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## Working Party on Innovation and Technology Policy

# APPENDIX TO THE TERMS OF REFERENCE FOR THE OECD KNOWLEDGE TRIANGLE PROJECT REGARDING WORK ON THE EVALUATION AND IMPACT ASSESSMENT OF STI POLICIES

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*This document is an appendix to document DSTI/STP/TIP(2014)11. It details the impact assessment module of the Knowledge Triangle Project.*

*Delegates are asked to discuss the proposal included in this document.*

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## APPENDIX: OPTIONS FOR THE IMPACT ASSESSMENT MODULE OF THE KNOWLEDGE TRIANGLE PROJECT

1. The note provides additional information about the proposed impact module of the knowledge triangle project. It presents a broad set of possibilities for research aimed at assessing impact of public research. It is planned that a number of these research possibilities will be implemented in the current biennium so as to inform the knowledge triangle project.

2. The structure of the note is as follows: Section 1 summarises the module's objectives, while Sections 2 and 3 describe the policy questions and proposed methodology for implementing the module. Section 4 describes data sources that could be used for the analysis.

### 1. Objective of Impact Evaluation Module

3. The contributions of public research, conducted at both public research institutes and universities (jointly referred to as public research organisations), to innovation can be substantial. The increased importance of knowledge-based capital for competitiveness and, what is more, the greater complexity of knowledge provides larger rewards to those countries with access to a strong research base and the ability to convert its contributions into innovations. Involving universities has been critical for the success of innovation clusters; providing a sustainable source of new idea, human capital and a knowledge hub for clusters. All success stories show this to be the case. It is also via their contributions to innovation that public research will address multiple socio-economic challenges.

4. The modalities of the public research-industry connection, one of the core angles of the knowledge triangle, critically affect impacts. By nature, this connection is not straightforward as it relates to institutions with different purposes and operating mechanisms. Solutions require optimising exchange without, however, affecting the most efficient but distinct ways for private sector and public research to operate. Evaluations need to consider those factors: Strong emphasis on publications in assessments and, consequently, funding can reduce incentives to engage in commercialisation. Emphasis on filing patents and other types of IP may not support effective commercialisation as patent filings themselves are only a first step towards introducing innovations and create commercial value out of patent-protected inventions.

5. The module will conduct i) a quantitative analysis of the contributions of public research to innovation and ii) a study of related national policy assessments. The analysis, which would include cross-country and country-specific studies, will aim to provide policy priorities that can strengthen the impact of public research. The analysis will also focus on spillover effects (that is, gains that may arise on top of private returns to scientific research) as these justify public funding on research. The module will also focus on specific national policy evaluations of instruments implemented to strengthen impacts of public research on innovation. The objective would be to understand the success factors of different policies but also to identify the "state-of-the-art" in policy evaluation exercises done by countries.

## 2. Research Questions

***Overview***

6. Research questions for the module might involve the following:

- What are the contributions of public research to innovation? To what extent will returns differ across disciplines and technology fields? Which industries benefit most?

- Which transmission channels from public research to innovation are most effective? What is the contribution of the commercialisation of public research? How important are more informal types of public research-industry linkages? What is the contribution of traditional research reproduced in publications?

- Does the involvement of public research organisations in the commercialisation of public research affect their research activities? Does encouraging public research organisation to co-operate with industry lead to trade-offs with regard to their roles in research?

- Is support of excellence in research critical to maximising the impacts of public research on innovation?

- How could public research contribute better to industries' and firms' needs? How important are "absorptive capacities" for businesses to benefit from public research? What are relevant steps to enhance those capacities? How should public research respond to industry priorities?

- What policy instruments support wider impact of public research? What has worked best to foster the commercialisation of public research? What about differential and joint impacts? What are implications of differences across fields of activity?

