The international dimension of research and innovation cooperation addressing the grand challenges in the global context
The international dimension of research and innovation cooperation addressing the grand challenges in the global context

Final Policy Brief

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Preface

Grand challenges, such as global warming or chronic and infectious diseases, are increasingly global and complex. Solving these challenges often requires international research collaboration. The European Commission is playing an increasing role in supporting research and innovation through Horizon 2020, the European Union’s comprehensive Framework Programme for Research and Technological Development. This policy brief provides an overview of the main research priorities, the main collaborative efforts in international research collaboration regarding grand challenges, and summarises the outcomes of an expert and stakeholders’ workshop conducted on the 3rd of April 2014. The brief is written to inform the European Research and Innovation Area Board regarding the state of research collaboration on grand challenges and what the EU could do to further improve research collaboration on these grand challenges.
Executive summary

Horizon 2020 is the EU’s largest research programme to date. A significant part of this research programme, i.e. 31 billion euros, is invested in solving the world’s biggest and most complex problems, called grand challenges, largely through calls for international research collaboration.

Soliciting international collaboration represents an ambitious effort given the common good problem related to grand challenges: each country, acting as a rational agent, has more incentive to deplete the world’s resources such as water or clean air than to collaborate on sustaining them despite the long-term benefits in doing so. The European Commission hence commissioned this brief in order to understand how Horizon 2020 could best tackle this common good problem, by making sense of when international research collaboration would be the most beneficial with major other global players, namely the US, China and India.

This brief reviews the research collaboration planned by the Horizon 2020 2014-2015 work programme, compares this work programme to research priorities in the US, China and India; summarises the opinions and recommendations of participants to a workshop held on the 3rd of April 2014 on the topics which requires international research collaboration and on potential improvements to Horizon 2020.

The main findings of this brief are the following:

- Certain challenges identified by other nations are not covered by Horizon 2020. These challenges identified by other nations may constitute a basis for further consideration by Horizon 2020. For example, India has identified building education and skills as a strategy challenge and the US has a large programme on space.
- Horizon 2020 aims to maintain strong relationships with the US. But this should not obscure the building of relationship with emerging economies. Collaboration with emerging does not only imply a transfer of knowledge part of a capacity building exercise with these economies, but may also result in learning to help solve some of Europe’s most fundamental challenges.

The main recommendations resulting from the workshop are that:

- International research collaboration requires researchers with a multidisciplinary and broad skillset. The European Commission needs to support researchers in acquiring such skills at the early stages of doctoral training.
- The European Commission is also encouraged to agree on strategic research agendas with each partner country and to establish further links with other intergovernmental initiatives aiming to solve societal challenges.
- Going further, a sound evaluation of the impact of research collaboration would be required in order to assess its broad impact.

The information and views set out in this policy brief are those of the authors and do not necessarily reflect the official opinion of the Commission. The Commission does not guarantee the accuracy of the data included in this study. Neither the Commission nor any person acting on the Commission’s behalf may be held responsible for the use which may be made of the information contained therein.
Acknowledgements

We would like to thank the European Commission project team from the Directorate General for Research and Innovation, Science Policy, Foresight and Data for their support during this study, including particularly Rene Von Schomberg and Silvia Lubêr. We have also engaged a number of experts and stakeholders to a workshop held on the 3rd of April 2014. We thank them for their active input and support. Finally, we need to thank our quality assurance reviewers Stijn Hoorens, David Kryl and Jo Ritzen for their helpful suggestions. Emma Harte, Alex Kokkoris, Morgan Robinson, Jess Plumridge, Claire O’Brien and Lynne Saylor have also provided further support. This report represents the views of the authors. Any remaining inaccuracies are our own.
Introduction

0.1 Defining grand challenges

Grand challenges have been defined as ‘shared visions or goals which guide the actions of a broad (international) stakeholders’ community’ (Joint Institute for Innovation Policy; 2011; 12). Grand challenges tend to be highly complex, constituted by ‘wicked problems’, difficult to solve by single agencies (Rittel and Weber, 1973). They are also not limited to a given country, but bear externalities beyond borders and affecting a large number of individuals. Finally, global challenges tend to be long-term problems. Grand challenges are understandably not new. But these challenges require action because their scale is unprecedented. For example, the global average temperature increase is projected to be 3°C to 6°C higher by the end of the century, exceeding the internationally agreed goal of limiting this increase to 2°C above pre-industrial levels (OECD, 2012c).

0.2 The common good problem related to international research collaboration on Grand challenges

Grand challenges are hard to solve because they pose a common good problem. It is in the self-interest and rational behavior of individuals to deplete the worlds’ common resources, such as oceans for example, even if it is in the global community’s best long-term interests to maintain such resources.

The same rationale applies to the international research community when the question of solving grand challenges arises. Investing in solving a grand challenge is costly, especially in the transaction costs involved in coordinating international research teams and large scale projects (Katz and Martin, 1997; 14-15; OECD, 2012: 13). And although the global research community benefits from unprecedented knowledge and resources in being able to understand how to solve such challenges, each nation has an incentive to free-ride on existing solutions rather than to invest in the costs of solving such challenges.

Research collaboration at the international level can hence be hard to achieve. Public and private science and technology spending still largely takes place in national contexts and are funded by mission-oriented national public R&D schemes (Fowery et al., 2012). The relevance of the European Union and Horizon 2020

0.3 The relevance of the European Union and Horizon 2020

Solving the common resource problem which arises from grand challenges hence requires an international governance structure, which encourages the pooling of financial resources, sharing of large scale infrastructure and improvement of global knowledge base according to the OECD (2012: 13-14).

Various intergovernmental initiatives admittedly already exist on the resolution of grand challenges. For example, the United Nations runs the Intergovernmental Panel on Climate Change. 21 countries are engaged in the Joint Research Programming Initiative on Agriculture, Food Security and Climate Change (FACCE-JPI), including the French research National Institute for Agronomical Research (Institut National de la Recherche Agronomique INRA) and the UK’s Biotechnology and Biological Sciences Research Council (BBSRC).

But the EU research programme Horizon 2020, the largest EU research programme to date has the advantage of pooling significant financial resources in solving grand
challenges, that it calls "societal challenges". Horizon 2020 invests 43% of its overall budget - 31 billion euros - in addressing societal challenges, as indicated in Figure 1.

Figure 1: Societal challenges as one of the three priorities of Horizon 2020

<table>
<thead>
<tr>
<th>Excellent science</th>
<th>Industrial leadership</th>
<th>Societal challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td>• European Research Council</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Future and emerging Research Technology</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Marie Curie Actions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Research infrastructures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Leadership in enabling and industrial technologies (LEIT), ICT and Space</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Access to risk finance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Innovation in SMEs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Health and wellbeing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Food security</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Transport</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Energy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Climate action</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Society</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Security</td>
<td></td>
<td></td>
</tr>
<tr>
<td>€24 billion</td>
<td>€17 billion</td>
<td>€31 billion</td>
</tr>
</tbody>
</table>

Grand challenges have featured in European policymaking and have become an established theme (European Research Area Board; 2012; European Commission; 2010). For example, the Lund declaration of researchers in 2009 stated that European research should focus on the grand challenges of our time. One theoretical basis underpinning such a strategy is the positive relation at an aggregate level between investment in research and development (R&D) and socio-economic growth, as well as the positive relation at firm level between such investment and productivity. The EU2020 strategy presented innovation and research as a key element in order to kick-start economic growth. This commitment became materialised in the increase in the amount of funding available to the 6 year framework programme for funding research, Horizon 2020, launched on 1 January 2014 (European Commission; 2013). The societal challenges included in Horizon 2020 are included in Table 1.

