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Review of Issues Related to Methods, Criteria and Indicators for Widening Actions

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EUROPEAN COMMISSION

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Directorate-General for Research and Innovation
Spreading Excellence and Widening Participation

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EXECUTIVE SUMMARY

1. This report considers issues related to the criteria and indicators that might be used to define targets for future "Widening Actions" designed to address inequality in research and innovation performance across EU Member States. Under Horizon 2020, this has been the focus of the "Spreading Excellence and Widening Participation" Work Programme.
2. The selection of indicators needs to be informed by the characteristic of inequality in research and innovation. In this regard, it is important to recognize that the overall purpose of the EU investment in science and innovation is to drive economic growth. This raises questions regarding the use of economic indicators alongside measures of research and innovation performance in future "widening" targeting.
3. Research and innovation systems operate at a variety of spatial scales, including regional as well as national and supra-national. However, it is recognized that national systems remain critical for innovative performance. The European Research Area (ERA) objective is to create a genuine "single market" for knowledge, research and innovation. ERA objectives have been strongly focused on integration of national research and innovation systems.
4. Recent research indicates the existence of various "innovation divides" between Member States. A difference in performance is still discernable between western and eastern Europe. There is also an emerging divide within eastern Europe as some Members States have outperformed others. Recent studies also show an emerging north-south divide in research and innovation performance with below average performances in Portugal, Spain and Greece.
5. There are variations between Member States in levels of participation in H2020. These patterns of participation do not precisely match the research and innovation divides. There are some very high performing Member States whose participation in H2020 is quite modest. Some EU13 Member States with below average performances in research also display low participation rates in H2020.
6. Research demonstrates that indicators of research and innovation are scale-dependent. Some larger countries may display only modest performance due to averaging between very high performing metropolitan regions and weaker peripheries. On the other hand, indicators can be misleading for smaller countries due to boundary effects and variability associated with small scale.
7. There may be advantages in closer alignment between research and innovation interventions and the European and Structural Investment Fund (ESIF). This suggests that indicators that are relevant to both these policy fields, and also available at national as well as regional scales, could be advantageous.

8. In the context described above, this document examines the merits of a range of possible indicators of future performance that includes socio-economic indicators alongside measures of research and innovation performance. The assessment covers the following indicators:

9. Socio-economic indicators

- Socio-economic status – GPD per capita (PPS Index)
- Productivity – GDP per worker / GDP per hour
- Economic Structure – Percent of employment in knowledge intensive activity
- Business Innovation - % Enterprises classed as "innovation active"

10. Research and innovation single indicators

- Expenditure – Gross R&D Expenditure as a percent of GDP
- Publication - highly-cited scientific publications per million population
- Publication – % total scientific publications that is highly-cited
- Research Excellence and Institutional Capability – Top 500 Universities
- Patents – total number of PCT patent applications per million population

11. Research and innovation composite indicators

- Research composite indicator - JRC Research Excellence Indicator
- Innovation composite indicator – European Innovation Scoreboard Index

12. The assessment indicates that there are advantages and disadvantages to all potential indicators and that no single indicator adequately captures all aspects of the research and innovation process. Existing composite indicators could be adopted, but there are disadvantages in terms of complexity, timeliness and the ease with which these indicators can be reproduced.

13. An alternative approach to combining indicators is proposed based on "filtering" Member States using their ranking on three selected variables:

- Economic status – GDP per head
- Research performance - % of scientific publications in the top 10% citations
- Innovation performance – Number of PCT Patent applications per million population

14. Of the three indicators short-listed, it is noted that "% of scientific publications in the top 10% citations" is the most direct anticipated outcome from any investment in research activity.

15. On this basis, the following recommendations are made:

a) That the Commission considers further the merits of a "filtering" approach based on the three shortlisted variables;

b) That further checks are made on the three shortlisted variables to test their reliability and consistency from year to year;

c) That a decision to select just one of the short-listed variable for targeting purposes should be accompanied by further detailed assessment of its sensitivity over time and between Member States.

REVIEW OF ISSUES RELATED TO METHODS, CRITERIA AND INDICATORS FOR WIDENING ACTIONS

This report contributes to discussions within the European Commission Directorate-General for Research & Innovation concerning the selection of indicators for future Widening Actions within EU Framework Programme 9. "Widening Actions" refers to the "Spreading Excellence and Widening Participation" objective that is currently being delivered under Horizon 2020. The purpose of "Widening" is to address uneven performance between Member States in research and innovation.

The report develops arguments that may be important in seeking to justify the appropriateness of different indicators and approaches to using data as a basis for selecting target countries. The structure of this report is predicated on the principle that the selection of indicators and use of data needs to be guided by understanding of the policy objectives and the rationale for intervention in research and innovation processes. Before addressing the specific issues surrounding data and indicators, this report reviews the context of "widening" by summarizing the following:

- The overall purpose of H2020
- Objectives of the European Research Area (ERA)
- The "innovation divides" in Europe
- Variation in participation in H2020
- Regions and the "scale" issue in Research & innovation
- FP Research & Innovation and European Structural and Investment Funds
- Objectives of Spreading Excellence and Widening Participation (SEWP)

The discussions in sections 2 to 8 are based on existing policy documents and recent publishes evaluations and analyses of data. This is not intended as a comprehensive review of these policies but a discussion focused on the relationships between overall purpose and targeting using indicators. Section 9 then attempts to summarise these issues and provide a framework for discussion of indicators for future Widening Actions.

On the basis of the analysis from literature, section 10 presents eight indicators that could form the basis of a methodology to define targets for future Widening. These include measures of socio-economic outcomes as well as those that relate to outputs from research & innovation activity. Consideration is given to single indicators as well as composite indicators.

1 Purpose of Horizon 2020: Measuring Outcomes

In approaching issues concerning targeting of resources in any future Widening programme, it is important to consider this in the context of the overall objectives of Research and Innovation in the European Union. If we assume continuity with Horizon 2020, the objectives will continue an emphasis on the three pillars that informed the current programme. There is likely, therefore, to be continued focus on promoting and supporting excellence in scientific research, generating economic impact through innovation and industrial leadership as well as addressing societal challenges (H2020 interim evaluation, EC 2017a).

It is also significant to note that while the objectives of H2020 are specified in relation to excellence in scientific research and innovation, the EU Framework Programme represent a response to the need to create jobs and growth in the EU. This is restated explicitly in the Interim Evaluation of Horizon 2020 published in 2017. *"Horizon 2020 was designed to drive economic growth and create jobs by coupling research and innovation (R&I) with an emphasis on excellent science, industrial leadership and tackling societal challenges. The general objective is to contribute to the EU's overarching jobs and growth strategy by; helping to build a society and an economy based on knowledge and innovation across the Union"* (EC 2017a, p. 10).

The vital link between scientific excellence and economic growth is also made explicitly in a recent report on Science, Research and Innovation Performance of the EU that addresses the significance of open innovation and open science (EC 2016). The executive summary starts as follows: *"A continuing productivity challenge is hindering the European Union from re-taking the path towards sustainable economic growth and the creation of high quality jobs"* (p.8). The clear inference to draw from this is that the commitment of the EU to invest in its science base is not simply for its own sake but because of the belief that a stronger science base will address the competitiveness or "productivity gap" between the EU and its major global competitors, in particular the US and Japan.

> *"Addressing the GDP gap between the EU and the US and thereby restoring the EU's long term competitiveness will therefore ultimately require raining labour productivity. This depends in turn on increasing multifactor productivity which relates to innovation and investments such as R&D, ICT and skills development"* (EC 2016, p. 8).

These policy statements and associated arguments about the causal links between investment in research and innovation and economic growth suggest that some consideration should be given to the possibility of including measures of the overall economy in targeting Widening Actions. This point is considered further in sections 9 and 10.

2 European Research Area (ERA): Headline Research Indicators

While implementation of Horizon 2020 has taken into consideration the spatial or territorial context, its priorities have primarily been guided by the need to strengthen the EU's science-base and improve innovation *in the EU as a whole.* Spatial considerations have therefore focused on the completion and development of the European Research Area and specifically through the implementation of the "Spreading Excellence & Widening Participation" objective.

Aligned to the EU Framework Programme, the general purpose of ERA has been to work towards the creation of a genuine "single market" for knowledge, research and innovation (EC 2017b). Its objectives have been defined as follows:

- To create more effective national research systems
- To promote optimal transnational co-operation and competition
- To create an open labour market for researchers
- To promote gender equality and gender mainstreaming in research
- To promote optimal circulation, access to and transfer of scientific knowledge including "knowledge circulation" and "Open Access"
- To promote international cooperation in science and innovation

The "Spreading Excellence and Widening Participation" work programme under H2020 has therefore been a significant contributor to attempts to deliver ERA objectives. It is particularly pertinent in the debate concerning indicators for future widening that the ERA objectives are strongly focused on the integration of *national* research and innovation systems.

As a policy objective for ERA, the emphasis on national systems and national indicators can be justified in various ways. National research and innovation systems have a very powerful influence on the knowledge base through government funding for research, industrial innovation and business support. Promoting transnational cooperation in research and innovation through the mechanism of H2020 is therefore entirely plausible as a means of improving the performance of the EU research base. This is likely to lead to greater knowledge exchange and wider access to new scientific ideas.

This approach to investment in research and innovation is consistent with a broad area of academic literature that considers the ways in which innovation occurs within economies. One of the leading authors in this field, Bengt-Ake Lundvall (2007), has reviewed the concept of innovation systems demonstrating that the concept originated in the 1980s as a phenomenon applied to the national scale. An "innovation system" has been variously defined as a set of public and private institutions that interact in the development and diffusion of economically useful new knowledge.