7. In order to enable a more in-depth analysis, the working group might choose to select two or three of these topics.

***A. Identifying the most effective impact channel***

8. Public research organisations support innovation by means of providing research outputs that can serve as firms as basis for developing innovations. They may also collaborate more directly by engaging in the commercialisation of their research outputs, by conducting co-operative R&D with industry, and by providing consulting services and ad hoc advice. While the former has received particular attention, a much more substantial share of university revenues comes from consulting services and the provision of ad hoc advice (Perkmann et al., 2013). Industry surveys also point to the larger importance, on average, of more informal linkages (Agrawal, 2001; Cohen et al., 2002). However, patenting by universities has proven of high impact for MIT and Stanford, where those engagements supported critically the development of bio-based industries (Colyvas et al., 2002; Nelson, 2007).

9. Engaging in the commercialisation of their research and conducting co-operative R&D with industry has received policy attention. A major reason is that those collaborations may accelerate the adoption of knowledge produced by public research on top of the traditional channel – i.e. research outputs omitted in publications. While meaningful, it is widely recognised that these might take long before they reach industry (Adams, 1990). The transfer of scientific knowledge might be hampered as knowledge is not easily accessible to industry, particularly in increasingly complex knowledge environments. Collaborations will become critical to speed up and improve the quality of information transferred. The

most effective channel for impacts may differ depending on context - notably industry needs and characteristics as well as characteristics of public research institutions.

10. Many of the most recent analyses of impacts of public research on industry have focused on formal knowledge transfer mechanisms, notably patenting and licensing activities. They paid less attention to complementary contributions from traditional research activities and from more informal channels of collaboration. The latter are much harder to evaluate, particularly in a comparative framework because longer time lags may need to be considered to evaluate impacts of research (Adams, 1990). Moreover, quantitative data will not be available to document more informal collaborations, requiring either indirect approaches to evaluating effects or the use of specific surveys of industry and public research organisations.

***B. Implications of commercialisation for public research***

11. Success of research-intensive universities such as MIT and Stanford, which effectively became knowledge hubs of vibrant industry, encouraged many countries to undertake a variety of policy measures in support of commercialisation. Such policy could help exploit stock of valuable knowledge residing in public research institutions (Mazzoleni and Nelson, 1998). However, if public research organisations collaborate more with industry and invest more in commercialisation, this may affect the quantity or quality of research conducted by these institutions. These potential costs need to be taken into account to fully evaluate contributions and downsides to the contributions of the commercialisation of public research to innovation.

12. Research outputs may be affected if collaboration efforts change researchers' incentives and make them focus more on developing commercial products than conduct research. Such collaboration may also have negative impacts if they reduce the time available for researchers, modify the direction of research away from basic research towards more applied fields or restrict the open dissemination of research discoveries. Moreover, if public research organisations develop strong commercial interests in selling their IP, valuable more informal collaborations with industry may be negatively affected (Valentin and Jensen, 2007). However, empirical evidence has shown stronger linkages with industry support scientific institutions and their research activities (Perkmann et al., 2013; Agrawal and Henderson, 2002; Thursby and Thursby, 2011).

***C. Excellence and its contributions to impact***

13. The distribution of value in research outcomes measured by publications is highly skewed, i.e. very few publications have high impact. Similarly only a small share of patents are widely cited and of large commercial value. It is, therefore, not surprising that leading scientists and research institutions have played a dominant role in science-industry collaborations with highest impacts on innovation (Jensen et al., 2003, Di Gregorio and Shane, 2003; Chapple et al., 2005). Star scientists were critical for the creation of start-ups in the fields of biotechnology and nanotechnology in the United States (Zucker and Darby, 1998). Thus, promoting excellence in research seems critical for policy if it is to have lasting impacts.

14. However, there are downsides to adopting too strong a focus on performance excellence in the funding different institutions receive. If only few institutions receive the bulk of funding and, consequently, concentrate capacities, then the emergence of other leaders may be constrained. In addition, if such concentration results in a focus on certain fields, the capacities for research to respond to new demands, as technological breakthrough across the globe change priorities for industry, is weakened. Importantly, to the extent that regional proximity continues to matter effective collaboration with industry, concentration in a few sources may weaken opportunities for regional development. Moreover, to the

extent that human capital formation continues to require physical campuses, the supply of adequately skilled human capital could also be affected.