Table 1: Definition of societal challenges according to the Horizon 2020 website

<table>
<thead>
<tr>
<th>Health, demographic change and wellbeing</th>
</tr>
</thead>
<tbody>
<tr>
<td>This challenge aims to improve better health for all. This includes keeping older people active and independent for longer and supporting the development of new, safer and more effective interventions. Research and innovation under Horizon 2020 also contributes to the sustainability of health and care systems.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Food security, sustainable agriculture and forestry, marine, maritime and inland water research and the bioeconomy</th>
</tr>
</thead>
<tbody>
<tr>
<td>This challenge aims to secure the transition towards an optimal and renewable use of biological resources and towards sustainable primary production and processing systems. These systems will need to produce more food, fibre and other bio-based products with minimised inputs, environmental impact and greenhouse gas emissions, and with enhanced ecosystem services, zero waste and adequate societal value.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Secure, clean and efficient energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Energy Challenge aims to support the transition to a reliable, sustainable and competitive energy system.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Smart, green and integrated transport</th>
</tr>
</thead>
</table>
| This Challenge aims to boost the competitiveness of the European transport industries and achieve a European transport system that is resource-efficient, climate-and-

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Horizon 2020 also offers the benefits of being able to pool large scale infrastructure, through cooperation between a set of EU member states, in addition to providing a framework for an EU-wide governance structure in international research collaboration. In addition, Horizon 2020 creates a clear point of contact for other nations. For example, there was a push for the US to cooperate directly with the EU rather than particular member states in the maritime field as the example of the Transatlantic Ocean Research Alliance suggests. Some of the benefits of such collaboration includes maximising funding, improving transparency in terms of research programme and achieving a broader diffusion of data access.

0.4 Third countries included in this brief

The global players selected by the study include China, the US, and India, as critical cases. The US was selected because it constitutes an example of a known leader in international research. The US has a strong reputation in research with more than twice the number of patent applications than the EU - 247,740 applications in 2012 (World Bank, 2013). China has been included because it has had an unprecedented scale of investment in research and rapidly increasing scientific outputs, according to the World Bank (2013)². By 2006, China had become the second largest investor in research and development in the world (OECD, 2006).

India is included in this study as an example of a country with a rapidly rising economy and population, but with a still emerging and more modest research profile than the US and China³. India, similarly to China, has a large population, 1.2 billion in 2012, with a GDP growth which was 3.5 percentage points higher than Europe in 2012, economists predicting that India will be the third largest economy in the world by 2050. However, India had the lowest input and output indicators in research of this group of countries, with 12 times fewer scientific publications than the EU and 3.5 times fewer than China in 2012 (World Bank, 2013, see appendix for more details).

This variation in the type of country included allows the research team to investigate patterns of research collaboration. Using such diverse cases allows understanding whether research collaboration is more likely with global players with a strong

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² This increase in quantitative outputs raises questions regarding the quality of output, which, according to Bound et al., (2013), may not be proportional to the rapid expansion of the number of scientific publications in China.

³ This does not imply that other countries are irrelevant in international research. Other emerging global research players exist. South Korea has the second highest number of patents proportionally to R&D expenditure after the US for example (Nesta, 2012). (See appendix for further additional comparisons of the research performance of countries other than the US, China and India).
international reputation, which would benefit the EU by establishing a transfer of knowledge for example. Or whether the EU benefits from collaboration with emerging players, in order to promote development, establish research links and/or use research collaboration to achieve other economic benefits such as stronger trade links for example.

0.5 Objectives of the study

The study concentrates on the role of the European Union programme Horizon 2020 in fostering international research on grand challenges with a select number of global players. The study covers public R&D federal and central funding and does not cover research collaboration with other levels, including states, individual research institutes or private bodies and their equivalent in other global players.

The study aims to:
• provide an overview of the priorities regarding the resolution of grand challenges across the EU, China, India and the US
• review international research collaborations, particularly those planned by the Horizon 2020 work programme
• summarise the opinions of participants to a workshop held on the 3rd of April regarding which grand challenges research collaboration could concentrate on further within the remit of Horizon 2020
• introduce some suggestions regarding further research.

0.6 Questions

The three questions covered by this brief include:

1 - How can the EU, USA, China and India work together on the societal challenges identified by Horizon 2020?

2 - On what issues can and should the global players collaborate?

3 - How do and to which extent can global players respond further to the priorities of Horizon 2020?

These questions are very broad in geographical and thematic scope. Sections, 2, 3, 4 and 5 hence do not aim to provide a clear cut answer but only aim to provide some of the main overviews and discuss some of the main dimensions to address these questions.

0.7 Outline of the brief

Section 1 introduces the approach used in this study. Section 2 discusses research collaboration and justifies the necessity of European Union intervention. Section 3 describes the priorities related to grand challenges in each country. Section 4 discusses the intended research collaborations planned by the Horizon 2020 work programme. Section 5 reviews participants’ opinions on research collaboration. The conclusion compares participants’ opinions to the Horizon 2020 work programme and the research priorities listed by each country; as well as presents avenues for further research.
1. Study approach

1.1 Steps of the study approach

Given the timeframe and resources available for this brief, we concentrated on providing a preliminary effort to identify the main priorities in research and existing collaboration originated by the federal/central Governments or equivalent in the EU, the US, China and India through desk research. The team then used the Horizon 2020 2014-2015 work programme. The team used a text analysis to code the number of times work programme explicitly call for collaboration with China, the US and India as an indicator of intend to collaborate with these countries. A visual representation of collaboration followed this text analysis. The team continued by assessing the advantages and disadvantages of ideal-types of modes of international collaboration (namely building multilateral collaboration, bilateral collaboration or achieving no further collaboration). The background document circulated prior to the workshop provides a detailed breakdown of the advantages and disadvantages of these ideal types. Participants provided a further opinion on these ideal types, and made some suggestions regarding the role of the European Union during a stakeholders’ workshop which took place on the 3rd of April 2014. The different steps of this approach are summarised in Table 2.

Table 2: Steps of the study approach

<table>
<thead>
<tr>
<th>Methodology</th>
<th>Objectives</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desk research, in-house and external expert input</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Visual representation</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Assessment of ideal types</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Experts and stakeholders’ workshop</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Reporting</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Understand research systems in the US, China and India as well as their main research priorities and existing collaboration

Mapping of international collaboration on grand challenges in Horizon 2020

Pros and cons ideal types of modes of collaboration

Discussion of ideal types of collaboration for each grand challenge.

Compile policy brief based on the data gathered above.

1.2 Experts and stakeholders’ workshop

The experts and stakeholders’ workshop provided a significant contribution to this study. In order to have a number of different perspectives, we targeted participants and stakeholders from a range of different countries (fourteen countries across twenty nine participants), with at least two participants and/or stakeholders for each of the countries of analysis, the US, China and India. These participants and stakeholders collectively covered the different areas of research areas of the grand challenges and they all had expertise or practical experience in research collaboration. They were largely from academia and research institutes as well as some national governments and international organisations.

Participants have received the draft of this brief and have had the opportunity to suggest corrections as part of a validation process, and in order to make sure that section 5 of the brief accurately represents the opinions of participants. The results of the workshop are presented in section 4 of this document agenda and the list of participants is

4 The map does not include the instances where international collaboration or collaboration with countries not included in the study is solicited.
presented in appendices 3 and 4. Section 4 also includes a summary of the most desirable research collaboration ideal type by grand challenge. This summary was constructed on the basis of the conclusions of break-out sessions, which included around 5-6 participants per group. A rapporteur, who was a volunteer participant, was assigned to each group. Each rapporteur reported the conclusions that their group put forward. The summaries provide further details regarding the variety of views expressed at the workshop and are hence not meant to represent the consensual views of all the participants to the workshop.
2. Clarifying international research collaboration and the relevance of Horizon 2020

Research collaboration typically follows a very general definition, namely ‘the working together of researchers to achieve the common goal of producing new scientific knowledge’ (Katz and Martin, 1997: 14-15). This section provides some elements of clarification regarding the term of international research collaboration, which has a ‘fuzzy’ border, in order to better understand how Horizon 2020 positions itself as a programme aiming to foster international research collaboration. Research collaboration indeed includes a variety of actors, modes of collaboration and stages.

2.1. Level of collaboration

Horizon 2020 typically involves individual researchers and research institutions. This is a particular level of collaboration. Research collaboration involves several levels. First, individual researchers may engage in research collaboration through self-organisation, organising themselves to explore a joint research idea. Second, research institutions collaborate as part of organised cooperation schemes, based for example on framework agreements and response to calls for more specific research agendas from donors. Here research collaboration is often a mix of bottom-up suggestion and top-down direction from funders and policymakers.

Third, governments may engage in formal intergovernmental coordination. Whilst the first two types of collaboration may or may not involve international collaboration, the third does so formally and by necessity. This third type of collaboration involves joint programming, where countries come together to define a common vision, a strategic research agenda and a management structure. Joint Programming in Research has been proposed in a communication of the European Commission from 2008.

Fourth, international organisations and EU institutions may also collaborate with other international organisations or Governments. In the EU, the Strategic Forum for International Collaboration (SFIC) plays a role in sharing information, coordinating activities and positions vis-à-vis third countries and within international fora. The SFIC has four pilot initiatives to develop international collaboration in science and technology, with India, China, the US and Brazil (European Commission, 2014(2)).