The significance of *National* Innovation Systems is that many of institutions that form innovation systems, including governments, operate at a national scale. It is, of course, evident that there will be variations between countries in terms of the role of sub-national territories that generate regional innovation systems (Asheim *et al*, 2016). Also, national innovation systems vary in their degree of openness to global influence particularly since the concept of open innovation has been widely promoted. Lundvall accepts that innovation systems can operate at a variety of spatial scales, but that these are not alternatives to the analysis of national systems. Furthermore, institutions that operate at the national scale still exercises a major influence over the process of research and innovation and that "especially in the current period of globalisation, the focus on the national level is important and legitimate (Lundvall 2007, p. 100).

Given these policy directions, it is clear, that the *relative performance of national research and innovation systems and the levels of interaction between them* are key phenomena for ERA and hence for the Spreading Excellence and Widening Participation agenda. In this context, ERA has invested considerably in distilling key variables for comparing the performance of Member States and Associate Countries. The ERA Monitoring Handbook (EC 2017b) assessing the relative merits of different indicators and produces a matrix of headline indicators aligned to each of the Strategic Priorities of ERA. Under Priority 1 – More effective national research systems – the handbook identifies three headline indicators as shown in Table 1.

Table 1: ERA Headline Indicators for Priority 1: More Effective National Research Systems

	Input Indicator	Output Indicator	Outcome/Impact Indicator
Definition	Government Budget Allocation for R&D (GBARD) as % of Gross Domestic Product (GDP)	Adjusted Research Excellence Index (REI)	European Innovation Scoreboard Summary Innovation Index (SII)
Source	Eurostat	Joint Research Centre (JRC)	European Innovation Scoreboard (EIS)

Source: EC (2017) ERA Monitoring Handbook 2016 Report by Science-Metrix, Page 5

The indicators identified as key for measuring progress towards targets for ERA focus understandably on different aspects of research and innovation (inputs, activities, outputs, impacts). It is significant to note, however, that measures of overall economic performance are not included. This is perhaps surprising given the statements noted above about the overall purpose of the Framework Programme and the logic of investment in "open science and open innovation". This point will be discussed further in relation to choice of indicators for SEWP that presently do not include measures of national economic performance.

3 Innovation Divides: Indicators

In the context of the relative performance of national research and innovation systems, there is considerable policy debate concerning what are referred to as "innovation divides" at the national scale across the EU. The existence of "innovation divides" is not new. Indeed, the whole concept of ERA from its inception was couched in terms of an innovation gap between the EU and its major global competitors in the United States and Japan. Europe, it was argued, needs to invest more in the production and dissemination of knowledge in order to maintain economic growth, competitiveness and employment (EC 2000, p.5).

It was argued that closing this global divide requires investment in the integration of European research effort in order to address the fact that "*Europe's scientific and technological fabric lacks cohesion*" p. 18. There needs to be a "*territorialisation of research policies……. a better understanding and strengthening is needed of the role that the regions can play, in addition to the Member States of the Union*".

However, the immediate focus of addressing cohesion since 2000 has been to integrate the scientific communities of Western and Eastern Europe. It was recognised that there was a need to "*improve the research capacities of the Countries applying for accession and integrating their researchers in the European scientific community"* (EC 2000, p. 18).

Studies applied to the period of FP7, 2006 to 2013, have identified some convergence in research and innovation performance but significant divides remain. There is no simple empirical description of this divide. Using indicators from the Innovation Union Scoreboard (IUS), Veugelers *et al* (2016) have shown that, at least in terms of IUS indicators, there is no simple east-west division.

Some countries that have joined the EU since 2000 outperform others considerably, in particular Estonia and Slovenia. There is also a strong north-south divide particularly with regard to finance as an enabler. Since the economic crisis, the divide between countries in terms of public spending on research and development relative to GDP has increased. *"Innovation–leading countries have forged ahead but the followers have not been able to keep up, leaving a wider gap in public R&I spending now than before the crisis"* Veugelers *et al* (2016 p. 11).

If the pattern of innovation performance defies simply description, the causes of these apparent variations between Member States and associate countries introduce even greater complexity. This can be seen by disaggregating some of the components of innovation performance. One key aspect concerns national variation in the level of "research intensity" (R&D Expenditure as a proportion of GDP) that is one of the five key headline targets of the Europe 2020 Strategy.

Quite clearly, variation in the level of resource input is likely to one key explanation for any variation in the quality and quantity of research output and innovation performance. In a recent review of science, research and innovation performance of the EU (EC 2016), R&D Intensity for 2014 is shown to vary considerably between member states. Table 2 reinforces the point made by Veugelers *et al* (2016) that while there are some systematic differences between east and west, this generalization has an increasing number of notable exceptions. Slovenia, the Czech Republic, Estonia and Hungary display high growth in R&D Intensity 2007-2014 and out-perform many EU-15 Countries in 2014. Several EU-15 countries are ranked below these high-performing EU-13 member states including several that have experienced recent decline in this indicator (Portugal -1.9%; Spain -0.4).

Data on R&D outputs are also analysed in this document, including levels of scientific publication. Table 3 shows countries ranked according to a measure of the quality of research outputs based on citation (percent of authors in each country that have been associated with at least one publication in the top 10% most highly cited in the world). There is no single or simple measure of research quality, but the level of citation by other authors is one indicator that has been used, though we should acknowledge that citation is a surrogate of quality and there may be reasons for variation in citation that have nothing to do with quality.

It is, however, likely that high quality research will also be widely cited. The rank order mirrors the conclusions drawn above concerning "divides" across the EU. There is a broad divide between east and west but also elements of a north-south divide with below average performance in Portugal, Spain and Greece. There are also contrasts within central and eastern Europe with stronger performances in Estonia, Slovenia, Hungary and the Czech Republic compared to others.

Table 2: National variations in R&D Intensity in 2014 (Expenditure on R&D as a percentage of GDP)

Member State	R&D Intensity 2014 (provisional)	R&D Intensity compound annual growth (%) 2007-2014
Finland	3.17	-0.8
Sweden	3.16	-0.4
Denmark	3.08	3
Austria	2.99	3
Germany	2.84	2.2
Belgium	2.46	4.2
Slovenia	2.39	4.5
France	2.26	2.1
Czech Republic	2	6.3
Netherlands	1.97	1
United Kingdom	1.72	0.3
Ireland	1.55	3.3
Estonia	1.46	4.6
Hungary	1.38	5.3
Italy	1.29	1.8
Portugal	1.29	-1.9
Luxembourg	1.24	-3.6
Spain	1.2	-0.4
Lithuania	1.02	3.5
Poland	0.94	7.5
Slovakia	0.89	10.2
Malta	0.85	6.4
Greece	0.83	3.8
Bulgaria	0.8	9
Croatia	0.79	-0.1
Latvia	0.68	2.9
Cyprus	0.47	2.2
Romania	0.38	-6.3
EU	**2.03**	**1.9**

Source: Data abstracted from figure 1-2-11 in EC (2016) Science, Research and Innovation Performance of the EU: Open Innovation, Open Science, Open to the World agenda P 3

Table 3: Authors in a country with at least one publication in top 10% most highly cited in the world (Citation window up to 2013)

	Authors with pub 10%	% Authors with top 10%
Netherlands	59,465	35.0
Switzerland	43,481	34.1
Denmark	21,891	33.9
Sweden	36,507	31.8
Finland	18,204	31.6
Belgium	28,378	30.8
United Kingdom	181,507	30.3
Iceland	4,088	28.7
France	123,774	28.6
Germany	171,508	28.6
Italy	96,604	28.5
Norway	14,060	28.1
EU	**822,456**	**27.4**
Austria	18,124	27.1
Ireland	9,157	25.4
Portugal	10,241	22.2
Luxembourg	398	21.3
Spain	69,639	21.1
Estonia	1,409	21.0
Greece	14,505	19.8
Cyprus	529	19.3
Slovenia	2,762	18.1
Hungary	6,739	16.5
Czech	8,970	15.8
Poland	14,668	12.3
Romania	3,722	11.6
Lithuania	1,042	11.5
Bulgaria	1,702	11.0
Slovakia	2,177	10.4
Malta	101	10.3
Latvia	337	10.2
Croatia	2,379	9.6
Serbia	1,275	9.1

Source: Analysis of data from SCOPUS database reported in EU (2016) *Science, Research and Innovation Performance of the EU*. Data abstracted from Fig 11-3-8. P. 169; N.B. Analysis relates to publications in the period 2000-2010 and citation window through to 2013.

4 Participation in H2020

The existence of complex innovation and research divides in Europe has been noted in section 4. A recent report produced by the European Technology Assessment Group (ETAG, 2017) has also investigated variation in patterns of participation in Horizon 2020 (Science and Technology Options Assessment (STOA-Project, 2017). This data also reveals variation across Member States. Before presenting these patterns, it should be noted that data on participation in H2020 is complex and considerable effort is required to "clean" information into a useable form. H2020 projects are, for most part, complex consortia across countries and roles and responsibilities vary considerably between individuals involved. Also, Member States vary in size considerably, and data therefore needs to be standardized using suitable denominators. It should be noted that the patterns displayed are highly sensitive to the choice of denominator (e.g. population, GDP or number of scientists in each Member State).

Data in Table 4 is taken from the STOA Report (ETAG, 2017). This shows the number of participations for each type of funding scheme for Member States in H2020 per thousand FTE researchers. It should be noted, therefore, that countries with comparatively small research communities could score very well on this indicator with relatively few successful participations. As in the case of innovation divides, it is evident that E-13 Member States are more commonly in the lower half of rankings. However, this is not always the case and significant exceptions remain. Rates of participation in CP/IA/RIA, for instance vary considerably within the EU-15 with some very low rates of participation in countries that have very good R&I performance.