15. A major challenge for policy with regards to excellence arises, however, with regards to adequate incentive schemes. One factor is risk: Early stage research is inherently risky. Failure is part of the process by which research is conducted. Thus, if success becomes a core determinant for future funding, then this may lower research undertaken. Another factor regards providing opportunities for researchers outside of leading institutions to compete for funding. Young researchers will not have the same track record as their senior colleagues, but should not on those grounds be excluded from possible funding opportunities. The same applies to institutions.

### *D. Identifying research priority in view of industry needs*

16. Wider impacts of public research depend on how relevant research is to industry needs. Research in applied sciences and engineering and, in particularly, the research aimed at directly addressing challenges faced by industry has contributed substantially to innovation. However, the overall contributions need to be evaluated with caution: the longer-term and often more indirect contributions of basic research render demonstrating impacts more challenging. Notwithstanding, the greater role of more applied research in public research organisations points to the need for differentiation within the research sector. The nature of research support for industry differs, as do optimal ways for delivering such support. For instance, tight collaboration matters more for applied sciences than for other research fields.

17. Moreover, the different industries will require research inputs from a different range of fields of research. That is, the pharmaceuticals sector will require different inputs than will the machinery industry. Only few research fields benefit a wider group of sectors: material sciences (cf. Cohen et al., 2002) and possibly also social sciences may qualify. Social science, often disregarded from analyses of public research contributions, might contribute at the stage of introducing and selling products on markets, for instance, with perspectives on how to best target products to consumers. The contributions of research will be maximised where research capacities meet countries' specialisation patterns and comparative strengths (OECD, 2014). Some industries stand to benefit more: most important benefit on industrial R&D have been identified in drugs, medicine, chemicals products and electronics (Nelson, 1986; Klevorick et al., 1995; Moretti and Wilson, 2014; Zucker and Darby, 2014a). Conversely, where research orientations do not meet industry needs, there will be limited opportunities. Thus, the correspondence of fields of research to industry requirements is critical with regards to maximising impacts.

18. In addition, in "incipient" industries research capacities are not contributing but a major driver of industry development, such as biotechnology and biomedical sciences. Effectively, it is in those sectors where most university patenting worldwide is centred (Mowery et al., 2002; Mowery and Sampat, 2005). The potential of "incipient" industries to become a source for competitiveness and generator of employment, render those research sectors particularly important for policy support. While there is uncertainty as to what will be the leading sectors, cross-disciplinary research is increasingly recognised important to support major scientific breakthroughs (Heinze et al., 2009). Enabling a research environment where cross-disciplinary approaches are fostered is not straightforward, with the peer review process operating on a strong disciplinary basis. It is, however, an area where support of "incipient" industries may be hampered by research structures.

### *E. Building absorptive capacities for firms to adopt research*

19. Tapping into knowledge created by public research is not straightforward. Even where knowledge is directly relevant to industries' needs, businesses may lack the capacities to appropriate knowledge as part of their business processes. In other words, own internal know-how increases the gains

from external knowledge-acquisition strategies due to “absorptive capacities” (Cohen and Levinthal, 1989). Strong internal R&D capacities increase the likelihood of firms to seek knowledge inputs from public research and raise impacts from public research on their innovation performance (Belderbos et al., 2004).

20. “Absorptive capacities” and will likely differ across firms and be of differential importance across different industries. Absorptive capacities are not the same across larger and smaller firms, across start-ups and established businesses, and other firm characteristics also influence capacities. There is little evidence to date providing insights on differential impacts across industries. The extent to which industry is “prepared” to make use of public research outputs is another critical policy area when it comes to maximising the impacts of public research.

***F. International and national research priorities***

21. Research is increasingly conducted in international research networks, particularly in frontier research areas and for the group of leading researchers. What is more, the Internet increasingly facilitates the cross-border dissemination of knowledge. Engaging in international research provides opportunities for maximising returns on national funding for research and global opportunities for industries to tap into relevant knowledge sources for their activities. The international dimensions of research raise the question: what research is most critical for national (or even regional) research institutions? The capacity to tap into those leading research projects puts further emphasis on seeking “excellence”. Own capacities will matter in the transmission of knowledge. Local industry might not effectively benefit much from research conducted abroad if distance hinders building collaborations. The tacit elements of knowledge, which continue to require face-to-face interactions, will also support a need for national research capacities, at least to translate research to industry allowing adoption. Such focus might require emphasis on “platform sciences”.