2.2. Research mode

Horizon 2020 sponsors a wide array of research, and concentrates on applied research. Applied research is called mode 2, following a distinction coined by Gibbons et al. (1994). Mode 2 research, aims to solve concrete world problems, tends to be interdisciplinary and thinking is enhanced through the interaction of applied and basic research. By contrast, mode 1, roughly the equivalent of fundamental research, is explicitly covered by the European Research Council. Both modes of research can be usefully deployed to address grand challenges. Different examples of research modes are included as an illustration in Table 3.
Table 3: Examples of research collaboration based on modes of research and level of actors

<table>
<thead>
<tr>
<th></th>
<th>International organisation</th>
<th>Governmental</th>
<th>Institutional</th>
<th>Individual</th>
</tr>
</thead>
</table>
| **Mode 1**     | European Organization for Nuclear Research (CERN)  
                 UK-India Education and Research Initiative (UKIERI)  
                 | Sino-German center for research promotion. Human Frontier Science Program  
                 | European Research Council  
                 |                       |                |
| **Mode 2**     | Intergovernmental panel on climate change (IPCC)  
                 | EU Joint Programme – Neurodegenerative Disease Research (JPND)  
                 | Horizon 2020  
                 | Horizon 2020  

For example, the IPCC, the UN panel aiming to tackle climate change issues, can be thought of as corresponding more to Mode 2 type collaboration. CERN represents an example of research centre which includes member states as participants and aims to generate mode 1 research as a particle physics laboratory. The JPND corresponds to an intergovernmental agreement originally launched by French and British public research institutes to address neurodegenerative research. The German Wuppertal Institute, the National Foundation of China (NSFC) and the German Research Foundation (DFG) have also set up the Sino-German centre for research promotion, which aims to create workshops and symposia, cooperation groups and bilateral research projects.

2.3. Demand-driven and supply-driven research

In addition, and although the line between demand-driven and supply-driven research can be blurry in practice, Horizon 2020 encourages demand-driven research. A demand-driven type of research collaboration would aim to solve a particular issue for a funder and research is stimulated by a defined reward or change in standards and regulation. A supply-driven type of research mechanism supplies money or resources for broad areas of research and is relatively open ended as to results required and expected. Both types of sponsoring mechanisms concerned with maximising impact and results but differ in the type of outputs and outcomes required. Both demand and supply driven mechanisms can be used to solve grand challenges. By lieu of illustration, Table 4 lists various examples of research collaboration that might relate to grand challenges, according to the degree to which they are demand or supply driven.
Table 4: Examples of demand and supply driven mechanisms for stimulating research

<table>
<thead>
<tr>
<th>Demand-driven mechanisms</th>
<th>Supply-driven mechanisms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collaboration</td>
<td></td>
</tr>
<tr>
<td>• Establishment of joint ‘prize’</td>
<td>• Exchanges of researchers</td>
</tr>
<tr>
<td>• Joint strategic fora and agenda-setting committees</td>
<td>• Grant and fellowship programmes</td>
</tr>
<tr>
<td>• Changes in standards and regulation to introduce new research</td>
<td>• Exchange programmes</td>
</tr>
<tr>
<td>• Contracted research with very specific demands</td>
<td>• Joint research programmes</td>
</tr>
<tr>
<td>• Public procurement</td>
<td>• Joint funding of research infrastructures</td>
</tr>
<tr>
<td></td>
<td>• Joint funding of physical researchers</td>
</tr>
<tr>
<td></td>
<td>• Joint funding through research funding bodies</td>
</tr>
<tr>
<td></td>
<td>• Annual summits, forums and international conference</td>
</tr>
<tr>
<td></td>
<td>• Dialogue</td>
</tr>
</tbody>
</table>

The distinction between demand-driven and supply-driven modes of collaboration may not be entirely clear cut in practice. But demand-driven modes of collaboration include components of Horizon 2020 which contract research around specific demands. The establishment of joint prizes or of joint strategic fora and agenda-setting committees where a particular solution is sought are included as demand-driven as is the public procurement of research. Demand-driven research also emerges from bodies explicitly concerned with more targeted research in set areas of cooperation (moving towards mode 2). Standards setting and regulatory bodies working together to provide demand driven stimulus (resulting in mode 2 research), could also be demand-driven.

By comparison, much of the previous European Framework Programme 7 (FP7) was more supply driven given that it had general requirements for the types of outputs and outcomes required. Research funding bodies may also come together in jointly supplying funds for more open ended research associated with grand Challenges (resulting in mode 1 research).

2.4. Stage of research collaboration

Finally, Horizon 2020 tends to encourage research at the conceptualisation stage, with the view to come up with solutions which would yield to research impact. Research goes through several stages from conception and prototyping to commercialisation, industrialisation and production, and each of these stages implies several modes of collaboration.

Hence, research collaboration includes several levels, modes, mechanisms and stages of research; and assessing international research collaboration requires an understanding of such diversity.
3. How are grand challenges defined in different parts of the world?

The priorities set by the US, China and India regarding grand challenges, in comparison to the European Union could also reflect some degree of diversity.

3.1. Different priorities across the US, China and India

The societal challenges adopted by Horizon 2020 may understandably be different from grand challenges as defined in the rest of the world. Only the US federal Government explicitly referred to grand challenges as specific subjects of research. The team used national strategic plans in order to find comparable documents regarding grand challenges in India and China. The Indian twelfth five year plan refers to twelve “strategy challenges”, defined as core areas that require new approaches to produce the desired results. And the Chinese Government identified seven priority industries in its twelfth five year plan. Yet, some comparability exists between the EU, the US, China and India.

Table 5 lists the seven grand challenges identified by the EU and maps some of the research priorities in the three countries covered in this study according to strategic governmental documents. (Other organisations, such as foundations as opposed to central or federal governments, may have different priorities, and joint research may arise in areas which are not listed in Table 5).

Table 5: Comparison of priorities across the EU, China, India and the US

<table>
<thead>
<tr>
<th></th>
<th>EU</th>
<th>China</th>
<th>India</th>
<th>US</th>
</tr>
</thead>
<tbody>
<tr>
<td>GC1</td>
<td>Health, demographic change and wellbeing</td>
<td>Biotechnology</td>
<td>Better preventive and curative healthcare</td>
<td>Brain initiative &amp; saving lives at birth</td>
</tr>
<tr>
<td>GC2</td>
<td>Food security</td>
<td>Food security</td>
<td>Rural transformation and sustained growth of agriculture</td>
<td></td>
</tr>
<tr>
<td>GC3</td>
<td>Secure and clean energy</td>
<td>New energy, new materials</td>
<td>Securing the energy future of India</td>
<td>SunShot</td>
</tr>
<tr>
<td>GC4</td>
<td>Inclusive societies</td>
<td></td>
<td>Markets for efficiency and inclusion</td>
<td></td>
</tr>
<tr>
<td>GC5</td>
<td>Smart transport</td>
<td>Clean energy vehicles</td>
<td>Accelerated development of transport infrastructure</td>
<td>EV Everywhere</td>
</tr>
<tr>
<td></td>
<td>Climate action</td>
<td>Climate change, environmental conservation</td>
<td>Managing urbanisation</td>
<td></td>
</tr>
<tr>
<td>GC7</td>
<td>Secure societies</td>
<td></td>
<td>Managing the environment</td>
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</table>
3.2. Priorities regarding grand challenges in China

The extraordinary growth of the past few years has come at high costs to its environment and sustainable development in China. The Chinese Government increasingly refers to the need for a more sustainable model of development and acknowledges the need to address grand challenges. The 12th Five-Year Plan (2011-2015) refers to the importance of sustainable development through ideas of the “harmonious society” (hexie shehui) and the “scientific development concept” (kexue fazhan guan), and has identified seven priority industries include: new energy (nuclear, wind and solar power in particular), energy conservation and environmental protection, biotechnology (new drugs and medical devices), new materials, new IT/high end equipment manufacturing, as well as clean energy vehicles (KPMG, 2011:2).

And the Plan has for example introduced mandatory targets to reduce pollutants and to grow and support new energy vehicles, as part of its a strategy to develop green transport, as well as green industry, energy efficiency, and pollution reduction.