The STOA report repeats a statement that has commonly been asserted that *"no single indicator can adequately provide a complete picture of FP participation. EU-13 underperformance is a complex problem"* (ETAG, 2017, p.19). In a commentary on low participation in FP7, the same point was made in 2011 (Council of the European Union 2011) that *"no single indicator can provide a complete picture of participation under FP8 or for that matter any other research programme".* (p.3).

Most of the time, EU13 can be found at the lower end of participating rankings. Yet some EU-13 Member States are developing quickly and have excellent research centre. There is, in fact, considerable heterogeneity within the EU-13 group and also within the EU-15. These variations in H2020 participation, however, do not precisely match the "research and innovation divides" noted in sections above. It is possible therefore to observe very high performing Member States whose participation in H2020 appears fairly modest (e.g. Denmark, Sweden).

The report seeks to offer an explanation for these variations in participation specifically within the EU-13. Statistical analysis provides some support for the following explanatory factors:

- Lack of experienced coordinators in some EU-13 Member States
- Weak collaborative networks with other centres of research
- Weak National R&I Systems with low capacity to support bids
- Perception of high administrative burden and low success rate

It is concluded that uneven participation is perhaps unavoidable simply because of the primacy given to research excellence in assessing proposals and the competitive process. However, the argument in support of special measures to spread excellence and widen participation remains compelling.

"The concentration of resources in a strong, excellent core whose competition position is reinforced through continued participation is problematic for organisations and countries that are currently excluded" (p. 29).

Table 4: Number of participations per type for selected funding schemes from the EU-15 and EU-13 in H2020 per thousand fte researchers

	CP/IA/RIA	CSAs
EU15	**10.7**	**2.9**
Austria	14.2	4.6
Belgium	16.9	7.8
Germany	8.1	1.8
Denmark	9.4	2.7
Greece	21.6	5.8
Spain	17.5	4.5
Finland	11.4	3.3
France	6.6	1.9
Ireland	15.2	4.3
Italy	16.5	4.8
Luxembourg	24.7	12.7
Netherlands	16.6	4.2
Portugal	11.4	4.8
Sweden	8.7	2.0
UK	8.0	1.8
EU13	**6.4**	**4.8**
Bulgaria	5.5	7.9
Cyprus	98.4	53.8
Czech Republic	5.7	2.5
Estonia	18.1	15.0
Croatia	8.8	13.6
Hungary	6.4	3.7
Lithuania	5.7	5.3
Latvia	10.1	13.3
Malta	29.9	36.2
Poland	3.2	2.2
Romania	9.1	8.0
Slovenia	20.8	10.7
Slovakia	4.9	4.7

Source: STOA (2017) abstracted from table on p. 40; IA - Innovation Actions; RIA - Research and Innovation Actions; CSA – Coordination and Support Actions.

5 H2020, Regions and the Scale Issue in Measurement

The objectives of ERA and SEWP Programmes are specifically directed towards the national scale. There is little doubt that national research and innovation systems are important in determining the capacity and capability to engage in high quality research and innovation. However, some of the socio-economic processes that influence research and innovation operate at other scales, including the regional. The STOA Report recognizes this in its discussions of variations in participation.

It is noted that participation is not just subject to national variation but there are also **significant regional variations within Member States.** The discussion that follows this identifies some of the key regional processes that influence research and innovation including prominently **institutional capacity, human capital and access to specialist equipment and facilities**. Agglomeration factors are also significant in that learning accumulates over long periods of time and major centres of population act as reservoirs of *"accumulated practical experience and skills".* (ETAG 2017, p. 23)

> *"Another way of looking at participation is the measure of regional concentration. Regional and institutional disparities of participants, i.e. spatial and institutional concentration of participants in more developed regions and in research stronger and larger institutions, concentration of research resources in terms of human capital, equipment, large infrastructure as well as in project management capacities through accumulation of practical experience and skills can be the most critical factors for success in EU projects". (ETAG 2017 p.23)*

It is relevant to note that an analysis of low participation in FP7 circulated by the Council of the European Union in 2011 refers to regional concentration as an issue for the future Framework Programme. It was noted that in many countries *"there appears to be a significant concentration of research activity in a few major centres"* (Council of the European Union, 2011, p.3). It is also the case that many high performing research institutions are concentrated within larger metropolitan areas and capital city-regions across Member States. There is, of course, a considerable academic literature on the role of regions in innovation processes that focuses in particular on the significance of institutional capacity and "tacit knowledge" for economic development.

The regional scale effects have several important implications for the present study that focuses on national variation in research and innovation. Firstly, some larger countries may in fact represent averages of very high performance research-intensive regions alongside much weaker peripheral regions. In these circumstances, national indicators will display only moderate or even poor performances. In other instances, some Member States occupy limited territories that are smaller than many regions in larger Member States. Indicators of research and innovation activity for small states are likely to experience much greater volatility over time and appear as outliers in statistical analyses.

6 Aligning FP Research and Innovation to ESIF

The Joint Institute for Innovation Policy (JIIP) has recently reported on the synergies between the Framework Programmes for Research and Innovation and European Structural and Investment Funds (EC 2017c). The document notes that most (86.8%) H2020 work programmes refer to European Structural and Investment Funds (ESIF) in their specifications although the reference is sometimes in passing or in footnotes. Most calls for proposals ask applicants to "consider" the link with ESIF but specific guidance on how to achieve this is often absent.

The results of a survey of H2020 National Contact Points (NCPs) reveal that there is limited exchange of information between these programmes but a recognition that there are benefits in achieving this for both. It is relevant to the context of SEWP, however, that proposals from EU-13 Member States are more active in this regard than the EU-15. The report highlights the need to harmonise the two programmes in terms of accounting practices, timing and methods of reporting.

The JIIP report suggests that strategic alignment between **place-based innovation investments** through ESIF and **world-class research and innovation initiatives** via the Framework Programme could be highly beneficial in maximizing the impact of both types of intervention. A range of types of potential synergy are identified;

- ESIF as a potential **alternative source of funding** for positively evaluated Framework Programme proposals that are currently not supported due to insufficient budget;
- A source of funding for actions designed to build **research and innovation capacity** of actors;
- Funding for "downstream" actions of Framework Programme research and innovation projects such as **market up-take**;
- Combining funding for **coordinated parallel actions** that complement one another in specific place-based settings;
- Fully **integrated research and innovation projects** that are jointly funded by ESIF and Framework Programme.

This range of possibilities suggests coordination between Structural Funds and Research and Innovation at the strategic level and in the design of whole programmes. However, there could also be actions to facilitate alignment between ESIF and Framework Programme at the level of individual calls for specific projects.

Interviews conducted with a range of stakeholders, including ESIF Managing Authorities and H2020 NCPs revealed that there are some successful experiences already with regard to coordinating ESIF and H2020 funded projects. These include examples where the results of H2020 projects are integrated into regional development initiatives funded by ESIF. Also, examples were identified where ESIF investments in regional research infrastructures provided a platform for successful proposals for H2020 projects. However, interviewees also drew attention to the need for awareness raising on the opportunities for synergies and harmonization of governance and management rules for the ESIF and Framework Programme.

This discussion does have a bearing on the selection of indicators for future Widening. While selection of indicators should not necessarily prevent closer alignment between these policy arenas, it is possible that alignment could be much more likely to take place if some of the selected indicators are relevant to both. Also, ESIF interventions are applied at the regional or sub-national scale while the Framework Programme largely seeks to influence national systems. It is possible, therefore, that there could be advantages in selected some indicators that are **relevant to both economic and research and innovation performance** and also **available at national as well as regional scales**.

At present, there is no explicit alignment of H2020 and ESIF in relation to targeting and use of indicators. Structural Funds are focused at regional scale while as noted above, H2020 seeks to address EU-wide objectives through inputs of resource at the spatial level of Member States. Also, target countries for Structural funding focuses on indicators of regional economic performance or status while H2020 emphasises measures of R&I performance. These issues affecting alignment are considered in further in sections 9 and 10.

7 Spreading Excellence and Widening Participation

As noted in section 1, while the priorities of Horizon 2020 have focused on the performance of research and innovation in the EU as a whole, territorial issues have been addressed through the implementation of the "Spreading Excellence & Widening Participation" objective. Actions under this objective have been designed to address uneven performance between Member States in research and innovation. Actions have addressed the need to build capacity for research and foster networks between countries that are lagging behind and researchers in high performing Member States. The "Widening agenda" also extends to spreading excellence to neighbouring non-Member States or "Associate Countries" that have subscribed to the concept of ERA.

Table 5: The Current "Widening Countries" under H2020

Member States	Associate Countries
Bulgaria	Albania
Croatia	Armenia
Cyprus	Bosnia and Herzegovina
Czech Republic	Faroe Islands
Estonia	Former Yugoslav Republic of Macedonia
Hungary	Georgia
Latvia	Moldova
Lithuania	Montenegro
Luxembourg	Serbia
Malta	Tunisia
Poland	Turkey
Portugal	Ukraine
Romania	
Slovakia	
Slovenia	

The Widening countries under H2020 were identified using a composite indicator of scientific and technological research excellence that combines four variables as follows (See Table 6 based on Hardeman *et al* 2013):

- Number of highly cited publications of a country measured by the top 10% most cited publications per total number of publications;
- Number of high quality patent applications of a country as measured by the number of patents filed under the Patent Cooperation Treaty (PCT) per million inhabitants;
- Number of world class universities and research institutes in a country measured by the number of organisations of a country in the top 250 universities and 50 research institutes divided by gross expenditure in R&D of a country; and
- Number of high prestige research grants received by a country as measured by the total value of ERC grants received divided by public R&D expenditures of a country.