***G. Understanding the broader policy environment for commercialisation***

22. Over the past decades much has changed with regard to policies in support of the commercialisation of public research. Initial steps taken across OECD countries focused on setting legislative arrangements granting public institutions ownership rights over the knowledge created and establishing technology transfer offices (TTOs) in universities (OECD, 2003). The Bayh-Dole Act was implemented in the 1980s and other countries implemented reforms over the 1990s. In the early 2000s, the new system was still quite young for most public institutions across the OECD (ibid.). A recent assessment shows success has in many cases been modest (OECD, 2013).

23. One response to such muted impacts has been greater emphasis on embracing a wider set of policy instruments to boost commercialisation. Many tools aim at creating better linkages (such as industry-university exchange programmes, voucher programmes and cluster policies). These are potentially more effective at breaking institutional distances that often remained a challenge in simple commercialisation approaches: On the side of public research institutions, missing interactions resulted in cases in institutions applying for patents that were only of limited interest to industry, thus, limiting licensing arrangements. On the side of industry, missing interactions resulted in cases in firms showing little willingness to engage with universities in developing prototypes on the basis of university inventions, even where potential existed. Moreover, limited funding opportunities, the industry context and institutional incentives all affected success in some cases and failures in others, thus, understanding the wider policy environments becomes particularly critical.

## 3. Description of Project Implementation

24. The project will be implemented across three components, i) a cross-country analysis (Section 3.1), ii) complementary national studies (Section 3.2) and iii) a cross-country analysis of policy evaluations (Section 3.3).

### *3.1 Description of Cross-Country Analysis*

25. A quantitative cross-country analysis will be undertaken. It will focus on impacts of public research on innovation, based on two measures of research outputs: publications and patents. Research outputs will not only be identified based on pure output counts but also on the type (such as, whether it was undertaken collaboratively, whether leading researchers were involved, whether the research conducted was cross-disciplinary, what disciplinary fields were covered, etc.), the quality of those knowledge contributions (including by analysing citations, the breadth of the contribution, etc.) as well as the characteristics of institutions (e.g. whether these are part of wider knowledge networks, whether we consider public research institutions or universities, etc.).

26. The analysis will then focus on establishing a link between research and industries and/or firms to assess differential contributions of research outputs for industries. This could be done exploiting differential public research needs across industries (e.g. the fact that a pharmaceutical company will benefit mostly from research done in medical fields which will matter less to firms in the field of communications machinery). For the firm-level analysis, regional-type matching could also be explored matching outputs in a specific country-region to industry. Approaches to establish these links include using information on i) citations of scientific publications in industry patents, on ii) scientific publications authored by industry and on iii) university patenting. Not only direct contributions to specific sectors but also indirect benefits from the growth of these sectors need to be considered to establish employment effects and other impact factors.

27. The evidence will contribute new evidence by exploiting the richness of bibliometric and scientific publication data that has become available in recent years in a cross-country analysis. The work will draw on existing OECD work on bibliometrics. The study will focus on distinguishing contributions from different disciplinary fields, coming from different institutions and produced in different country policy environments.

28. Causality will also be discussed. In this context, developing a randomised control trial (RCT) framework could be of interest to the project. Such an RCT framework would not only need to consider what questions could suitably be assessed as part of such a framework but also how ethical questions regarding preferential treatment of some actors over others could be dealt with best.

29. In a further step the impact of policies implemented to support commercialisation would be introduced and assessed. For this purpose, policy indicators have to be developed. The work would build on the information provided in the Science, Technology and Industry Outlook policy database and possibly further data collection efforts.

### *3.2 National Studies*

30. National studies using alternative national data sources can deepen insights from the project. Possible analyses may include the following:

- National studies can contribute by focusing on specific policies implemented in support of transferring knowledge generated by public research organisations to innovation; complementing the qualitative analysis described in Section 3.3.