Allied to the 12th Five-Year Plan, a number of key strategies address grand challenges. The Chinese Government had also developed a legislative framework for addressing Grand challenges through a variety of laws. And Development Priority Zones were launched in 2010 to develop sustainable development plans at the regional level, to consider resource availability and environmental needs for localities and regions. Finally, the plan identified a number of key industries that will drive sustainable economic growth. These are biotechnology, new energy, high-end electronic equipment manufacturing, energy conservation and environmental protection, clean energy vehicles, metal products, transport equipment, chemicals and minerals, new materials, and next-generation IT.

3.3. Priorities regarding grand challenges in India

Addressing grand challenges fits the Indian Government’s development of a rights’ based approach to basic human needs, including education, food, information and healthcare (through a Universal health care system). The twelfth five year plan has identified twelve strategy challenges, which cover most of the challenges identified by Horizon 2020: enhancing the capacity for growth; enhancing skills and faster generation of employment; managing the environment; markets for efficiency and inclusion; decentralisation, empowerment and information; technology and innovation; securing the energy future of India, accelerated development of transport infrastructure; rural transformation and sustained growth of agriculture; managing urbanization; improved access to quality education; better preventive and curative health care.

The Government of India declared 2010 – 2020 as the “Decade of Innovation” with a focus on inclusive growth. The primary objective of this declaration was to foster an innovation ecosystem within India that stimulated innovation and focused on addressing problems faced by society in critical areas such as healthcare, water, energy, transportation and urban infrastructure. To this end, the Government of India set up the high-profile National Innovation Council (NIC) to “discuss, analyse, and help implement strategies for inclusive innovation in India and prepare a Roadmap for Innovation 2010 – 2020.” (Government of India, National Innovation Council, 2010).

An innovation paradigm that has shown clear signs of success in India is that of ‘jugaad’ or ‘frugal’ innovation and many participants believe that this concept has the prospect of revolutionising innovation ecosystems worldwide. Often motivated by a social mission, frugal innovation involves the creation of low-cost products and services by using available resources efficiently, with the focus being on producing ‘better’ things by remodelling existing features of products and services (e.g. significantly low-cost eye operations priced at 36.22 euros ($50 USD) compared to 1195 euros ($1,650 USD) in USA that do not compromise on surgical standards). To quote India’s 12th Five-Year Plan document, “frugal innovation is focused on the efficiency of innovation and on outcomes that benefit people, especially the poor.”

Another clear indication of India’s commitment to enhancing its capabilities with regard to scientific research and innovation with a focus on addressing critical problems facing the nation was the recent publication of the Science, Technology and Innovation Policy (2013). This document underlined the importance of science and technology policy to maintain India’s international competitiveness. The Government of India, specifically the Department of Biotechnology (DBT) and the Biotechnology Industry Research Assistance Council (BIRAC), and the Bill & Melinda Gates Foundation have also recently launched a Grand Challenge funding opportunity (Grand challenges India: Achieving healthy growth through agriculture and nutrition), which aims to provide support agriculture and nutrition research and innovation (Bill and Melinda Gates Foundation, 2013).

3.4. Priorities regarding grand challenges in the US

Grand challenges are a core part of President Obama’s strategy refresh of the American Innovation Strategy (2009), which aims to detail how collaboration between American people, businesses and administration can ensure continued and fast economic growth. The Innovation strategy refresh focuses on three central areas: education, scientific

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6 As part of its strategy to promote a widespread culture of inclusive innovation, the National Innovation Council (NIC) has supported a number of different initiatives like ‘Innovation Toolkits’, ‘National Innovation Scholarships’, the ‘India Innovation Portal’, ‘Industry Innovation Clusters’, ‘Innovation Challenges’, and annual ‘Global Innovation Roundtables’ (Government of India, National Innovation Council, 2010b).

7 Government of India planning commission, 2013.
research and infrastructure. The President’s plan for Science and Innovation promised to double the budget of the National Science Foundation by 2017. In addition, President Obama appealed to foundations, universities, businesses and humanitarian representatives to engage in the pursuit of the next grand challenges for the 21st Century in a speech delivered on April 2013.

These challenges include:

- In health, the brain initiative aims revolutionise the understanding of the human mind.
- Another health grand challenge includes international development objectives through Saving Lives at Birth, which targets pregnant women and new-borns in poor, low resource communities.
- In terms of energy policy, the SunShot Grand challenge, to make solar energy cost competitive with coal
- In addition, the EV Everywhere Grand challenge aims to make electric vehicles that are as affordable as today’s gasoline power vehicles.
- The US federal government also has a Space related grand challenge, called the Asteroid grand challenge, which aims to reduce threats to human populations (White House, 2014).

In summary, assuming that a comparison with federal governments’ general plans is valid, similar grand challenges were identified in health and energy by the US, China, India and the European Union. Certain challenges identified by global players were however not included in the EU Horizon 2020 programme, as was the case for research on Asteroids or the promotion of skills and education. The following section explains how the EU aims to collaborate with the US, China and India, especially on these challenges.

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8 There have also been commitments from the Gates Foundation to award grants for research into Grand challenges in Global Health, engagement of the National Academy of Engineering and Duke and Southern Californian Universities in a Grand challenges scholars’ programme and projects driven by IBM to further develop computing and artificial intelligence.
4. **How does the EU aim to collaborate with the US, China and India? An overview of Horizon 2020’s work programme**

This section describes existing EU initiatives, particularly with the US, China and India, and positions these EU initiatives in the landscape of collaboration between the US, China and India - independently of the EU.

4.1 **Mapping of international collaboration according to Horizon 2020’s 2014-2015 work programme**

The Horizon 2020 round of research proposals follows a similar international cooperation framework as FP7, with the European Free Trade Association countries and countries covered by the European Neighbourhood Policy being considered for inclusion on a merit-based selection process. While Horizon 2020 is open to international participation, the list of countries that are automatically eligible for funding is restricted based upon Gross National Income (GNI) per capita and total Gross Domestic Product (GDP). The EU will allocate funding to countries whose research strengths can fill a capability gap within the EU research community, with priority being allocated to entities which can contribute to societal challenges and industrial challenges segments of Horizon 2020’s grand challenges (European Commission, 2012c).

Figure 2 provides an overview of research collaboration in the Horizon 2020 2014-2015 work programme.

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5 This is designed to address the fact that some countries will already have the capacity to cooperate on a reciprocal basis with the EU, and need not apply for research funding. European Commission, 2012a
Figure 2 leads to the following remarks:

**A preference for bilateral collaboration over multilateral collaboration.** Out of 29 Horizon 2020 registered calls for collaboration, 23 were bilateral, while six actions required multilateral collaboration between more than one global player. The six actions requiring multilateral collaboration include researching solutions to chronic diseases and polar research, aeronautics and water; as well as two more transversal topics, which consist in helping Europe to position itself as a global actor and enhancing and focusing research and innovation cooperation with the Union’s key institutional partners.
The US as the main collaborator. Figure 2 shows that the EU intends to develop the highest number of research collaborations with the US, 17 of the 29 calls for collaboration were with the US.

Societal challenges which call for strong collaboration with the US include health (human safety and eHealth), clean energy (gas exploitation and decarbonisation), marine research and raw materials. The US is the only intended collaborator of the EU regarding secure societies, which ranges from investigating how to manage extreme weather events to increasing the peace building capacity of the EU and civilian conflict prevention.

Joint Consultative Group meetings between the State Department Office of Science and Technology Cooperation and the EU, which take place every two years, influences the choice of these topics for collaboration between the EU and the US. The last Joint Consultative group took place in Washington in 2013.

Otherwise, the largest joint activity between the EU and the US is the BILAT-USA 2.0 project. BILAT-USA 2.0 was funded by FP7 and founded in 2012, and aimed to enhance research and innovation partnerships between the EU and the US, particularly in the areas of marine and arctic research, nanotechnologies, health, and transport. It should be noted, however, that while BILAT-USA 2.0 aims to support S&T dialogue on these areas between EU and US, for instance by organising workshops, it does not specifically fund calls on these topics. Additionally, the EURAXESS-Links US was launched in 2007 as a networking tool for European and non-European researchers to collaborate and pursue FP7 contracts.

This collaboration occurs despite broad differences in research systems. The US has a very flexible research system, given the annual cycle of research funding and its governance through a network of agencies rather than a federal Ministry for Science and Technology. And private donors are acquiring an increasing role in funding research on grand challenges10.