The rankings produced by the Composite Research Excellence Index using the most recent data available in 2013 are shown in Table 6. It is worth noting that the indicators used to create this index are all at national level, not regional or sub-national. Also, the four indicators used capture different aspects of research and innovation - the first two can be regarded as "outputs" from the innovation system (publications quality and patents) while variables three and four represent different inputs to the process (Institutional capacity and funding). These indicators are combined using a *geometric* average. As a measure of central tendency, the geometric average reduces the effects of extreme values. The target "Widening" countries were defined as those that fall below the threshold of 70% of the EU average on this composite indicator (i.e. circa 33.5).

SEWP's key actions to address widening participation have included principally:

- Teaming – creation of new or updating existing centres of excellence in low R&I performing Member States through "teaming" with internationally leading institutes in Europe
- Twinning – strengthening a defined field of research inan emerging institution in a low performing R&I Member State by linking to at least two internationally leading counterparts in Europe
- ERA Chairs – supports universities or research organisations in low R&I performing Member States by attracting and maintaining high quality human resources under the direction of an outstanding researcher or research manager (the "ERA-Chair holder").

In addition, SEWP provides funding to support Member States in the development and implementation of research and innovation policies (Policy-Support Facility; PSF) and support for a dedicated network of Widening National Contact Points (NCPs). Support for Co-operation in Science and Technology (COST) is also provided for a range of other networking actions.

The activities funded through SEWP have been subject to appraisal as part of the Horizon 2020 mid-term review and various other groups have reported on particular elements of the overall programme. An issue paper prepared for the High level Group on maximizing the impact of EU Research and Innovation Programmes (EC 2017d) noted the high level of response to calls under SEWP, especially for Teaming Actions.

Table 6: Composite Research Excellence Index "2010" by Country

EU Member State	Research Excellence Index
Switzerland*	97.6
Netherlands	78.9
Denmark	77.7
Sweden	77.2
Finland	62.9
Germany	62.8
Belgium	59.9
United Kingdom	56.1
Norway*	51.8
Austria	50.5
France	48.2
EU (27 countries)	*47.9*
Italy	43.1
Iceland*	38.8
Ireland	38.1
Spain	36.6
Greece	35.3
Hungary	31.9
Czech Republic	29.9
Cyprus	27.8
Slovenia	27.5
Portugal	26.5
Estonia	25.9
Bulgaria	24.7
Poland	20.5
Luxembourg	19.8
Romania	17.8
Slovakia	17.7
Malta	17.5
Lithuania	13.9
Croatia*	12.2
Latvia	11.5

Source: Abstracted from Hardeman S, Van Roy, V and Vertesy D (2013). p. 55
*Includes data on several non-EU Countries at time of calculation, marked **

The interim evaluation of the Twinning and ERA Chairs actions (EC 2017) concluded that progress has been made in both these areas. Under Twinning, projects have successfully established effective partnerships between institutions. For instance, even by the time of the survey conducted Aug-Nov 2016, 43 percent of the respondents to the Twinning survey (circa 45 replies) indicate that the project had led to the production of joint peer reviewed publications and one quarter had submitted a joint research proposal (EC 2017e p. 18).

While SEWP has undoubtedly produced benefits for participants, assessing the overall impact of Widening is a more complex task. The final report on the Horizon 2020 Advisory Group (2016) on SEWP indicated that there had been early success by concentration of funding on leading locations and institutions within the target countries but that this may have contributed to an "emerging gap among the target countries" (H2020 Advisory Group, 2016, p. 2). This suggests that there are still significant challenges for the Widening agenda.

8 Implications for Indicators for Future Widening Action

The themes discussed above could all have some bearing on the design of future Widening actions but also the choice of indicators and methodologies for targeting these Actions. The following key points appear to be of relevance:

a) Horizon 2020 is "designed to *drive economic growth and create jobs by coupling R&I with excellent science*…."

b) Open innovation and open science is regarded as a key strategy for *sustaining economic growth and the creation of high quality jobs*.

c) The concept of ERA is primarily a response to the identified need to strengthen and integrate the science base *in the EU as a whole*

d) One key objective of ERA aims to increase collaboration between more effective *national research systems*

e) There are still *significant divides between member states* in terms of performance in research and innovation. These divides are *not simply east – west*. There are also *significant and growing divides between EU-13 Member States and between north and south within the EU-15.*

f) Patterns of participation in H2020 are *complex and not subject to simple explanation using single variables.* EU-13 Member States are more commonly found in the lower half of any ranking on different indicators (especially those that refer to coordinators). However, there are significant exceptions to this generalisation.

g) There are *significant variations in patterns of R&I performance and also levels of H2020 participation at the regional scale.* R&I distribution in characterised by significant concentrations of activity in relatively few capital city-regions.

h) Some *large countries can display only moderate performance* in R&I due to scale effects (averaging across regions with varied performance)

i) Some *very small countries can appear as outliers* in distributions (both high and low) due to boundary effects and the influence of scale on data

j) Indicators used to target Widening Countries under H2020 do not currently include measures of economic performance and indicators that are available at regional as well as national scale.

k) Published evaluations of H2020 and specific elements of the current SEWP programme conclude that there has been *successful delivery*. In particular, there has been a *high level of application* especially for Teaming Actions.

l) Evidence suggests that there is an *emerging gap among the present target countries*. Also, there is a need to consider how to ensure *positive legacy* from the current SEWP programme.

These preliminary conclusions from the review of literature suggest a number of general principles to guide selection of indicators that are *relevant to* future widening actions.

- The discussion suggests that there is a need to *consider socio-economic indicators alongside more immediate research & innovation measures* in order to capture the overall intended purpose of investment in science and innovation.
- The literature also indicates that the processes and institutions that generate research and innovation are complex and varied and that the performance of these *national systems cannot easily be captured reliably in a single indicator*.
- Choice of indicators, however, not only needs to be justified in terms of relevance but also in terms of *ease of data collection and analysis*. This is important not only for the *efficiency with which data can be replicated* in future but also in relation to *communication of indicators to stakeholders*.
- Finally, the possibility of alignment between future Widening interventions and ESIF could be facilitated by selecting some indicators that are *relevant to both economic and research and innovation performance* and also *available at national as well as regional scales*.

It is proposed therefore that a range of indicators should be considered covering both economic and research domains and including both single and composite forms of measurement. With this in mind, the following indicators have been selected as a possible basis for possible targeting of future Widening Actions:

Socio-economic indicators

- Socio-economic status – GPD per capita (PPS Index)
- Productivity – GDP per worker / GDP per hour
- Economic Structure – Percent of employment in knowledge intensive activity
- Business Innovation - % Enterprises classed as "innovation active"

Research and innovation single indicators

- Expenditure - R&D intensity – Gross Research and Development Expenditure as a percent of GDP
- Publication - Total number of highly-cited scientific publications per million population (citation window 2014-2016)
- Publication – Proportion of total scientific publications that is highly-cited (citation window 2014-2016)
- Research Excellence and Institutional Capability – Top 500 Universities
- Patents – total number of PCT patent applications per million population

Research and innovation composite indicators

- Research composite indicator - JRC Research Excellence Indicator
- Innovation composite indicator – European Innovation Scoreboard Index

9 Indicators for Future Widening Actions

This section considers each of the "long-list" of indicators identified in chapter 9. The rationale for their consideration is explained and the technicalities of data collection are evaluated. These indicators are all derived from data that is collected routinely for other purposes and likely to be available on a time series bases.

9.1 Socio-economic status – GDP per capita (PPS Index)

As argued elsewhere in this report, the commitment of the Commission to support investment in research and innovation arises from a desire to see improved socio-economic conditions across the European Union. It is expected that increasing investment in research and development will create new knowledge, increase knowledge intensity in the economy, improve competitiveness and enhance wealth creation. Extending this logic, it can be argued that Member States with lower living standards have a greater need for interventions to support research and innovation activities.

Gross Domestic Product (GDP) can be regarded as a measure of national wealth and expressed *per capita*, it is commonly viewed as a proxy for living standards. GDP measures the value of final output of goods and services produced by an economy less the value of any goods and services used in their creation. It is not a complete measure of the economy as it excludes some aspects such as unpaid work and activities in the informal economy. Also, it does not account for negative externalities created, for instance, by environmental degradation. However, expressed as a ratio to population, GDP is used as a broad indicator of variation in *material living standards* across different countries.

The indicator available on Eurostat for cross-country comparison is GDP *per capita in Purchasing Power Standards (PPS*). Eurostat footnotes to this dataset indicate that PPS expresses GDP in a common currency that seeks to minimize the effects of differences in price levels (i.e. the cost of living) between countries. The data is also available as an index with EU average set to 100 (Table 7).

Table 7: EU Member States: GDP per capita 2016

Index EU28=100	Current status	GDP per capita (PPS index) 2016
EU (28 countries)		**100**
Luxembourg	w	258
Ireland		183
Switzerland		161
Norway		148
Netherlands		128
Austria		128
Iceland		128
Denmark		124
Germany		123
Sweden		123
Belgium		118
Finland		109
United Kingdom		107
France		104
Italy		97
Malta	w	96
Spain		92
Czech Republic	w	88
Cyprus	w	83
Slovenia	w	83
Portugal	w	77
Slovakia	w	77
Estonia	w	75
Lithuania	w	75
Greece		68
Poland	w	68
Hungary	w	67
Latvia	w	65
Croatia	w	60
Romania	w	58
Bulgaria	w	49

Source: Eurostat (last updated 14.02.2018)
http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&plugin=1&language=en&pcode=tec00114

9.2 Productivity – GDP per worker and per hour

EU support for research and innovation is intended to improve the competitiveness of the economy through the impact that research outcomes have on the level of knowledge-intensity in the economy. The effect of this is to produce higher paid jobs and ultimately, to stimulate an increase in the level of labour productivity. It can be argued, therefore, that Member States that display lower levels of labour productivity have a greater need for interventions to stimulate research and innovation.

