, 2a&b, 3, 4, 5a&b, 6). Note that each of the six intermediate priority composite indicators were weighted equally, yet accounting for redundancy in the dataset.
Missing indicators: Less than 75 % of indicators covered for: Priority 2 (TK); Priority 3 (EL, LU, MT, RS); Priority 4 (RS, TK); Priority 5 (CH)
Data unavailable: ME, MK, AL, BA, IL, FO, MD, UA

Source: Calculations by Science-Metrix; for details on the methodology, please refer to Section 2.3.2 of this report or to the 2016 ERA Monitoring Handbook

ANNEX 2: INDEX LIST OF INDICATORS

Priority 1 – More effective national research systems

Headline indicator
— Adjusted Research Excellence Indicator (REI)

EMM indicators
— GBARD as a percentage of GDP

— European Innovation Scoreboard Summary Innovation Index (SII)

Additional priority 1 indicators
— GBARD as a percentage of government expenditures

— Percentage of GBARD allocated as project based funding

— Researchers per 1 000 active population

— R&D tax incentives as a proportion GBARD**Error! Reference source not found.**

— Number of patent applications per 1 000 researchers

— Number of publications per 1 000 researchers in the public sector

Priority 2a – Transnational cooperation

Headline indicator
— GBARD allocated to transnational cooperation per researcher in the public sector

EMM indicators
— Participation in Public-to-public partnerships per researcher in the public sector

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

Additional priority 2 indicator
— International co-invention rate with ERA partners

— International co-publication rate with ERA partners

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

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

EMM indicators
— Share of developing ESFRI Projects in which a Member State or an Associated Country participates

— Share of operational ESFRI Landmarks in which a Member State or an Associated Country is a partner**Error! Reference source not found.**

Priority 3 – Open labour market for researchers

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

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

— Share of researchers expressing satisfaction that the hiring procedures in their institution are open, transparent and merit-based**Error! Reference source not found.**

Priority 4 – Gender equality and gender mainstreaming in research

Headline indicator
— Share of women in Grade A positions in HES

EMM indicators
— Gender dimension in research content

— Share of female PhD graduates**Error! Reference source not found.**

Additional priority 4 indicators
— Share of women researchers

— Share of women heads of institutions in the Higher Education Sector

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

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

EMM indicators
— Share of public research financed by the private sector

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

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

Headline indicator
— Share of publications available in open access (green and gold)

EMM indicator
— Open access policies in national action plans

Priority 6 – International cooperation

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

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

— Licence and patent revenues from abroad as a share of GDP

Additional priority 6 indicators

— International co-publication rate with non-ERA partners**Error! Reference source not found.**

— International co-invention rate with non-ERA partners

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The European Research Area (ERA) Progress Report 2016 shows the state of play in ERA. A lot has happened in the European research landscape since the last edition in 2014. The ERA Roadmap at EU level was endorsed by the Council in early 2015. This called for top action priorities that will have the biggest impact on Europe's science and innovation systems. Member States were invited to draw up national action plans based on this approach. Last year almost all Member States and a number of Associated Countries have published their National Action Plans on ERA showing clear political ownership of ERA.

This analysis carried out in 2016 shows strong progress in all ERA priorities across the EU. This was possible because of a true partnership among the Member States and Associated Countries, the Commission and research stakeholder organisations. But we cannot be complacent. European strength in the field of Research and Innovation is needed more than ever to reinforce competitiveness but is also increasingly challenged to deliver on impacts. The Commission’s policy agenda on Open Science, Open Innovation and Open to the World will open up ERA to future challenges, like digitalisation and global networks. There are new barriers to break down to create more wealth and security for our citizens.

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