A reflection of the global presence of China. In addition, research collaboration appears more established with China than with India. Six of the bilateral calls concerned China. Research collaboration with China includes food security - to create sustainable livestock or to prevent the biological contamination of crops in the food chain, secure energy in order to support joint actions on innovative energy solutions, transport to test clean urban transport and mobility, the reduction of food waste and ensuring the sustainable use of agricultural waste.

EU-China collaboration benefits from high level discussion platforms and agreements. Research collaboration has been influenced by collaboration on nuclear energy under the agreement R&D-PUNE, which entered into force in August 2008. The EU-China summit, which last took place in November 2013, decides on a cooperation agenda between the EU and China.

In the first three years of FP7, Chinese researchers were some of the most successful at receiving grants. In fact, China was the third country with the highest number FP7 grants awarded (European Commission; 2010). An increasing number of Chinese scholars have participated in the EU Framework Programme after the EU-China Science and Technology agreement of 1998.

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10 Michael Bloomberg, James Simons, David Koch, Bill Gates (Microsoft) Eric Schmidt (Google), and Lawrence Ellison (Oracle) increasingly funding research on Grand challenges related to health and the environment for example. Private donations may be more limited in the European Union, although there are admittedly some variations across countries of Europe, certain private foundations being fairly prominent, for example in Germany (e.g. Bertelsmann Stiftung).
The EU-funded Dragon Star programme supports bilateral collaboration between Chinese and EU researchers, for example by investigating the possibilities of other joint research activities (twinning of labs, joint liaison offices, etc.).

Various initiatives also took place outside of the Framework Programmes, including the Open China-ICT project, a European Commission-funded initiative that aimed to utilise Chinese research on ICT through EU-China cooperation (Open China-ICT), in order to investigate how ICT collaboration could support sustainable development and the social safety and security of its citizens. Several targeted initiatives also exist, including a joint Food, Agriculture and Biotechnology taskforce, or a joint expert seminar, which aimed to define priorities in food security and food safety in October 2013. In terms of sustainable urbanisation, a major challenge for China, an EU-China summit took place in 2012 to substantiate a partnership and a stakeholder workshop was held in Foshan in 2013.

**A much less established collaboration with India.** India was admittedly included in multilateral collaboration schemes regarding chronic diseases, polar research, water, and establishing the role of Europe as a global actor for example. And numerous Framework Programme research projects have involved Indian research partners. India ranked number five in terms of applications to FP7 proposals, with particular activity in the research fields of health, environment, technology, and biotechnology (European Commission; 2012b).

However, none of Horizon 2020 bilateral calls concerned India for the 2014-2015 Work Programme, illustrating a much less established collaboration. This difference may have to do with the fact that India has a less established presence in international research (see appendix). The country remains largely rural, with high rates of illiteracy. Moreover, India has the lowest input and output indicators in research of the group. And the share of India’s R&D investment in science, technology and innovation is less than 2.5% of the global figure of 1.2 trillion USD (Government of India, 2013).

Yet, the Government has committed to improve on this performance. Prime Minister Manmohan Singh recently stressed his commitment to increase R&D spending from 0.9% to 2% by 2017 (Patnaik, 2012), which may encourage further research collaboration with India.

A primary vehicle of collaboration between the EU and India has been the EU-India Science and Technological Cooperation Agreement, complemented by the Joint Declaration on Research and Innovation Cooperation signed between India and the EU in 2012. The declaration is meant to bridge India’s ‘Decade of Innovation’ and the EU’s Europe 2020 initiatives and foster research and innovation in both countries.

**A partial coverage of global players’ priorities.** The Horizon 2020 2014-2015 work programme collaboration covers the challenges of commonly identified by all the global players with relative heterogeneity. Some Horizon 2020 calls include all the global players who have identified a certain topic as a challenge, as is the case for health for example on the resolution of chronic diseases. And Horizon 2020 also has bilateral schemes to cover some challenges of mutual relevance between the EU and a given partner, such as clean energy vehicles with China. On other instances however, Horizon 2020 calls for collaboration on a topic that it unilaterally defines as a grand challenge, as is the case on marine research with the US. Or it does not explicitly call for collaboration with countries with similar challenges, as is the case of India on secure energy or the creation of inclusive societies.
4.2 Other international initiatives beyond the EU: examples from the US, China and India

International research collaboration is not restricted to EU initiatives. There are various bilateral and multilateral cooperation agreements between individual countries.

**China.** A number of bilateral and multilateral cooperation agreements and programmes with different countries have been established to stimulate knowledge transfer across national borders. China has collaborated with the US since 1979, as the result of cold war science diplomacy, and has since then evolved in collaboration in a variety of areas with a high level bilateral meeting on S&T cooperation every year. The Sino-US Science and Technology Agreement and the Joint Fund on Major Scientific Equipment Research constitute other types of collaboration. These programmes have served to strengthen formal collaborations and to enhance the scope for institutional cooperation (universities, state institutes, academies of sciences).

The 12th Five-Year Plan for Science and Technology development underlined that internationalisation of scientific research activities will be further enhanced, and China will actively participate in international science and technology organisations and large international science programmes.

In addition, various Western universities are opening branch campuses in China. There is also generous government funding for Chinese scholars and students from elite universities to conduct research overseas on collaborative projects. Finally, China is in discussions to form stronger links with East Asia, particularly with Japan and South Korea.

**India.** India has been keen to forge strategic research and innovation partnerships with other countries and has collaborations with more than 70 countries in last decade and its top five partners are, in descending order, the USA, Germany, the UK, Japan and France. Some institutions leading research collaboration include the Tata Institute of Fundamental Research (TIFR) and Bhabha Atomic Research Centre (BARC) in Mumbai (Nesta, 2012). Research collaboration between India and the US has increased from 1.4 million euros (2 million USD) in 2008 to 159 million euros (220 million USD) in 2013. Joint collaboration has been influenced by the Indo-US Civil nuclear agreement, signed in 2008, which has led to a number of initiatives on solar and nuclear energy, the Indo-US science and technology forum, which has established 40 virtual joint research centres, the US-India endowment board, which will lead to around 2.5 million USD a year to promote commercialisation of innovative technologies, as well as the Millennium Alliance, launched in 2011 between the US Agency for international development (USAID) and the Federation of Indian Chambers of Commerce and Industry (FICCI) to scale development solutions developed and tested in India. India’s collaboration programs also exist with national EU member states. These programmes include the Indo-French Centre for the Promotion of Advanced Research, whose annual budget is €3 million.

**The US.** The US Government and other US actors are sponsoring various forms of international collaborative research through the National Science Foundation or Foundations, such as the Bill and Melinda Gates foundation. In addition, various institutions sponsor scholars’ programs. The Department of State sponsors bilateral exchanges of scholars, for example through the Fulbright Program, and the National Academy of Engineering sponsors the Grand Challenge Scholars program. The Partnership for International Research and Education enables researchers from institutions in the US to collaborate with scientists around the world. An award to Michigan Technological University (MTU) enabled researchers to work with researchers from Nicaragua, Guatemala, El Salvador, and Ecuador on remote-sensing tools for...
hazard mitigation and water resource development (National Science Foundation, 2013: 17).

To sum up, some societal challenges require less collaboration, and global players already have some collaboration independently from the EU. But the European Union aims to continue to develop several areas of research collaboration to solve some of its societal challenges, particularly with the US.
5. When is collaboration desirable? Opinions of workshop participants by grand challenge

In order to define when to collaborate, this brief relies on participants’ opinions on the desirability of certain types of collaboration by grand challenge. This section aims to provide a simplified overview of participants’ opinions, while acknowledging the fact that grand challenges are broad in nature and several topics may be suited to different forms of collaboration.

5.1 Three ideal types for research collaboration

Generally speaking, modes of international collaboration fall in two broad categories: bilateral or multilateral. Bilateral collaboration involves two parties (countries or research teams), and covers, for instance, bilateral exchange programmes. Multilateral collaboration includes joint networks, research centres and universities. Bilateral agreements tend to be the most common type of intervention for activities outside Horizon 2020 (Kamalski and Plum, 2013).