The conventional measures of labour productivity are based on GDP *per person employed* or GDP *per hour*, both of which are available for country comparisons on a consistent basis on Eurostat (based on "purchasing power standards", see above). The notes to this dataset draw attention to the fact that "persons employed" do not distinguish between full-time and part-time employment which varies considerably between Member States. For this reason, it is suggested that GDP per hour is a more accurate means of comparing levels of productivity between countries (Table 8).

Table 8: EU Member States: Productivity 2016

	Current status	GDP per worker	GDP per hour
Index EU 28 = 100		2016	2016
Ireland		190	179
Luxembourg	w	163	176
Norway		128	146
Belgium		130	137
Denmark		112	130
Germany		106	127
Switzerland		124	127
Netherlands		111	126
France		115	125
Austria		117	118
Sweden		114	114
Iceland		103	113
Finland		109	109
Italy		108	102
United Kingdom		101	99
Spain		102	98
Slovenia	w	81	79
Slovakia	w	82	77
Cyprus	w	84	77
Malta	w	93	75
Czech Republic	w	80	74
Portugal	w	78	68
Greece		81	65
Estonia	w	72	63
Croatia	w	71	63
Hungary	w	68	63
Lithuania	w	72	63
Poland	w	74	59
Romania	w	62	56
Latvia	w	65	56
Bulgaria	w	45	45

Source: Eurostat (last updated 14.02.2018)
http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&plugin=1&language=en&pcode=tec00114

9.3 Economic Structure – Employment in knowledge intensive activity

Support for research and innovation is intended to increase competitiveness by its impact on the knowledge economy. In seeking to raise living standards and improve productivity, it might be expected, therefore, that the structure of the economy would shift away from labour-intensive activities towards those that are more knowledge-intensive. Again, it can be argued that Member States whose economies have lower levels of knowledge intensity have a greater need for support to stimulate research and innovation.

Data on the percentage of employment in knowledge intensive activities is available on Eurostat on an annual basis by Member State. "Activities" are defined using the 2 digit codes in the Statistical Classification of Economic Activities in the EU (NACE Revised version 2 introduced in 2008). An activity is classed as "knowledge intensive" if workers with higher level qualifications (levels 5-8) represent more that 33% of total employment (Table 9).

Table 9: EU Member States: Knowledge Intensity 2016

	Current status	% Empl Knowledge Intensive activity
Luxembourg	w	51.1
Sweden		44.8
United Kingdom		43.7
Malta	w	43.5
Iceland		43.3
Switzerland		42.9
Belgium		42.5
Ireland		41.1
Norway		39.7
France		39.4
Denmark		38.8
Netherlands		37.9
Cyprus	w	37.9
Finland		37.5
Germany		37.2
Austria		36.2
EU (28 countries)		**36.1**
Greece		35.4
Hungary	w	34.9
Slovenia	w	34.7
Estonia	w	33.4
Italy		32.9
Spain		32.5
Portugal	w	32.4
Lithuania	w	32.2
Latvia	w	32.0
Croatia	w	31.7
Czech Republic	w	31.3
Slovakia	w	30.4
Poland	w	29.1
Bulgaria	w	28.2
Romania	w	21.1

Source: Eurostat: Annual data on Employment in KIAs at National Level NACE Rev 2 (htec_kia_emp2)
Last updated 17.01.18

9.4 Levels of Innovation in Business Enterprises

Historically, it has proved problematic to assess the levels of innovation in business partly due to the challenges posed by defining "innovation" but also the cost of data collection. Since 2014, however, Member States have been required to conduct surveys of enterprises to contribute towards a European-wide "Community Innovation Survey" (CIS). The survey is carried out every 2 years using a standardised survey instrument designed to record different types of innovation. Each survey has a reference period. Most recently published data is for 2014 with a focus on changes introduced in enterprises during 2012-14. Enterprise owners and managers are asked to indicate whether they have engaged in innovation activities in this time period and to describe the nature of that innovation (e.g. involved in new product, process, marketing initiative or R&D collaboration).

Table 10 shows that the proportion of enterprises that are classed as "innovation-active" during 2012-14 varied considerably between Member States. Some Countries lie well above the EU average of 49.1%, in particular in Germany, Luxembourg, Belgium, Ireland and the UK which all score above 60%. At the other extreme, innovation is much less widespread in enterprises in Estonia, Bulgaria, Hungary, Latvia, Poland and Romania (below 30%). As might be expected, the existing Widening Countries are predominantly placed in the lower half of this distribution, although there are outliers where scores are higher for Portugal (54%) and more especially, Luxembourg (65.1%).

This data can be further disaggregated to show how the characteristics of innovative processes vary between Member States. Table 11, for instance, shows the proportion of designated innovative enterprises that are involved specifically in some form of research and development cooperation either with a Institute for Higher Education, research entity or public sector body. This data indicates that, while innovation is not so widespread in most current Widening Countries, for some of these, the innovation that does occur involves longer-term commitments to collaboration. The proportion of innovative small and medium-sized enterprises that are involved in R&D collaborations is well above average, for instance, in Estonia, Slovakia, Lithuania, Slovenia and Hungary.

Table 10: Innovative Enterprises as % of Total Number of Enterprises 2014

	Current Status	% enterprises classed as "innovation-active"
EU		**49.1**
Germany		67.0
Luxembourg	w	65.1
Belgium		64.2
Ireland		61.0
United Kingdom		60.2
Austria		59.5
France		56.4
Netherlands		55.3
Finland		55.3
Sweden		54.2
Portugal	w	54.0
Greece		51.0
Denmark		49.5
Italy		48.7
Slovenia	w	45.9
Lithuania	w	43.3
Czech Republic	w	42.0
Cyprus	w	41.8
Malta	w	41.2
Croatia	w	39.7
Spain		36.4
Slovakia	w	31.8
Estonia	w	26.5
Bulgaria	w	26.1
Hungary	w	25.6
Latvia	w	25.5
Poland	w	21.0
Romania	w	12.8

Data reported in "Science, Research and Innovation Performance of the EU 2018" and provided by Unit 4: Monitoring and Analysis of national research and innovation policies European Commission

Data: Eurostat (Community Innovation Survey (CIS) 2014)

Table 11: % Share of Innovative Enterprises involved in R&D Cooperation 2014

	Current Status	2014: Large companies	2014: SMEs
EU 28		**55.4**	**31.5**
United Kingdom		68.0	61.0
Belgium		75.6	55.2
Estonia	w	89.5	54.4
Austria		75.5	48.2
Slovakia	w	74.1	44.9
Lithuania	w	66.7	43.0
Slovenia	w	66.7	42.2
Greece		77.5	38.8
Netherlands		52.1	37.7
Hungary	w	58.7	36.2
Denmark		67.1	35.9
Cyprus		88.5	35.6
Finland		75.5	35.6
France		62.8	33.5
Sweden		61.8	31.2
Spain		57.3	30.0
Czech Republic	w	59.6	29.8
Romania	w	37.9	29.7
Ireland		55.4	29.4
Croatia	w	57.5	26.3
Poland	w	50.9	24.6
Luxembourg	w	42.6	22.5
Latvia	w	43.1	21.9
Germany		46.4	19.8
Bulgaria	w	32.3	19.4
Italy		42.4	18.5
Portugal	w	56.2	17.6
Malta	w	28.6	14.3

Data reported in "Science, Research and Innovation Performance of the EU 2018" and provided by Unit 4: Monitoring and Analysis of national research and innovation policies European Commission

Data: Eurostat (Community Innovation Survey (CIS) 2014)

9.5 R&D Expenditure

The level of research and innovation activity can be measured using a variety of indicators that represent key inputs, activities as well as outputs. The most significant input concerns funding or expenditure on research and development. At EU level, a key target for research and innovation relates to a commitment to increase expenditure on R&D to 3 percent by 2010 (Lisbon Target). Achieving this target has proved to be elusive[1] but it remains a key goal for 2020. R&D expenditure can be regarded as a significant and relevant measure of the level of research activity (Table 12).

Reliance on R&D expenditure alone as an indicator of the need for future EU investment is, however, likely to introduce anomalies. Member States vary, for instance, in their capacity to absorb R&D expenditure; this can be related to the prevalence of research-intensive universities or the preponderance of research institutes. More significantly though, use of this measure to determine targeting for widening initiatives risks penalizing Member States that choose to prioritise R&D in national policies while rewarding those that may be underinvesting in their research and innovation activities.

[1] http://bruegel.org/wp-content/uploads/2016/10/Presentation-Georgios-Petropolous.pdf

Table 12: EU Member States: R&D Intensity

	Current status	R&D Intensity (based on Gross R&D Expenditure as % GDP) 2015
EU 28 =100		
Sweden		160
Austria		152
Germany		145
Denmark		142
Finland		135
Belgium		123
France		109
Netherlands		100
Slovenia	w	99
United Kingdom		83
Czech Republic	w	83
Estonia	w	63
Italy		63
Portugal	w	62
Luxembourg	w	61
Spain		59
Hungary	w	59
Ireland		58
Greece		49
Poland	w	49
Croatia	w	41
Slovakia	w	39
Bulgaria	w	38
Lithuania	w	36
Malta	w	30
Cyprus	w	25
Romania	w	24
Latvia	w	22

Source: Data compiled by Unit 4: Monitoring and Analysis of national research and innovation policies

9.6 Publication

The level of publication is a significant measure of research output. The term "bibliometrics" is now commonly used to refer to the application of quantitative measures to assess various attributes of scientific production and communication. It is used, in particular to inform assessments of research quality (Butler 2008; Frey and Rost 2010) and research impact (Penfield *et al* 2014) as well as a means to map the evolution of different scientific fields (Liu *et al* 2015). Research assessment exercises developed in recent years in many countries include bibliometrics as part of the process of assessing research.

