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Investigating the Impact of the **Innovation Union**

D1.1 | *Literature Review and Data Sources*

Deliverable: *Promoting excellence in education and skills development (WP1): Literature review and data sources*

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Introduction

The goal of this document is to provide an overview of the Innovation Unions' commitments on promoting excellence in education, science and skills development. The document firstly describes the commitments and secondly provides information about the potential impact of these commitments. A secondary objective of the report is to identify potential sources of data, and the opportunities for assessing the degree of implementation and the effects of the commitments in European countries. Finally, we discuss the potential impact of the set of commitments on the overall goals of the Innovation Union, and the way in which these impacts will be measured by the NEMESIS model in the next phase of this project.

1. Committments related to promoting excellence in education and skills development

The background for the Innovation Union commitments investigated in work package 1 of the I3U project concerns a worry that European countries may underinvest in their knowledge base in periods of fiscal constraints and increased global competition in science and innovation. Particularly, several problems are noted in the EU Commission's communication, such as weak level of STEM competencies compared to other regions (Asia), losing out in the global competition for talent, comparatively lower levels of researchers in the population compared to other regions, innovation skills shortages and lack of well-developed partnerships between higher education and businesses in curriculum development and skill formation. Based on these assumed deficiencies, three commitments have been formulated, and should have been implemented by 2011:

1. Development of strategies for training enough researchers to meet national R&D targets (In this document we will label this commitment 1.1) and promoting of attractive employment conditions in public research institutions (commitment 1.2).

2. Development of a benchmarking and ranking system of European universities (commitment 2.1).

3. Development of knowledge alliances between education and business to develop new curricula addressing innovation and skills gaps (commitment 2.2), and particularly e-skills for innovation (commitment 3).

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All of the commitments in WP 1 refer to policies that promote the development of knowledge and skills in the public and private sector. The commitments' overall rationale is to increase the number and quality of individuals with high level scientific competencies (commitment 1.1), also by fostering high quality academic institutions (commitment 2.1) with good working conditions for scientists (1.1) and to ensure that high level skills will also flow to the private sector and develop within the context of private firms (2.2 and 3).
These commitments encompass both very broad and very specific issues. In our literature review on these topics, we have searched through relevant databases (Web of Knowledge, Scopus, ScienceDirect and Google Scholar) for publications on doctoral education and researcher training, working conditions for scientists, benchmarking and ranking of universities, university-business alliances (for educational purposes and skills development) and innovation skills/e-skills. Specifically we have used the following keywords (and variations and combinations of them):

- 1.1: Doctoral training, doctoral education, doctoral research training, research training, PhD training, PhD education.

- 1.2: Academic labour market, academic work, academic working conditions, researcher work, academic career, researcher career.

- 2.1: University ranking, university excellence.

- 2.2: University-industry, university-industry relation, university-industry partnership, university-industry cooperation, university-industry collaboration.

- 3: E-skills, e-leadership, e-business, ICT skills.

In each literature segment, we have targeted publications that are relevant for the specific commitments (but not only on the particular policy tool suggested, as literature on these policy tools can typically be very limited), that focus on European countries, and that are empirical contributions to the literature. We have excluded publications that are not research papers or reports, such as perspectives and opinion pieces. Conceptual papers, policy reviews and literature reviews have been included if they contain relevant information on the topics of interest for each commitment. After some cleaning up to remove irrelevant and doublets, all the literature was downloaded in full text.

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In this report, we complete the following tasks for each commitment: 1) we review published research of relevance to understanding the knowledge status of research related to each commitment; 2) we review and discuss relevant indicators and secondary data available for investigating the commitment on a European level, based on extant research, and suggest the extent to which and how the impact of these commitments can be tested.
The remainder of this document consists of our analysis of these texts, and it is organized as follows. Sections 2 and 3 review the literature related to commitment 1; sections 4 and 5 summarize extant research in relation to commitment 2; section 6 focuses on the literature on commitment 3; and section 7 concludes by summarizing the main points of the literature review and pointing out the links of this research to the economic mechanisms investigated in the NEMESIS model to be used in the I3U project.