Hence, research collaboration was summarised in ideal-types options to simplify the participants’ input:

**Ideal-type 1**: EU enacts no further collaboration

**Ideal-type 2**: EU engages in bilateral collaboration with partners in a third country

**Ideal type 3**: EU engages in multilateral collaboration with partners in a number of different third countries.

5.2 The consensual bottom-line: the importance of international research collaboration

In general, workshop participants recognised that collaboration was valid when the urgency and scale of the challenge outweighed the geopolitical, context-specific and commercial difficulties related to collaboration. More generally, participants tended to be in favour of promoting research collaboration with the rest of the world in order to benefit from knowledge transfer and indirect advantages (such as an increase in trade). Participants underlined that research collaboration would also be beneficial with developing country to support capacity building and depending on historical relationships with the EU. In addition, participants recognised that multilateral collaboration may be relevant in certain research areas, such as climate change. They also stressed that multilateral collaboration could be used as a form of science diplomacy in order to build constructive international relationships. The value of bilateral collaboration was also strongly acknowledged. Bilateral collaboration could further research opportunities by encouraging competitiveness, help to resolve local problems, and may be quicker and more effective than multilateral collaboration.

Participants acknowledged the current role of the EU as a standard setter, gateway for information and funder of research. Promoting a uniform system of intellectual property rights across the EU, for example through a Community patent system that the European Commission is currently campaigning for, could facilitate international negotiations on research collaboration.

In addition, workshop participants recognised the value of Horizon 2020 being open to non-EU researchers, and the unique character of this scheme. Participants recognised how open Horizon 2020 was, given the barriers imposed to access research funding by other countries. Indeed, the access to Chinese funds and for European scholars has been
more challenging than the access of Chinese scholars to EU funds. The recent China Science Fund open for foreign scholars (with some Grand Challenge resonance) and EU initiatives (EuroAaxes programme) aim to provide better access. Finally, some participants reminded others that the support of the EU in international research collaboration needed to respect the subsidiarity principle, according to which the EU may only intervene if it is able to act more effectively than Member States, and that EU competitiveness and interests should be preserved.

5.3 Participants’ opinions on the desirability of research collaboration by grand challenge

The participants’ assessment of the appropriateness of ideal types of research collaboration for each one of the grand challenges are summarised in Table 6. As indicated in section 1, Table 6 is based on the summaries emerging from the break-out of each session. The text following Table 6 provides further explanation regarding the positions of participants.

Table 6: Expert assessment of the most desirable research collaboration ideal-type between the EU and third countries by grand challenge

<table>
<thead>
<tr>
<th>Grand Challenge</th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
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<tr>
<td>GC1: health</td>
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<tr>
<td>Health</td>
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<tr>
<td>Demographic change</td>
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<tr>
<td>Well-being</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a [bis]</td>
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<td>GC2: food security</td>
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<td>Food security</td>
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<tr>
<td>Sustainable agriculture and forestry</td>
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<tr>
<td>Marine, maritime and inland water research</td>
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<tr>
<td>Bio-economy</td>
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<td>GC3: energy</td>
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<td>GC4: transport</td>
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<td>GC5: climate action</td>
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<tr>
<td>Climate action</td>
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<tr>
<td>Environment</td>
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<td>Resource efficiency</td>
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<tr>
<td>Raw materials</td>
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11 See section 2.3 on international collaboration for more information on international collaboration between China and the EU
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<table>
<thead>
<tr>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>No collaboration</td>
<td>Bilateral collaboration</td>
<td>Multilateral collaboration</td>
</tr>
</tbody>
</table>

GC6: Europe in a changing world
GC7: Secure societies

Note: certain challenges appeared broader than others, and led to different expert considerations. The Table hence breaks down the topics included in these broader challenges. The arrows are used as a representation of the agreement of a break-out group on an ideal type of research collaboration.

Note bis: the conclusions of the break-out groups did not include any information on the most desirable type of collaboration regarding ‘well-being’.

Grand challenges best suited for multilateral collaboration

*Grand challenge 1 Health, demographic change and well-being.* Multilateral collaboration was acknowledged as relevant in the context of health, since similar solutions could be applicable to a range of players, and given that barriers to collaboration (such as different IP rights) could have direct consequences on the treatment of patients.

*Parts of Grand challenge 2 on food security.* In addition, a certain consensus also emerged regarding the fact that a global need for action was necessary for food security, and given that this challenge directly affected lives across the world.

*Parts of Grand challenge 5 on climate action and the environment.* Climate action and the environment were deemed more suited for multilateral collaboration for the same reasoning as for Grand challenge 2 on food security.

Grand challenges best suited for bilateral collaboration

*Grand challenge 3 Secure, clean and efficient energy.* Some participants thought that collaboration in energy research may bear highly political and difficult issues and that any collaboration would require the active role of the international community. However, it was also argued that collaboration on this grand challenge would be useful to help the EU develop alternative modes of energy provision, especially given the intent to reduce nuclear energy, as well as complement climate change research. If individual countries do separate research on this challenge, the new energy (and presumably non-fuel) technologies developed will (1) not be harmonised and compatible globally in terms of standards and regulations, and (2) involve high royalties charged by the patent owners, potentially slowing down deployment in other countries (such as emerging markets in Asia). The resulting lack of take-up of energy technologies would worsen the climate change problem. Collaboration on this grand challenge is therefore essential for the success of the related grand challenge 5. Collaboration could hence occur bilaterally, with specific third countries depending on their interest in a particular source of new energy technology.

*Grand challenge 4 Smart, green and integrated transport* Smart, green and integrated transports were recognised as an area for bilateral collaboration, particularly with China, where the demand for green and smart transport, as well as efforts to build ‘smart cities’, were due to increase. Some participants also underlined the impact of EU-US collaborative research on car designs in the US. Multilateral collaboration may be less suitable given the strong trade dimension related to transport as well as the specific requirements in each region of the world.

*Grand challenge 7 Secure societies.* Some participants were of the opinion that this challenge may be more internal to the EU, but they recognised that making societies...
more secure may require important knowledge from other countries. This may be the case especially on certain applied issues that require a specific knowhow to be transferred to the EU. Examples may include issues related to cybersecurity, data protection or extreme weather conditions. On the other hand, participants suggested that the selection of partners would need to occur very selectively because there may be risks to collaboration related to sharing sensitive information. These issues may limit the opportunities and add to the complexity of multilateral collaboration.

Parts of Grand challenge 2. Marine, maritime and inland water research. This topic may be best suited to bilateral collaboration given that certain maritime issues may arise in oceans targeting a particular group of countries. Bilateral collaboration in this field includes the Transatlantic Ocean Research Alliance for example, which aims to increase the knowledge of the Atlantic Ocean and its dynamic systems - including interlinks with the portion of the Arctic region that borders the Atlantic" and to promote the sustainable management of its resources.

Grand challenges best suited for no further collaboration

Parts of Grand challenge 2 sustainable agriculture and bio-economy. Participants explained that certain elements of this grand challenge may not be entirely suitable for multilateral collaboration, such as bio-economy or certain aspects of research which had some implications for the food industry. The need to protect the international competitiveness of national food industries meant that sharing information in multilateral collaboration would be difficult. In addition, the topic of sustainable agriculture, given that it requires local engagement and is context specific, was not deemed to the best suited for international (mutliateral or bilateral) collaboration.

Parts of Grand Challenge 5: resource efficiency and raw materials. Research collaboration on resource efficiency and raw materials called for more caution according to some participants. Certain countries, such as China, have shown a strong interest in collaboration on this issue, for example by developing links with Africa. But some participants were of the opinion that raw materials and resource efficiency had a conflict sensitivity element which meant that research collaboration would need to be treated with caution and an understanding of the geopolitical issues surrounding the topic.

Grand challenge 6 Europe in a changing world, inclusive, innovative and reflective societies. Workshop participants underlined that Grand Challenge 6, although global in nature, was the least prone to international collaboration, because it concentrated on European integration. Various topics related to building inclusive, innovative and reflective societies, such as education or immigration, were deemed to be context-specific and dependent on the institutional landscape. A collaboration to explore parallel issues and solutions with other countries may help Europe to generate innovative ideas to solve some of its challenges, including maintaining a balance between inclusive social system and boosting economic growth. For example, a bilateral collaboration exists between China and certain European countries to develop global inclusive growth. In addition, looking toward foreign concepts such as ‘frugal innovation’ in India; or how the concept of smart specialisation may be understood and applied abroad, could help Europe to build its society in a changing world. However, participants recommended concentrating on gaining further understanding, exploiting and resolving the dynamics arising from the high heterogeneity of social systems across the European Union.

5.4 Further participants’ recommendations on the role of the EU

In addition, workshop participants also issued some recommendations regarding the role of EU intervention on international research collaboration on grand challenges. These are summarised below.
Developing an agenda for collaboration with each partner country. A first recommendation referred to developing an institutional agenda for collaboration with the countries which do not benefit from such an agenda yet. Such an agenda would increase visibility, incentivise research collaboration in these countries and should take into account existing cooperation between EU member states and the partner country. The EU should also discuss these agendas with its member states within the Strategic Forum for International Cooperation (SFIC), referring to the willingness shown by the respective member states in the European Research Area.