A key metric for assessing research quality concerns the rate at which a publication is cited. Studies have shown that there is a degree of correlation between peer review assessments of research quality and levels of citation. However, authors also caution against over-reliance on citation data to assess quality. While not denying the value of citation, Frey and Rost (2010) identify a range of shortcomings in using citation to infer research quality:

- Citation does not distinguish whether a scholar is being cited for positive or negative reasons;
- Publication is known to be subject to "herding" tendencies as ideas go in and out of fashion;
- Citation does not necessarily mean that a publication has been read;
- Citation habits vary between disciplines and fields of study which can make comparisons unreliable;
- Easily accessed publications can be more highly referenced.

Most authors conclude that bibliometrics are useful but as a check on conventional peer review methods (Penfield *et al* 2014). Butler (2008) suggests that bibliometrics play a role in that they *make peer evaluation transparent* as assessors need to justify evaluations that differ from bibliometrics.

It should be noted that most previous published articles on the use of citation to infer research quality have been conducted in the context of *national research quality assessments* designed to determine funding of universities. They have not been developed to enable international comparisons. It is quite likely that citation behaviour will vary between countries and the rate of citation could well be influenced by the varied size of research communities. High quality research can also be published in different languages that have varied readership.

While recognizing these caveats, data that compares the level of citation for Member States can be accessed on the EU Research and Innovation Observatory – H2020 Policy Support Facility. Member States can be compared using the level of citation of publications associated with authors affiliated to each country (with adjustment for co-authoring). Scores for each country show the number of publications in the 10% most cited publications in a specified time period. It is possible to express this as a proportion of all publications in each country or as an index relative to size of population.

Table 13 shows highly cited publication relative to size of population. Member States deviate from the average considerably with high rates of citation in Denmark, Netherlands, Sweden, UK, Finland and Belgium but low levels in many existing widening countries (notably Bulgaria, Romania and Latvia). Two current Widening Countries perform well (Slovenia, Luxembourg) while several countries not currently part of Widening are ranked below average (in particular, Greece).

Table 13: Highly cited publication per million population (Citation window 2014-2016)

	Current status	Total number of highly cited scientific publications per million population
EU		*100*
Denmark		257
Netherlands		219
Sweden		197
United Kingdom		176
Finland		169
Belgium		152
Ireland		135
Austria		120
Slovenia	w	113
Luxembourg	w	111
Germany		108
Spain		90
France		86
Portugal	w	83
Italy		83
Estonia	w	69
Cyprus	w	67
Greece		61
Czech Republic	w	55
Malta	w	31
Hungary	w	27
Poland	w	27
Slovakia	w	24
Croatia	w	24
Lithuania	w	22
Romania	w	14
Latvia	w	8
Bulgaria	w	8

Source: Data compiled by Unit 4: Monitoring and Analysis of national research and innovation policies

The patterns created by any indicators can be affected considerably by the choice of denominator. Citation data in Table 13 standardises the level of highly-cited publication by expressing this number in relation to size of population in each Member State. A different pattern emerges, however, when the same data is expressed as a percentage of total publications. Arguably, this indicator is a more direct surrogate of the quality of the research outputs from each Member State. This data is ranked in Table 14. On this indicator, Luxembourg is the only current "Widening" Member State above the EU average.

Table 14: Highly –cited publication as % total publication

	Current Status	Top 10% highly cited publications as % all publications	Index EU28=100
EU 28		*11.1*	*100*
United Kingdom		14.8	133.3
Netherlands		14.3	128.8
Denmark		13.2	118.9
Belgium		12.6	113.5
Ireland		11.9	107.2
Austria		11.5	103.6
Sweden		11.5	103.6
Germany		11.5	103.6
Luxembourg	w	11.4	102.7
France		11.3	101.8
Finland		10.7	96.4
Italy		10.1	91.0
Cyprus	w	9.6	86.5
Spain		9.5	85.6
Malta	w	9.4	84.7
Portugal	w	8.9	80.2
Greece		8.7	78.4
Slovenia	w	8.3	74.8
Estonia	w	7.8	70.3
Czech Republic	w	6.7	60.4
Hungary	w	5.7	51.4
Slovakia	w	5.3	47.7
Poland	w	4.8	43.2
Romania	w	4.8	43.2
Croatia	w	4.1	36.9
Latvia	w	3.7	33.3
Lithuania	w	3.7	33.3
Bulgaria	w	3.6	32.4

Data reported in EC (2018) "Science, Research and Innovation Performance of the EU 2018" and provided by Unit 4: Monitoring and Analysis of national research and innovation policies European Commission

9.7 Research Excellence and Institutional Status of HEIs

Previous attempts to assess the level of research excellence have included consideration of the distribution of highly ranked Institutions of Higher Education measured by their research impact. A measure of this type, for instance, is included in the Joint Research Centre's Research Excellence Index (see below).

There are various published league tables of HEIs globally that attempt to rank institutions using combinations of indicators of teaching and research performance. The two most widely used indicators are drawn from The Times Education (THE) rankings and the Shanghai Ranking (Academic Ranking of World Universities (ARWU)). These league tables are increasingly influential in shaping the strategic decisions of many HEIs that aspire to global status. It should be noted, however, that while there are broad similarities between these various rankings, the outcome for individual institutions can vary considerably depending on which indicators are included or excluded. For instance, the ARWU ranking is based on six indicators that capture different types of institutional scientific output while THE covers a wider range of attributes including more qualitative assessments of reputation and image. These measures are perhaps subjective but they are nonetheless significant in determining the global reach and influence exercised by institutions.

It should be noted that the use of this indicator is not robust for small countries that have a low number of institutions. It is also the case that high performing HEIs are concentrated in relatively few countries and there are several Member States that do not have any HEIs listed in these tables (EC 2018, p. 167).

These points can be illustrated with reference to data from the Times Higher Education that lists the top 500 universities worldwide according to a range of measures that include consideration of the following aspects of performance:

- Teaching (aspects of the learning environment)
- Research indicators (volume, income, reputation)
- Citations (research influence)
- International outlook (staff, students and research)
- Industry income (knowledge transfer)

This listing for 2018 is shown in Table 15. The most striking feature of this listing is that that the majority of the current Widening countries (12 Member States) do not have any institutions ranked in the top 500. Luxembourg is the most highly ranked country, although this needs careful interpretation due to the Index being expressed as a number related to resident population. As noted elsewhere in this report, per capita indicators for Luxembourg can be misleading due to high levels of in-commuting which reduce the size of the denominator. Estonia, however, also performs well above average on this indicator. These characteristics suggest that league tables of this type may not be reliable as a single indicator of research and innovation performance but they may have some value as part of a combined index or a methodology that uses a number of indicators.

Table 15: Number of top 500 universities in the Times Higher Education World University Ranking per million population(1), 2018

	Current Status	Number of to 500 Universities per Million Popn 2018(1)
EU(2)		**0.44**
Luxembourg	w	1.74
Ireland		1.48
Finland		1.28
Denmark		1.23
Sweden		1.12
United Kingdom		0.90
Austria		0.81
Netherlands		0.77
Estonia	w	0.76
Belgium		0.71
Germany		0.52
Italy		0.51
France		0.30
Spain		0.15
Hungary	w	0.10
Greece		0.09
Not listed:		
Bulgaria	w	
Croatia	w	
Cyprus	w	
Czech Republic	w	
Latvia	w	
Lithuania	w	
Malta	w	
Poland	w	
Portugal	w	
Romania	w	
Slovakia	w	
Slovenia	w	

Source: Data reported in EC (2018) "Science, Research and Innovation Performance of the EU 2018" and provided by Unit 4: Monitoring and Analysis of national research and innovation policies European Commission

1) Times Higher Education - World university rankings (https://www.timeshighereducation.com/world-university-rankings/2018)

2) EU was estimated by DG Research and Innovation based on the data available for the Member States

9.8 Patenting

Patent statistics are commonly used as a measure of innovative performance not only in business but also across territories. Patent applications are counted in the year in which they were filed and can be assigned to countries according to the applicant's place of residence. As in the case of publications, fractional counting can be used where there are multiple applicants to avoid double counting. Patent applications can be expressed in terms rates per million population as in indication of the level of inventiveness in each Member State (Table 16).

Data on patenting attributed to the European Patent Office (EPO) is available on Eurostat by Member State. The OECD also publishes patent data filed under the Patent Cooperation Treaty (PCT) that enables inventors to submit one application covering a very wide range of signatory countries including Member States of the EU.

It is important to recognize that there are widely recognized disadvantages to using patent data to describe patterns of innovation (Archibugi and Pianta 1996). There is likely to be spatial bias in patent data particularly affecting smaller Member States and patterns at regional level. Patenting is costly and so the propensity to apply for patents is likely to vary between Member States. There are also likely to be variations in rates of patenting between counties caused by structural differences, as patenting is more common in some sectors than others. Finally, the location at which larger firms in particular choose to apply for patents may not necessarily correspond with the locations where such activities take place, as when files are submitted from a head office location. A study by Svensson (2015) in Sweden also shows that "patent quality" varies as not all patents lead to commercialization.