1. Commitment 1.1: Training of researchers

To collect the literature on research themes related to this first part of commitment 1, we have searched for publications on research training systems, levels of investment in researcher training and impact of such investments on different research and innovation outcomes.
Doctoral education and researcher training is a large and heterogeneous area of research, which means that most publications retrieved have not been included in our review. We have excluded publications that focus on the educational content and pedagogy of doctoral training, students' and supervisors' perspectives on PhD training and most studies of learning outcomes on PhD level.
We have included in the review data base publications that describe and analyse PhD training systems in Europe, overall levels of investment in PhD training, funding of researcher training and studies that focus on outcomes of investment in researcher training (such as the number of doctoral degree graduates, the number of theses produced or the number and quality of scientific outcomes, skills acquisition during the PhD and labour marked outcomes of researcher training). Below, the evidence on the research questions of particular interest to the I3U project is reviewed. The articles and their main characteristics (research questions, methods/data, findings and relevance to understanding impact on research and innovation) are summarized in table 1.
From the literature reviewed in table 1, two separate topics emerge as relevant for the I3U project: 1) The level of investment in researcher training; and 2) the outcomes of increased investment in researcher training.

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Actually, few scientific articles discuss the level of investment in researcher training in relation to growth in the overall spending on R&D. But several of the papers provide evidence and discuss the large-scale growth in expenditures and numbers of PhD candidates, which have occurred in Asia, North-America, Europe and Australia the last twenty years (Nerad 2008, Kehm 2006). Numbers on expenditures on R&D and candidate/degrees produced are collected by national statistical agencies and by the OECD and Eurostat, and then reported in different governmental and international agency reports, as well as in academic publications. The overall picture is that researcher training (in the form of doctoral education) has been massively expanded in many countries, from a marginal phenomenon in most European and Asian countries to becoming a more important area of policy and practice with rapidly increasing student numbers (Nerad 2008). In the last years, growth has levelled off in many European countries, however.

Most papers focus on the trends in doctoral education that are seen as both direct and indirect results of expansion in enrolments (Kehm 2004, 2006, Massue & Schink 2006, Enders 2006, Nerad 2008, Kot & Hendel 2012, Halse & Mowbray 2011). Trends reported includes increased standardization and shortening of the degree (with the implementation of the PhD degree in Europe), increased diversity in programme offerings, particularly with so-called professional doctorates and industry doctorates, and increased diversity in the PhD student group. These trends have implications for structure and content of researcher training and on results achieved.

The other main question of interest to I3U is to what extent there exists evidence for the results and outcomes that are achieved by investing in researcher training. For the most part, studies have investigated the impact of obtaining a doctoral degree for the individual, and particularly for transition to work. A few studies have looked into the wage premium of obtaining a doctoral degree (Casey 2009 for example); others have looked into the competencies achieved during doctoral training and how these competencies are valued in the post-phd work situation (Durette et al 2014, Lee et al 2010), which again is related to a larger stream of studies into the careers and career destinations of doctoral degree holders (Stephan et al 2004, Neuman & Tan 2011, Gaughan & Robin 2004). On the latter issue, the OECD, Eurostat and UNESCO have a had a joint project on mapping careers of doctoral degree holders, which have resulted in a number of publications (Auriol et al 2010; Auriol et al 2013) which provides the most comprehensive knowledge base on this issue.

Broadly speaking, investing in a doctoral degree is seen to have a wage premium, depending on gender and field of science, and that the competencies achieved during the PhD period is valued highly both by the candidates and by their employers, particularly problem solving and analytical skills. Further, the unemployment level among PhD holders is generally low. On average, about half of PhD holders have career outside academic institutions. Other than higher education, the health care

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sector, the business sector and the governmental sector are main career destinations for PhD holders. Skills acquired during the PhD are seen as relevant for both academic and non-academic jobs. There are off course large variations between fields of science and occupational categories on these questions.

The fact that half of all PhD holders work outside academic institutions is also relevant for understanding societal effects of investing in researcher training. As PhD holders to a large extent work outside academic positions, skills and competencies flow to a large number of other sectors. There has been particular interest in the flow of research competencies to industry (Stephan et al 2004, Cruz-Castro & Sans-Mendez 2005, Herstad et al 2015).