Recognising the need to address training needs required to address global challenges. Being able to collaborate internationally in research as well as to work on solving major global challenges requires a particular skillset, which involves being able to understand a varied body of research, a strong general grasp on one’s discipline, as well as working fluently in foreign languages or within teams for example. A participant suggested that the EU supports the acquisition of these skills at the early stages of doctoral training in order to make it easier for future researchers to develop international collaboration.

Liaising with other intergovernmental efforts. Horizon 2020 may also gain in liaising further with other intergovernmental efforts undertaken by European Governments in solving grand challenges (such as Joint Programme Initiatives), in order to build mutually beneficial ways to solve grand challenges12.

Meeting the trade-off between flexibility and predictability. Finally, one of the participants underlined that the European Union’s research funding scheme guaranteed a certain predictability to researchers, it could also acquire more flexibility, in order to adapt quickly to changing global needs.

12 Intergovernmental and EU initiatives are mutually beneficial. In the case of higher education for example, the European Commission supported the intergovernmental Bologna process, which aimed to create greater comparability and recognition in the levels of qualifications and quality of higher education (Hoareau, 2012).
6. Conclusions and avenues for further research

In summary, the demand-driven, applied research solicited by Horizon 2020 stands out given its openness to international research collaboration on societal challenges, which include a wide range of seven topics.

The opinions of workshop participants on the type of cooperation across challenges were more or less in line with the work programme developed by Horizon 2020. Health, climate action and food security were identified as requiring multilateral collaboration given the breadth and imminence of these challenges; while others, such as building inclusive societies, were deemed to be more context-specific. Participants also isolated a number of topics on which bilateral collaboration was suitable, including transport for example, where collaboration with China is deemed to be increasing as the result of growing need to build clean transports, although traditionally, bilateral collaboration with the US has been the most developed (questions 1 and 2).

But certain challenges identified by other nations are not covered by Horizon 2020. For example, India has identified building education and skills as a strategy challenge and the US has a large programme on space research. These differences may be because of the salience of certain issues for some countries rather than others, or national efforts to build internationally competitive advantage.

And traditional relationships should not obscure the building of relationship with emerging economies. Collaboration does not only imply a transfer of knowledge part of a capacity building exercise with these economies, but may also result in learning to help solve some of Europe’s most fundamental challenges, such as how to build a trade-off between growth and inclusion. India’s concentration on developing ‘frugal innovations’ was highlighted as an area of potential learning for Europe for example (question 2).

Participants provided a wide range of recommendations to help the EU respond further to the resolution of the societal challenges of Horizon 2020. These recommendations called for the attention of the European Commission toward the need to further equip researchers to conduct international collaboration in their doctoral training, to agree on strategic research agendas with a broader range of partner countries, to link with other intergovernmental initiatives, to find a balance between predictability and flexibility and to preserve EU competitiveness (question 3).

Going further, the study team suggests the following for further research.

The study team suggests a sound evaluation of the impact of collaboration in order to assess the broad impact of research collaboration. Research collaboration on grand challenges is motivated by a wide range of dynamics, including importing expertise or exporting knowhow in order to build diplomatic or trade connexions. An evaluation of Horizon 2020’s research collaboration would be beneficial given this wider context. This evaluation could also compare Horizon 2020 to other intergovernmental efforts to address societal challenges, such as the UN international panel on climate change, or joint programming efforts for example in order to further substantiate how Horizon 2020 positions itself within the international landscape. This evaluation could include an international bibliometric analysis aiming to map the existing output of collaboration across the seven societal challenges of Horizon 2020 and the global players included in this brief.
**Appendix 1: Differences between the research landscape of China, the US and India**

This appendix provides an overview of research and innovation systems in China, the US and India.

**China:** Most research and innovation policies are designed and implemented from the top-down, the Central Committee of the Chinese Communist Party setting agendas for research and innovation. Below the Central Committee is the State Council which is the highest-ranking governmental policy-making body in China and has ultimate decision-making power for S&T and innovation policy. In addition, the Steering Committee of Science, Technology and Education of the State Council have an influential role in decision-making. Figure 3 provides an outline of the key stakeholders involved in research and innovation in China (OECD, 2009). The State Council has nine member-ministries: 1) National Reform and Development Commission (NDRC), 2) Ministry of Education (MOE), 3) Ministry of Science and Technology (MOST), 4) Ministry of Industry and Information Technology (MIIT), 5) Ministry of Finance (MOF), 6) Ministry of Agriculture (MOA), 7) Chinese Academy of Sciences (CAS), 8) Chinese Academy of Engineering (CAE), 9) National Natural Science Foundation of China (NSFC). There are two other important institutions with key strategic functions for research and innovation alongside the State Council. First, the National Development and Reform Commission formulates and delivers plans for social and economic development. It also provides monitoring and analysis on the macro-economic context and facilitates broad processes of continued reform and opening. Second, the Ministry of Science and Technology (MOST) designs science and technology plans, research programmes, invests in research and innovation infrastructures (hard and soft) and implements reforms for innovation and research. In the public sector most research and innovation activity is funded through centralised R&D programmes that are operated and managed by MOST.

**US:** The White House Office of Science and Technology Policy leads interagency efforts to develop and implement sound science and technology policies and budgets, and works with the private sector, state and local governments, the science and higher education communities, and other nations toward this end (from Dale Eppler presentation 3rd of April 2014). But research addressing grand challenges in the US also tends to be influenced by various federal bodies, including the Office of Science and Technology Policy (OSTP). The OSTP has recently stressed the relevance of solving grand challenges as “ambitious but achievable goals that harness technology, and innovation to solve important national or global problems and that have the potential to capture the public’s imagination” (White House, 2013). The OSTP, part of the U.S. State Department, leads on international cooperation in science and technology, but does not allocate funds. Grand challenges are outlined as being able to help create future jobs and industries, further push the boundaries of human knowledge, drive collaboration between the private and public sectors and help grapple with issues surrounding health, environment, national security, health, energy and education. The National Science Board, and various federal agencies, such as the Environmental Protection Agency, also have a relevant say in grand challenges. This research is funded by a variety of entities, including public bodies, such as the National Science Foundation (NSF), or the National institute of Health (NIH) for example. Multilateral collaboration is encouraged. For example the NSF Partnership for International Research and Education enables researchers from institutions in the US to collaborate with scientists around the world. An award to Michigan Technological University (MTU) enabled researchers to work with researchers from Nicaragua, Guatemala, El Salvador, and Ecuador on remote-sensing tools for hazard mitigation and water resource development (NSF, 2013: 17.). Foundations, including the Bill and Melinda Gates Foundation, as well as companies, such as Google
also invest in grand challenges. For example, Google is investing in developing an energy efficient car following the DARPA Grand Challenge.\textsuperscript{13}

India: The science and technology system is complex in India and takes its roots in the 1950s when the political leadership of Nehru gave top priority to science and technology in institution building. The Department of Science and Technology assumes a particularly relevant function. Within its general remit to organise and promote science and technology (S&T) related activities within India, the Department of Science and Technology (DST) has a number of specific responsibilities, including being responsible for international science and technology cooperation. Some of these may have particular implications for pursuing grand Challenge research. These relevant responsibilities include the: formulation of relevant policies; promotion of new areas with special emphasis on emerging areas; co-ordination and integration of areas having cross-sectorial linkages in which a number of institutions and departments have interests and capabilities; all matters concerning international co-operation; matters concerning domestic technology particularly the promotion of ventures involving the commercialisation of such technology; application of S&T for weaker sections, women and other disadvantaged sections of society (Ministry of Science and Technology, 2005). The Council for Scientific and Industrial Research is the largest R&D organisation in India, with 4,500 scientists working in 38 research laboratories. The Science, Technology and Innovation Policy strategy of 2013 set up the National Innovation Council and the National Knowledge commission in order to promote innovation.

Figure 3: R&D landscape in China, the US and India

<table>
<thead>
<tr>
<th>Chinese stakeholders</th>
<th>State Council</th>
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<tr>
<td>National development and reform commission</td>
<td>National Science Foundation of China</td>
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<tr>
<td>Productivity promotion center</td>
<td>State IP office</td>
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<tr>
<td>Universities</td>
<td>Resarch institutes</td>
</tr>
</tbody>
</table>

Acronyms (MOST: Ministry of Science and Technology; MOE: Ministry of Education; MOP: Ministry of Personnel) SOURCE: OECD, 2011.