Despite these shortcomings, patent data has been used as a surrogate measure of innovation in research for several decades and this data is still regarded as the most reliable measure of spatial variation in innovation that is currently available (Sleiwaegen and Borardi 2014).

Table 16: EU Member States: PCT Patent Applications 2014

	Current status	Total number of PCT Patent applications per million popn
		2014
EU		*100*
Sweden		319
Finland		246
Germany		216
Netherlands		209
Denmark		207
Austria		173
Luxembourg	w	139
France		120
Belgium		107
United Kingdom		96
Ireland		90
Slovenia	w	67
Italy		56
Spain		39
Malta	w	32
Estonia	w	27
Czech Republic	w	24
Hungary	w	24
Cyprus	w	17
Lithuania	w	16
Portugal	w	15
Greece		11
Poland	w	11
Croatia	w	10
Slovakia	w	9
Bulgaria	w	8
Latvia	w	5
Romania	w	4

Source: Data compiled by Unit 4: Monitoring and Analysis of national research and innovation policies

9.9 *JRC Research Excellence Index*

As noted earlier in this report, the H2020 definition of Widening Countries was based on a composite indicator developed by the Joint Research Centre (JRC). The methodology used in this process has been outlined in Hardeman *et al* (2013) and updated in Hardeman and Vertesy (2015). Briefly, the method devised then combined the following four variables into one composite indicator:

- Highly cited publications per total publications - a count of the 10 percent most highly cited publications divided by the total publications with an author from each country;
- PCT Patent applications per million inhabitants – Patent applications filed under PCT by inventors' country of residence (fractional counting) per million inhabitants;
- Top universities and public research institutes – Number of the top 250 world scientific universities and top 50 public research organisations in a country divided by total R&D expenditures;
- Value of ERC grants received by country of host organization divided by public R&D expenditures.

It should be noted that three of these four variables are similar to indicators already discussed – citations, patents and high ranking universities– although "total publications" rather than "total population" is used as a denominator for publications. It is likely that this will create considerable variability in this data for countries with small scientific communities and low levels of publication. The third variable (top universities and public research institutes) is also likely to be associated with very low counts in some smaller countries that could generate anomalies.

Correlation of these four variables demonstrated very strong association between them (all significant at the 1% level). This close association was confirmed using principle components analysis that revealed that the first component accounted for over 70 percent of all variability in the dataset.

Despite being highly correlated, the four variables displayed very different degrees of variance and it was noted that the outliers in some distributions could have a significant effect on use of the mean (arithmetic average) to create the composite index. To reduce this, the four variables were combined using a geometric average.

In February 2018, JRC calculated at update of the Research Excellence Index using the most recent data available, following, to the extent possible, the methodology described in Hardeman *et al* (2013) and Hardeman and Vertesy (2015). It should be noted, however, that while this index has been produced in 2018, the input data is drawn mainly from performance in 2015 (Table 17).

Table 17: EU Member States: JRC Research Excellence Index 2015

	Current status	JRC Research Excellence Index (REI) 2015	REI 2015 Indexed to EU28=100
EU 28		*41.3*	*100.0*
Netherlands		59.5	144.1
United Kingdom		56.2	136.1
Finland		52.7	127.6
Ireland		52.5	127.1
Sweden		52.0	125.9
Denmark		52.0	125.9
Austria		46.8	113.3
Belgium		45.3	109.7
Germany		43.2	104.6
France		40.5	98.1
Italy		37.9	91.8
Spain		34.7	84.0
Estonia	w	33.2	80.4
Portugal	w	32.3	78.2
Greece		30.8	74.6
Hungary	w	30.5	73.8
Cyprus	w	29.1	70.5
Luxembourg	w	26.1	63.2
Czech Republic	w	21.4	51.8
Slovenia	w	19.0	46.0
Malta	w	17.6	42.6
Poland	w	16.4	39.7
Croatia	w	16.2	39.2
Latvia	w	14.9	36.1
Slovakia	w	14.4	34.9
Romania	w	13.9	33.7
Bulgaria	w	13.6	32.9
Lithuania	w	13.5	32.7

Source: Data provided by Joint Research Centre; The Research Excellence Index February 2018 Revision.

9.10 European Innovation Scoreboard Index

The European Innovation Scoreboard (EIS) is an index that combines a wide range of measures of innovation designed to capture progress towards achieving the goals of the Europe 2020 Strategy. Initially the indicator was based on four components. As in the case of the JRC Research Excellence index, several of the single indicators evaluated above are incorporated into the EIS, some using different denominators. These are:

- PCT patent applications per billion GDP;
- Share of employees in knowledge-intensive industries in total business enterprise sector employment and the share of medium-high and high-tech goods in total exports;
- Share of knowledge-intensive services in total service exports;
- Employment in fast-growing firms from innovative sectors.

Since 2014, however, the European Innovation Scoreboard (EIS) Index has been revised and extended and the latest version introduced in 2017 distinguishes between ten innovation dimensions and incorporates 27 different variables. The ten dimensions are as follows:

- Human resources
- Attractive research systems
- Innovation-friendly environment
- Finance and support
- Firm investments
- Innovators
- Iinkages
- Intellectual property
- Sales impact

The EIS Index has been subject to critique. The index combines measures of research input, activity and output which makes it difficult to interpret trends over time. It has been suggested that the indicator depends too much on formal R&D and associated radical innovations and does not capture the significance of smaller scale incremental innovation that characterizes change in small and medium-sized enterprises. Janger *et al* (2016) also argue that the EIS Index is not consistent with current policy thinking in relation to smart specialization because several of the variables focus on a defined set of "knowledge-intensive industries" which overlook the importance of improvements in knowledge intensity within traditional sectors of economies.

Despite these criticisms, the EIS Index combines a large set of variables and is therefore less exposed to anomalies that can be found in single indicators. It is also a widely used and accepted indicator in policymaking at both national and regional scales and offers a broad perspective on innovative performance (Table 18).

Table 18: EU Member States: Summary Innovation Index

	Current status	European Innovation Scoreboard Summary Innovation Index
		2016
EU		*100*
Sweden		141
Denmark		134
Finland		128
Netherlands		127
United Kingdom		123
Germany		121
Austria		119
Belgium		119
Luxembourg	w	119
Ireland		114
France		107
Slovenia	w	96
Czech Republic	w	83
Portugal	w	81
Estonia	w	78
Lithuania	w	78
Spain		77
Malta	w	75
Italy		74
Cyprus	w	73
Slovakia	w	69
Greece		67
Hungary	w	66
Latvia	w	57
Poland	w	54
Croatia	w	54
Bulgaria	w	47
Romania	w	33

Source: Data compiled by Unit 4: Monitoring and Analysis of national research and innovation policies

10 Conclusion and Recommendations

The indicators presented in section 10 are assessed in summary in Table 19. As shown, the various indicators vary in character across a range of criteria, including relevance to the issues of Widening, timeliness, spatial scales, complexity and coverage within and beyond EU States. Given the complexities of the research and innovation process, none of these indicators can be regarded as a “perfect” solution to the measurement problem. However, identifying the main advantages and disadvantages of each indicator ensures an informed approach to selecting indicators that best reflect the purpose of Widening.

The information presented in Table 19a, 19b and 19c suggests the following key points:

10.1 Economic Indicators

GDP per head as a measure of level of economic development has significant advantages in terms of timeliness, spatial scale and coverage. **GDP per worker or per hour** has similar advantages but involves more complexities in terms of concept (productivity) and measurement (hours worked).

The **proportion of people employed in knowledge-intensive activity** has many advantages in terms of timeliness, spatial scale, coverage and is relatively simple to calculate from published statistics. The major disadvantage is that this overlooks the possible impact of innovation within traditional sectors.

Data on levels of **business innovation and engagement in R&D collaborations** from the Community Innovation Survey adds very useful insights and patterns, but has disadvantages in terms of timeliness, coverage and reliability especially for smaller territories.

10.2 Research & Innovation single indicators

Selecting a single indicator to represent research & innovation performance is more difficult due to the very varied nature of outputs and outcomes. **R&D Expenditure (Intensity)** is the most commonly used measure but this has significant shortcomings for the purpose of targeting for future widening as Countries that strive to meet targets can be penalized for this effort.

The **distribution of the top 500 HEIs** is clearly relevant and simple to apply but rankings are based on complex combinations of factors and can be disputed.

Despite their limitations, the **level of citation for publications** and **numbers of patents** most closely reflect readily-available outputs from the research and innovation processes (at least for physical products). This data is collected systematically and displays good coverage.

10.3 Research & Innovation composite indicators

As a general principle, indicators that combine different single measures can **better reflect the range of outputs and outcomes** from research and innovation processes. There is less likelihood of generating anomalies due to averaging effects of combining different datasets.

There are disadvantages in reliance on composite indicators because of their **complexity, lack of timeliness and varied availability** for countries outside the EU. Patterns displayed by composite indicators are also **difficult to interpret**.

Of the two composite indicators examined, there is some overlap between them in terms of source data (most recent versions both include, for instance, patent data and citation data).

The **European Innovation Scoreboard Index** is much better established and accepted in practice and covers a wider range of outcomes for innovation as well as research. It has also been subject to greater scrutiny and testing for sensitivity to data changes.

The **JRC Research Excellence Index** is more focused on research outcomes but is less widely applied in policymaking. Due to changes in source data, it has also not been possible to replicate precisely the method used in 2013 using more recent data.