There has been however surprisingly little effort to investigate the impacts of investment in researcher training on research and innovation outcomes, assumingly due to large measurement difficulties. Very few papers attempt to investigate the linkage between investment in research training and scientific outcomes (such as numbers of scientific publications made by PhD candidates) (Lariviere 2011). Likewise, very few have attempted to map the contribution of PhD candidates to research-based innovation (Chellarjai et al. 2008), or to map the extent to what recruitment of PhD holders increase innovation in firms (Herstad et al 2015).

Indicators and data sources for commitment 1.1

There is a number of relevant data sources and variables on investment in researcher training in Europe: Both Eurostat and the OECD systematise national level data on researcher training and doctoral education. The OECD collects information on the yearly numbers of awarded doctoral degrees and doctoral degree holders (in the relevant age cohort, in the working population, new doctoral degrees awarded and doctoral degrees by field of science and gender) and also has time series on some of these variables (OECD 2013). Eurostat and OECD also have information on overall R&D expenditures and population working with R&D. Eurostat collects statistics on numbers of doctoral students in science and technology in European countries (Eurostat 2015).

In addition, some countries have data on the careers of doctoral degree holders (countries that have participated in the CDH project especially). Such data consists of either register—based information on educational level and employment data by sectors (Educational statistics). Some countries collect data from PhD holders by surveys to PhD graduates on a regular or irregular basis relatively shortly after they have graduated (Germany, US, UK, Norway, probably several more). The CDH-project run by the OECD is perhaps the most systematic source of knowledge and data on careers of doctoral degree holders, but have data on a limited number of countries (Auriol et al 2010; 2013).

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The impact of increased investment in researcher training on scientific productivity, has not been systematically studied, according to the OECD. It could be possible to investigate the impact of this commitment by collecting data on the relationship between annual growth in the numbers of doctoral degree holders and growth in scientific publications in a later period. Annual publication levels by countries could be obtainable from WOS or Scopus. Data would however only indicate whether there is an association, and could not easily be used to establish a causal relationship, as multiple factors influence scientific productivity other than the growth in numbers of awarded doctoral degrees.
In terms of innovation impacts of increased numbers of individuals with PhD level qualification, this is an even more difficult relationship to investigate. In a similar fashion, it could be possible to look at the relationship between growth in the numbers of doctoral degrees awarded to growth in academic and non-academic patents. In some countries (like Norway and Sweden), it would be possible to look at the relationship between recruitment of different kinds of staff and firm innovation, by use of combined CIS data and employee registers (Herstad et al 2015).

Summary on commitment 1.1.

The review of literature of relevance to commitment 1.1 – training of researchers – is mainly descriptive. The literature indicates that in many European countries, in North America and elsewhere we have seen a massive expansion of PhD education. This indicates that many EU countries have taken steps to achieve the goal of the Innovation Union in expanding the volume of researcher training. However, this trend has levelled off during the last years. There exists several good data sources collected by the EU and OECD on numbers of PhD students and degrees conferred, meaning that it is easy to obtain an overview of the implementation of this commitment on country and EU levels.

Turning to the issue of impact of this commitment, evidence is very limited. The literature reviewed indicates that there is a well-established understanding of the micro-level effects of investments in PhD training (employment destinations, skills use and salary levels), but evidence on macro-level effects is almost non-existent. The OECD acknowledges that it is very hard to identify macro-level effects of investment in PhD training, and that effects are likely indirect. Relevant indicators for the *direct impact assessment* for this commitment would be scientific productivity and academic patenting, as one would expect that higher volumes of people with scientific training would increase the volume of research being carried out in a country. One would also

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expect that higher levels of formal qualifications would have spill-over effects, and indirectly influence innovation performance, particularly science-based innovations. This could be measured by number of spin-off companies or number of patents from scientific communities. The evidence for a link between higher levels of formal qualifications and innovation outcomes at macro-level is still weak.