- Firm-level analyses using information from research quality could provide for a better understanding on the differentiated impacts of public research, looking into the contributions to different types of firms (for instance, by analysing size and productivity differences among others). Community Innovation Surveys (CIS) provide information on university-industry collaborations and, particularly if linked to firm panel data, can help look into specific innovation outcomes of linkages with industry. These studies may also use information obtained from publications and patent databases described in 3.1 on public research's impacts.

- Detailed surveys of academics can help strengthen understanding of what drives academics to collaborate with industry, providing a complementary perspective as to what policies can do in support of collaborations with industry.

- Country analyses can also help shed light on the propensity of firms to engage in collaboration with public research institutions. Such information could, for instance, be obtained on the basis of results from CIS data.

### *3.3 Policy Analysis*

31. The cross-country policy dialogue would focus on specific policies aimed at enhancing the impacts of public research on innovation and their evaluations.

#### *3.3.1 Policy Options for the Discussion*

32. Policies in Support of Co-operative Research: An interesting focus could be set on policies that explicitly focus on establishing those industry-university linkages. This includes co-operative research programmes, such as matching grants and consortia, as well as the creation of joint research centres/ agencies (including that is any institutional arrangements, governance structures, etc.), and voucher programmes. These policies share a focus on creating joint work practices in order to facilitate the transfer of "latent" knowledge. They are in many ways a reaction to the often still limited levels of interaction between research and innovation. Involving the inventor is critical as i) a significant fraction of the non-codified knowledge may be codifiable, the inventor is able to effectively transfer this knowledge if given the appropriate incentives and mechanisms (Arora, 1995), ii) as inventors can teach all the necessary components to the licensee, iii) as inventors have intuition and can better predict behaviour for "trial-and-error" process that often characterizes new product development, iv) given inventors' ability to adjust to new changes unpredictable before licensing starts.

33. Funding Schemes for Public Research: An issue question that necessarily requires understanding regards funding schemes for public research institutions. This concerns incentives and funding opportunities set for commercializing research outputs (and its weight relative to the other tasks), the importance given to engaging with the private sector as well as more generally to wider socio-economic impacts of research outcomes. This also includes funding opportunities for proof-of-concept or prototypes. Aside from the objective set in evaluations, the process adopted to evaluate these outcomes will also matter (incl. e.g. whether the private sector is participating in evaluations or whether it is peer-review that creates the basis of those evaluations). This is relevant up to the level of researchers, where a model where entrepreneurial impact comes to matter as do publication, will change the very dynamic of institutions. Some of the institutions that have been most successful, such as Stanford, have started recruited on the basis of not only publications but also their entrepreneurial capacities.

34. Legislative Arrangements and the Creation of Technology Transfer Offices (TTOs): Another focus could be on the two types of major policy measures most countries implemented in the early 2000s and, for some countries, even earlier (OECD, 2003). These are modified legislative arrangements that clarified the ownership of intellectual property created by public research. It also includes the creation of technology transfer offices (TTOs) many countries experimented with. Looking into those policies and their evaluations could provide for an analysis aimed at a much longer time series.

35. Exploring Connections with the Broader Context: Business incubation facilities and more generally opportunities for start-ups generated, including cluster policies, which might be critical in that these are more used to commercialize new technologies that are radical, tacit, at an early stage and of general purpose (Shane 2002; 2004). Local institutions (including the research infrastructure) have been identified as critical for cases of Silicon Valley and Route 128 (Saxenian, 1994). Policies aimed at creating firms' capacities to absorb university knowledge, a factor that has commonly been identified as an obstacle. It could also usefully focus on complementarities with policy support to firm innovation activities given the substantial complementarities between internal R&D and external knowledge acquisition (Cassiman and Veugelers, 2006).