10.4 Summary

Based on the assessment of the options, it is suggested that the most appropriate and transparent method for identifying future target countries for widening interventions could involve filtering countries on three selected single variables representing economic status, research and innovation. From the assessments made, it is suggested that the three most suited would be:

- Economic status – GDP per head
- Research performance - % of scientific publications in the top 10% citations
- Innovation performance – Number of PCT Patent applications per million population.

Table 19a: Indicators for future Widening Actions: Economic Indicators Summary Assessment

Indicator	Source	Timeliness and availability	Spatial scale	Complexity of indicator	Coverage	Reliability and other issues
GDP per head	Eurostat	Annual	National and regional	Well established methodology	Widespread use in EU and globally	GDP is based on "production" and may not always reflect individual or household standard of living. GDP per head can be affected by variations in population age structure
GDP per hour	Eurostat	Annual	National and regional	Well-established methodology	Widespread use in EU and globally	GDP per hour can be distorted by variations in working patterns and employment in different countries. "Productivity" is a complex concept
% empl in knowledge intensive activity	Eurostat	Annual	National and regional	Relatively simple measure based on employment structure	Based on data that is widely available	Based on an fixed definition of "knowledge industries" Growth in traditional sectors due to innovation will be regarded as negative
% Enterprises that are innovation active	Eurostat - data derived from Community Innovation Survey	Biennial Time delay in publication	National Regional data available but low sample sizes	Based on a series of questions in a standard questionnaire	Covers all EU countries and some non-EU European	Sample sizes can be low in smaller countries and in most regions.

Table 19b: Indicators for future Widening Actions: R&I Single Indicators Summary Assessment

Indicator	Source	Timeliness and availability	Spatial scale	Complexity of indicator	Coverage	Reliability and other issues
Gross R&D expenditure as % GDP	Eurostat	Annual	National only	Simple measure of expenditure on national accounts	Widely available within and outside EU	Single indicator that only measures financial inputs. Countries may be penalized for responding to EU targets
Publication – high citation per m popn	Web of Science database accessed via CWTS Leiden Ranking	Annual 2 year delay in publication	National and regional	Data is complex to analyse due to time lag in citation	Citation data has wide international coverage	Single indicator Citation data on its own can be misleading (see section 11.6)
Publication - % highly cited publications	Web of Science database accessed via CWTS Leiden Ranking	Annual 2 year delay in publication	National and regional	Data is complex to analyse due to time lag in citation	Citation data has wide international coverage	Citation data can be misleading - effects of "herding", variations in size of academia, impacts of social media
Research Excellence and Top 500 HEIs	Times Higher Education	Published annually by Times Higher Education (THE)	Institutional-level data that can be aggregated to any scale.	Ranking is based on a complex combination of institutional factors	Global coverage	Coverage of the top 500 HEIs is sparse for many countries where there is no representation
Total n of PCT patent applications for m popn	Eurostat	Annual	National Regional data available but less reliable	Some complexity at small scales in attributing patents to locations	Global coverage	Single indicator Patenting data on its own can be misleading (see section 10.8)

Table 19c: Indicators for future Widening Actions: R&I Composite Indicators Summary Assessment

Indicator	Source	Timeliness and availability	Spatial scale	Complexity of indicator	Coverage	Reliability and other issues
JRC Research Excellence Index	Joint Research Centre	Provisional data has recently been calculated to create an annual time series	National only	Time consuming to replicate dataset	Covers EU countries with some international comparators	Method combines data that has been critiqued above Outcome depends on implicit assumptions
European Scoreboard Innovation Summary Innovation Index	European Innovation Scoreboard (EC)	Annual	National and regional	Current method is complex involving combination of 27 different variables	Coverage limited beyond EU	Reliance on measures associated with formal R&D rather than incremental innovation Under-represents technical innovation in traditional sectors

10.5 Using Indicators as Filters for Identifying Future Widening Countries

Table 20 summarises the patterns in the data assembled in this report. This shows which Member States fall **below the EU average** on each of the variables listed. It can be seen that there are 17 Member States that fall below the average on the three key variables that represent economic status and the two most suitable and widely accepted indicators of research performance and innovation: **GDP Per head, % highly cited publications and Patenting.** Using these three variables as filters with the EU average as the threshold, the targets for future widening interventions would include all the existing Widening Countries with the exception of Luxembourg but would include also Italy, Spain and Greece.

Table 20: Member States ranked below the EU28 average for each Indicators

	Current Status	**GDP/Head**	GDP/Hour	% Employed in KIAs	% Innovation-active	R&D Expenditure	Citation per m Popn	**% highly cited**	Top 500 Universities	**Patenting**	JRC REI	EIS index
Austria												
Belgium												
Bulgaria	w	**X**	X	X	X	X	X	**X**	X	**X**	X	X
Croatia	w	**X**	X	X	X	X	X	**X**	X	**X**	X	X
Cyprus	w	**X**	X		X	X	X	**X**	X	**X**	X	X
Czech R	w	**X**	X	X	X	X	X	**X**	X	**X**	X	X
Denmark												
Estonia	w	**X**	X	X	X	X	X	**X**		**X**	X	X
Finland								**X**				
France							X		X		X	
Germany												
Greece		**X**	X	X		X	X	**X**	X	**X**	X	X
Hungary	w	**X**	X	X	X	X	X	**X**	X	**X**	X	X
Ireland						X				**X**		
Italy		**X**		X	X	X	X	**X**		**X**	X	X
Latvia	w	**X**	X	X	X	X	X	**X**	X	**X**	X	X
Lithuania	w	**X**	X	X	X	X	X	**X**	X	**X**	X	X
Luxembourg	w					X					X	
Malta	w	**X**	X		X	X	X	**X**	X	**X**	X	X
Netherlands												
Poland	w	**X**	X	X	X	X	X	**X**	X	**X**	X	X
Portugal	w	**X**	X	X		X	X	**X**	X	**X**	X	X
Romania	w	**X**	X	X	X	X	X	**X**	X	**X**	X	X
Slovakia	w	**X**	X	X	X	X	X	**X**	X	**X**	X	X
Slovenia	w	**X**	X	X	X	X		**X**	X	**X**	X	X
Spain		**X**	X	X	X	X	X	**X**	X	**X**	X	X
Sweden												
UK			X			X				**X**		

A similar analysis can be performed using the **90% of the EU average** as the threshold (Table 21). Using the same three key variables and applying the 90% threshold, the targets for future widening interventions would include all the existing Widening Countries with the exception of Luxembourg and Malta but add Greece as a target country.

Table 21: Member States ranked below 90 percentile across each Indicators

	Current Status	**GDP/Head**	GDP/Hour	% Employed in KIAs	% Innovation-active	R&D Expenditure	Citation per m Popn	**% highly cited**	Top 500 Universities	**Patenting**	JRC REI	EIS index
Austria												
Belgium												
Bulgaria	w	**X**	X	X	X	X	X	**X**	X	**X**	X	X
Croatia	w	**X**	X	X	X	X	X	**X**	X	**X**	X	X
Cyprus	w	**X**	X		X	X	X	**X**	X	**X**	X	X
Czech R	w	**X**	X	X	X	X	X	**X**	X	**X**	X	X
Denmark												
Estonia	w	**X**	X		X	X	X	**X**		**X**	X	X
Finland												
France							X		X			
Germany												
Greece		**X**	X			X	X	**X**	X	**X**	X	X
Hungary	w	**X**	X		X	X	X	**X**	X	**X**	X	X
Ireland						X						
Italy						X	X			**X**		X
Latvia	w	**X**	X	X	X	X	X	**X**	X	**X**	X	X
Lithuania	w	**X**	X	X	X	X	X	**X**	X	**X**	X	X
Luxembourg	w					X					X	
Malta	w		X		X	X	X	**X**	X	**X**	X	X
Netherlands												
Poland	w	**X**	X	X	X	X	X	**X**	X	**X**	X	X
Portugal	w	**X**	X	X		X	X	**X**	X	**X**	X	X
Romania	w	**X**	X	X	X	X	X	**X**	X	**X**	X	X
Slovakia	w	**X**	X	X	X	X	X	**X**	X	**X**	X	X
Slovenia	w	**X**	X					**X**	X	**X**	X	
Spain					X	X		**X**	X	**X**	X	X
Sweden												
UK						X						

While it is recommended that the Commission explore further the use of these three variables together as a basis for identifying target Countries for Widening, it is recognized that policymakers may still prefer a single indicator solution. In these circumstances, the relative reliability of the three shortlisted indicators must be considered, but so too the question would arise as to what type of outcome from Widening Actions the Commission wishes to emphasise – the quality of research outputs, commercialization of research through patenting or its subsequent impact on the economic performance of different Member States. In addressing this question, it is evident that the **quality of scientific publication is the most direct and least ambiguous outcome** from any investment in research activity. This argument could be used to justify selecting "% of scientific publications in the top 10% citations" as a key indicator. The advantages of using this as a single indicator, however, would need to be weighed against the shortcoming of this particular data as illustrated in section 10.6 and summarized in tables 19a-c.

Finally it is recommended that whether a combination of variables or single variable is used for identifying Widening Member States, there is a need to carry out further sensitivity checks on the selected data. These indicators may vary in the level of volatility from year to year, so some time series analysis would be prudent. Also, these variables may show different types of volatility in different countries, especially in smaller Member States.

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The purpose of this report is to assess the criteria that might be used to assist in targeting future "widening actions" that are intended to address inequality in research and innovation performance between EU Member States. A range of single indicators is assessed including measures based on expenditure, publication and patenting. Composite indicators are also considered. The report further includes socio-economic indicators alongside conventional measures of research and innovation. It is recommended that the Commission consider further the merits of a "filtering" methodology based on headline measures of economic performance (GDP per head), research performance (scientific publication in the top 10% citations) and innovation (PCT patent applications).

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