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Table 1: Overview of papers on training of researchers (doctoral education and researcher training) and impact on research and innovation

Reference	RQ addressed	Data sources/method	Key findings	Addresses impact on research and innovation related variables?
Enders, J. 2005	Changing practices of doctoral training in Europe	Conceptual paper; policy and literature review	Increasing diversity of doctoral training, moving away from disciplinary model of training to interdisciplinary and multi-institutional training	No
Kehm, B. 2007	Compares and contrasts European doctoral education with the system in US	Conceptual paper; policy and literature review	Identifies key trends in doctoral education; increasing attention, increased structure, increased enrolment, increasing diversity	No
Cumming, J. 2010	Changing conceptualization of doctoral training	Conceptual paper, supported by survey to PhD students and interviews	Identifies key practices in doctoral training from the perspective of the PhD candidate, and discusses potential changes in doctoral training in light of these	No
Massue, J.P. & Schinck, G. 2006	Reviews doctoral education in selected European countries	Conceptual, review of policy and other documentation	Identifies key trends in European doctoral education, with the advent of the short-duration doctoral degree PhD following the implementation of the Bologna reform	No

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Kot, F. & Hendel, D.D. 2012	Compares the development in four countries of professional doctoral degrees	Documentary analysis of policy and programme documents, descriptive statistics for enrolment	Increased growth in professional doctoral programmes in UK, US and Aus, but very heterogeneous. Efforts to limit the expansion in Canada.	No
Neuman, R. & Tan, K.K. 2011	Labour market destinations for PhD holders in Australia, compared to OECD countries	Survey data of initial and early career destinations	Less than half doctoral degree recipients work in higher education sector, and less than 1/3 in scientific positions. This is largely comparable to other countries. Indicates multiple destinations, but little is known about careers of doctoral degree holders outside academe	Yes, mobility to other sectors, skills
Gaughan, M. & Robin, S. 2004	Compares level of investment in researcher training and early career destinations of PhD graduates in France and USA	Descriptive statistics on R&D spending and numbers of researchers in the economy, economic support to PhD students, and basic statistics of the research training system. Career data from survey (France) and CV-analysis (US)	Identifies different labour market characteristics for PhD holders in the two countries, and identifies characteristics of individuals that are successful in obtaining permanent jobs in science after the PhD	Yes, investment levels and career outcomes
Kehm, B. 2004	Describes trends and changes in doctoral training in Europe and North-America	Secondary documents and policy	Describes trends and initiatives in European doctoral training	No
Kottman, A. 2011	Describes trends and changes in doctoral training	Secondary documents and policy	Describes trends and initiatives in European doctoral training; analyses the process in	No

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	in Europe; particularly the development of the third cycle of the Bologna reform and increased standardization of PhD training		the perspective on institutional theory. Identifies development as a silent or grass root movement	
McAlpine & Norton 2006	Review of literature to increase knowledge of factors that increase outcomes (reduce attrition rates) of doctoral training	Literature review	Describes an integrated framework of contexts and factors that contributes to promoting successful completion of doctoral studies	No
Nerad & Hegglund 2008	Reviews global trends in doctoral education	Policy review and descriptive statistics	Global trend of expansion of researcher training, particularly in Asia. Modest increase in Europe, driven by increasing international recruitment of PhD students. Increased female participation, older entrants, development of professional doctoral degrees	No
Durette et al 2014	Empirically investigates core competencies developed during PhD training	Survey to 3000 PhD graduates from French universities, cluster analysis of expression of competencies	Finds six core competencies that are not dependent on a range of individual and institutional factors	Skills
Halse & Mowbray 2011 (intro to special issue on the	Reviews policy and research into investment and impact of PhD training	Literature review and documentary analysis	Increased enrolments and increased diversity of programmes have led to increased interest in outcomes and impact	Labour market outcomes, skills