*3.3.2 Questions for Policy Analysis Work*

36. The policy assessment exercise would also focus on the tools and methods applied to evaluate impacts focusing on the following questions:

i) What opportunities are available to deal with the challenges of multiple outcomes, interaction between policy instruments, difficulties in measuring outcomes (including, for instance, the fact that economic outcomes of research will materialise over the longer term), accounting for spillover effects and the limited availability of indicators to assess performance)?

ii) How can performance assessments be designed to avoid undesirable biases in the behaviour of the evaluated entities, e.g. focus exclusively on a selection of tasks (namely those that can be assessed) while ignoring tasks which are not directly evaluated?

iii) How can policy assessments be done optimally with limited resources and often short available timeframe for assessing policies and programmes?)?

iv) Are there novel approaches, based on the use of more sophisticated and diversified data sources and/or the internet, including e.g. information on researchers' career paths and their publications, to conduct new assessments? Could the internet provide wider opportunities for implementing experiments to conduct policy instrument assessments more rigorously?

v) What approaches can ensure assessments are as rigorous as possible while allowing for efficient assessments that do not lead to evaluation fatigue?

*3.3.3 Creating Policy Indicators*

37. The discussion of policies and their evaluations will also support efforts aimed at creating indicators of qualitative dimensions of innovation policies, with a focus on those specific to the knowledge triangle. Examples of indicators developed in other fields include the World Bank's Doing Business indicators and the OECD's Product Market Competition and the Services Trade Openness Indices. There are multiple challenges that need to be addressed if one is to create indicators of qualitative policy characteristics, even more if one is to obtain composite indices (OECD-JRC, 2008).

38. The complexity of the realm of innovation policies requires in a first stage developing a framework on the basis of which policy indicators could be developed. Starting with a particular field, such as the commercialisation of public research, stylised characteristics of policies will be identified. A possible starting point is provided in Zuniga (2011), where a list of characteristics of such policies includes i) whether there are policies/guidelines (on IP, R&D and technology transfer), ii) ownership characteristics of IP (for the institution, researchers or others), iii) policy revenue sharing (share for inventors) and iv) other incentive policies (including awards or prizes, equity participation or temporary leave). Synergies with OECD work on IP regimes will be explored. These characteristics should be sufficiently rich to differentiate across different countries' approaches to commercialisation policies. At the same time, they have to be simple enough to allow gathering relevant policy information across countries.

39. In a second stage, the methodology will be tested by gathering policy indicators for a selection of countries, using information from the STI Outlook policy questionnaire as a starting point. Other sources of information on relevant national policies such as the Innovation Policy reviews and relevant thematic exercises will also be used. The country case studies the project will undertake will also help provide additional data. In addition to information on country characteristics, the collection of country information will also involve gathering information on institutional characteristics, such as e.g. the legal status of universities and research institutions that will likely affect policies' impacts.

## 4. Overview of Data Sources

### *4.1 Data on Public Research Outputs and Inputs*

40. The proposed study will rely on detailed information on research outputs generated by public research organisations. The information will be obtained from international databases of publications and patents. These data provide quantitative and rich information on research outputs; it is possible to differentiate across different types of research contributions (including, for instance, proxying for the quality of outputs, focusing on institutions and researchers' generating such knowledge, as well as the geographic location where such knowledge inputs where generated). Evidence on joint industry-university publications or patents provide direct evidence of public research organisations' relations with industry. Patenting and publications data also allow applying network analysis tools to map linkages across institutions, a particularly useful dimension in the context of this project.

41. Three different publications databases are available - Thomson Reuters' Web of Science, Elsevier's Scopus (Version 6.2014, April 2014) and Google Scholar. The databases provide information about publications with detail disaggregated at the level of the scientific article, allowing disaggregation by scientific field among other criteria. In addition, other databases, such as, for instance, the COMETSandStars database and nanobank.org, can provide complementary information on research outputs in specific fields and/or countries (Zucker et al., 2011, Zucker and Darby, 2014b). Moreover, several relevant research output indicators are available from university rankings such as the Leiden Ranking of universities. The latter includes indicators for about 750 universities, this includes information on university-industry co-operation obtained based on the database by Thomson Reuters.