\textsuperscript{13} For more information, see Darpa, n/a.
### Indian stakeholders

<table>
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<tr>
<th>Category</th>
<th>Indian Council of Medical Research</th>
<th>Indian Council of Agricultural Research</th>
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<td>Department of Science and Technology</td>
<td>In-house R&amp;D in private industry</td>
<td>S&amp;T non-governmental organisation</td>
</tr>
<tr>
<td>Defence and research organisation</td>
<td></td>
<td>Central socio-economic and other ministries</td>
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<tr>
<td>Defence, R&amp;D development organisation</td>
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<tr>
<td>Department of biotechnology</td>
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<tr>
<td>Council of scientific and industrial research</td>
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**Source:** Adapted from the website of the Department of Science and Technology, Government of India

### US stakeholders

<table>
<thead>
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<th>Office of Science and Technology Policy</th>
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<td>National Science and Technology Council</td>
<td>National Science Board</td>
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<tr>
<td>National academies, e.g. National Academy of engineering</td>
<td>Private Foundations</td>
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<tr>
<td>National Science Foundation</td>
<td>Other donors, e.g. IBM &amp; Google</td>
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<tr>
<td>Private Foundations</td>
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<td>Think tanks</td>
<td>Universities</td>
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<tr>
<td>Universities</td>
<td>Private research institutes</td>
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</table>

**Source:** Authors' own

**Note:** This Figure provides a graphic (and general) representation of relevant stakeholders. It lists these bodies by order of policy decision-making power and relative position in terms of research funding, e.g. think tanks, universities and research institutes are grant receiving bodies and are hence below the National Science Foundation, private foundations and other donors which are grant awarding bodies.
Appendix 2 Comparative overview of relevant research output indicators

The team used a range of macroeconomic indicators to understand the relevance of the country in a global research landscape. The graphs in Table 7 provide a comparison of relevant macroeconomic indicators. This table compares the EU, the US, China and India - countries mentioned in the terms of reference. Table 7 also includes data from Japan and the Republic of Korea, given their comparatively high performance on the selected indicators for information (although for budgetary reasons the research team will concentrate on covering the EU, the US, China and India).

Table 7 presents some general data on population size and GDP growth\(^{14}\), as well as input and output indicators on research. Input indicators include R&D expenditure as a percentage of GDP per capita and the number of researchers in R&D per million inhabitants\(^{15}\). Output the number of scientific and technical journal articles published each year\(^{16}\), as well as the number of patent applications submitted annually by residents\(^{17}\).

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\(^{14}\) Annual percentage growth rate of GDP at market prices based on constant local currency. Aggregates are based on constant 2005 U.S. dollars. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources.

\(^{15}\) Researchers in R&D are professionals engaged in the conception or creation of new knowledge, products, processes, methods, or systems and in the management of the projects concerned. Postgraduate PhD students (ISCED97 level 6) engaged in R&D are included.

\(^{16}\) Scientific and technical journal articles refer to the number of scientific and engineering articles published in the following fields: physics, biology, chemistry, mathematics, clinical medicine, biomedical research, engineering and technology, and earth and space sciences.

\(^{17}\) Patent applications are worldwide patent applications filed through the Patent Cooperation Treaty procedure or with a national patent office for exclusive rights for an invention—a product or process that provides a new way of doing something or offers a new technical solution to a problem. A patent provides protection for the invention to the owner of the patent for a limited period, generally 20 years.
Table 7: International comparison of relevant macro-indicators

SOURCE: World Bank data bank, 2013
The graphs illustrate the well-known European paradox (European Commission, 1995):

The EU has one of the highest numbers of scientific publications, but the translation of this research into practical innovation does not follow (the EU having a comparatively much lower performance in terms of patent applications, with 108,762 patent applications submitted in 2011). In addition, the EU was the only country of the group to have registered a negative growth rate of -0.29 % in 2012. According to analysis by Leydesdorff et al. (2014) the EU has increased its share among top-cited publications between 2000 and 2010.

These comparative graphs also illustrate why China, India and the US are particularly relevant as global players in research.

The US has a strong reputation has global player in research. It has more than twice the number of patent applications than the EU (247,740 applications in 2012). But emerging economies are catching up fast. The R&D expenditure and number of researchers of the US have been overtaken by the Republic of Korea between 2007 and 2009. And China started to have a much higher number of patent applications than the US in 2009.

China has the most extraordinary growth figures of the group of countries presented in the graph. Known for having the world’s biggest population of 1.3 billion inhabitants in 2012, China also had the highest GDP growth (7.8% in 2012). As the world’s second largest economy and largest exporter, China has a major impact on the global economy, patterns of trade and investment and growth in all regions of the world, including Europe. A key trend in the past decade has been the unprecedented scale of China's investment in research and the accompanying acceleration of scientific output. China has had the largest increase in R&D expenditures as a percentage of GDP between 2008 and 2009 (+0.23 percentage points), and the steepest increase in patent applications (+122,763 in 2011). China is now recognised as a major global player in science and technology and by 2005 had become the second largest investor in research and development in the world (OECD, 2006).

India, a country with a similarly large population, 1.2 billion in 2012, also had a GDP growth which was 3.5 percentage points higher than Europe in 2012. Economists have predicted that India will be the third largest economy in the world by 2050. Yet the country, heavily dependent on agriculture, has a rural population of 70%, and high rates of illiteracy, and approximately a quarter of its population still lives below the national poverty line, leading the World Bank to label India an "extreme dual economy" (Dutz, 2007). Moreover, India has the lowest input and output indicators in research of the group, its number of scientific publications 12 times fewer than the EU and 3.5 times fewer than China in 2012, which reflects the different focus of the Governments of both countries regarding research. Despite being the second most populous country in the world (with the United Nations projecting India to overtake China as the world’s most populous country as early as 2028), the share of India’s R&D investment in science, technology and innovation is less than 2.5% of the global figure (Government of India, 2013). The Government has however committed to improve on this performance.

Other countries covered for comparative purposes included Japan and South Korea. Japan, a country four times smaller than the EU, has the highest numbers of researchers per million inhabitants (5,180 in 2012) and the highest numbers of patent applications submitted (287,580 in 2011). And South Korea has had the highest increase in R&D expenditure (34% growth rate since 2005) and increase in numbers of researchers (40% in five years).
The International dimension of research and innovation cooperation
Appendix 3 Agenda of the workshop

08:30 - 09:00 Registration and arrival
09:00 - 09:30 Welcome and introduction to the study - Joanna Chataway and Cecile Hoareau McGrath (RAND Europe)

Plenary session Moderator: Stijn Hoorens, RAND Europe
09:30 - 10:00 Opening address - Jean-Pierre Bourguignon (European Research Council)
10:00 - 10:05 Background of the work - Rene Von Schomberg (European Commission, Directorate-General for Research)
10:05 - 10:15 Overview of current international research priorities of DG Research - John Claxton (European Commission, Directorate-General for Research)
10:15 - 10:30 Coffee break

Regional overviews Moderator: Stijn Hoorens, RAND Europe
10:30 - 11:00 Overview of Grand challenges and research collaboration in India - Dinar Kale (Open University)
11:00 - 11:30 Overview of Grand challenges and research collaboration in the US - Dale Eppler (US Mission to the European Union)
11:30 - 12:00 Overview of Grand challenges and research collaboration in China; and Meeting Global Challenges through Better Governance - Gang Zhang (OECD)
12:00 - 12:30 Presentation of working group sessions - Veronika Horvath (RAND Europe)
12:30 - 13:30 Lunch

Facing Grand challenges: Interactive afternoon session
13:30 - 14:55 Interactive plenary afternoon: Defining modes of collaboration - Moderator TBC
14:55 - 15:05 Coffee break
15:05 - 16:30 Breakout sessions: Defining topics for collaboration and option for collaboration on the 7 Grand challenges (Moderators to be assigned on a voluntary basis)
16:30-17:00 Coffee break
17:00-17:30 Wrap-up and reporting back to the plenary on the outcomes of the breakout sessions by the rapporteurs
17:30-18:00 Conclusion

The workshop will be followed by an optional dinner at the Brasserie Le Saint Germain, Place Rogier 1. Please note that the dinner is not covered by the project.
## Appendix 4 List of participants to the workshop

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