42. Information on patents issued by public research organisations will be taken from the PatStat database. Similarly to information on publications, a distinct advantage of these data consists in the specific information on specific patents by technology type, geographic location, etc. (OECD, 2009). In addition, citations of scientific publications in patent application documents are a useful source to identify industries' needs for scientific inputs. Industries would be identified based on the identity of industry inventors who filed patent applications.

43. With regards to data on research inputs, there are few international sources of similarly comprehensive information. The EUMIDA research project resulted in a baseline dataset with some information on student numbers, specialisation, research activities and international as well as regional engagements of universities in Europe. For the world's leading universities, some information can be obtained from university rankings, including, for instance, information about faculty, research student numbers, etc. Bodies in charge of funding research, such as the Higher Education Funding Council for England, also collect and provide statistics on public research organisations, sometimes at the level of departments.

### *4.2 Data on Innovation Performance*

44. The Orbis database can be used to analyse impacts of public research at the establishment level across countries. The linking of firms in the database to the PatStat database is particularly interesting as impacts of research on patenting of firms could be analysed. Firm-level data are interesting also in order to investigate heterogeneous impacts across different types of firms. Well-known caveats regarding the coverage of firms across countries and other shortcomings would have to be accounted for. Moreover, the STAN database allows conducting an alternative cross-country impact analysis at industry rather than firm level.

45. Relevant national sources include R&D and other firm surveys/censuses. These data are not only valuable as they provide a representative sample. Panel data also allow more robust identification of causal relationships. The Community Innovation Surveys (CIS) can provide perspectives on collaboration based on the value firms give to inputs from public research. Firms provide information on their collaboration with public research institutions, including on whether innovations were developed involving universities and research institutes. The CIS also contains information on whether universities or higher education institutes, government or public research institutes were important and what role scientific journals and trade/technical publications played.

### *4.3 Information on Commercialisation Efforts*

46. Various surveys of public research organisations have been undertaken with the objective of obtaining information on commercialisation. In some cases the initial survey was implemented a decade ago with follow-up surveys subsequently, providing for a potentially useful time series. A multi-country survey of public research institutions in 13 OECD countries was conducted at the OECD in 2001-02 (OECD, 2003). The Association of Pacific Rim Universities, the Association of European Science and Technology Transfer Professionals and the Milken Institute have also carried out cross-country surveys of public research organisations' commercialisation activities. At the country level, the Association of University Technology Managers (AUTM) collects information on the commercialisation of US and Canadian universities and research institutes. Australia, Canada, Denmark, the United Kingdom, South Korea also have surveys. These could be a useful source of information for national studies (see Section 3.2).

### *4.4 Additional Data Sources*

47. "Big data" can prove a useful source of additional information for this project, complementing the available data sources. This is particularly the case as researchers have a strong incentive to make their work widely known, also as a way to seek future collaborations. Incorporating these data sources requires careful consideration of the representativeness of the samples obtained as well as adequate interpretations of new data obtained. Box A.2. summarises some of the most interesting data sources.

**Box 1. Additional Data Sources**

Platforms storing academic research are probably most relevant initially: This includes Google Scholar, a source that can be used as complementary to the Scopus and Web of Science databases. Certain of its features, such as the option for researchers to publish author pages, can help better identification (e.g. by attributing the author information adequately to a body of researchers). The database is also more comprehensive by including not only publications but also working papers, some of which might be useful as translating more applied research. There are also other platforms (such as IDEAS, SSRN) and specific social networks for academics (such as ResearchGate.Net). These can help go beyond publications information, they provide information on article downloads, they give information on networks of researchers and collaborations, and so on.

An example of how linkages have been explored with web information includes the attempt at using machine learning tools to identify hyperlinks on university pages to identify collaborations, but still require improvements to be useable as valid alternatives. e.g. at scale of web sites, web pages, words in web pages, hyperlinks. Building such networks has to date mostly been used to capture opinions and in the area has been related to the occurrence of university-industry terms, e.g. in line with Google Trends or Twitter debates. At this stage much of the analysis is more experimental.

Several services provide access to linked information about researchers and research institution and their collaborations, including for specific fields of analysis (e.g. Thomson Reuters Research Analytics services, the Centre for Science and Technology Studies at the University of Leiden, etc.).

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