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impact of doctoral training)				
Lee et al 2010	Skill development and career trajectories for PhD holders in science and engineering	Survey to PhD graduates at large UK university	Career destinations outside academic positions most common, different skills regarded as important for persons with different jobs, analytical skills and problem solving capability important for all	Yes, link between skills and labour market destinations
Chellarjai, Maskus & Mattoo 2008	The contribution of skilled immigrants and foreign graduate students to innovation	Econometric, uses patent data, data on R&D expenditures, ST personnel, and enrolment of international graduate students as a proportion of all graduate students	Finds that skilled immigrants and foreign born PhD students increases patenting by US universities and non-university patents	Yes, on patenting
Casey 2009	The economic contribution of PhDs	Conceptual; review of arguments for different kinds of contributions	Social benefits outweighs private; diverse benefits but difficult to measure	Yes, but no suggested indicators
Stephan et al 2004	Flow of PhDs to industry; seen as a measure for economic impact of researcher training	Survey data of earned doctorates in the US; mainly descriptive	Analyses patterns of education and patterns of employment of doctoral degree holders	Yes, mobility patterns to industry
Cruz-Castro & Sans-Mendez 2005	Career trajectories of PhD holders, and hiring of PhD holder in industry. Also focus on innovation outcomes of hinring PhDs	Survey to a sample of PhD holders in Spain (involved in a publicly funded programme)	Analyses career destinations, career ambitions and outcomes of working in industry	Yes, firm level publications, patents and collaboration with academic sector

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2. Commitment 1.2: Research careers and employment conditions in public research institutions

This second part of commitment 1 is about the creation and support of attractive employment conditions for researchers in public research institutions. This question is related to the very broad issue of employment conditions for academics and changes in academic labour markets and the academic profession. This is an area where there is limited statistical data available across a number of countries. There have been several international research projects on the academic profession and their working conditions, and it is possible to utilise these to some extent. Some of these projects and their results are listed in table 2.

In the nineties there was a comparative study on the academic profession sponsored by the Carnegie foundation (see Holer & Teichler 2013), and then the so-called "Changing academic profession"-project than run from 2004 to 2011. In the CAP-project 17 countries participated, and the main thrust of the project was the collection of survey data from academics about the nature of their work, employment conditions, career trajectories and a range of other individual level variables, and the comparative analysis of these data. A number of books, papers and reports have been published from these datasets (Teichler & Holer 2013, Kehm & Teichler 2013). There have also been a few more macro-oriented approaches, focusing on describing differences in academic systems and market conditions for academic labour (Musselin 2010).

The European commission have also funded two large projects on careers and mobility of European researchers, which have collected survey data on these questions from more than 15 000 researchers inside and outside the European Union (Idea consult 2013b). Results from these large-scale surveys are available in reports, and the data from 33 European countries are available on 150 indicators on an online platform.

Overall, the rich micro datasets provide the opportunity for doing detailed, comparative analysis of working conditions for different kinds of academic staff, different functions and work that academics do, working time and salaries, and satisfaction with working conditions. The analyses are largely descriptive and comparative.

As far as we can see from this review, very few efforts so far to investigate the relationship between working conditions for researchers in public research organisations, and research and innovation outcomes. It could be possible to look at the relationship between working conditions and scientific productivity (measured by

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publication data), but also for this variable the relationship is not likely to be direct and a range of factors influence scientific productivity.

Indicators and secondary data sources for commitment 1.2

In the MORE2 project (Idea consult 2013a, 2013b) which covers both the EU27 countries and selected non-EU European countries, there are several relevant variables, collected from both available registries and surveys among academics. The dataset includes information about career structures, opportunities and patterns of remuneration of academics, but also subjective assessment of different aspects of working conditions. The underlying rationale for studying working conditions is that they directly and indirectly influence academics' career and mobility choices. There is a range of variables from the MORE2 dataset that can be used as indicators for good working conditions. There is information available about kinds of employment contracts (full, part-time, dual, fixed, permanent). There is also information on academics' satisfaction with working conditions (4 dimensions; academic, personal, career related and employment aspects). All of these data have been collected using surveys among the academic population and covers 33 European countries. Separate data are found on PhD and post doc groups, and also for comparing academics on different career stages (Idea 2013a).

Data on numbers of researchers in the economy and researchers employed in the public sector are available through Eurostat, but these data are not relevant for understanding the quality of working conditions in public research organisations.

Summary on commitment 1.2

The literature of relevance to commitment 1.2 is mainly descriptive and comparative. Working conditions of academics have been studied through several international research projects, with detailed micro-level data from academics. The most recent projects is the so-called MORE1 and 2 projects funded by the EC. These data along with the monitoring activities being carried out by the EC should enable an implementation analysis of this commitment to be carried out.

As to the direct impact assessment, the MORE2 data on working conditions may have limited relevance, as they are cross-sectional and not panel data. We will however use data from MORE2 to look at whether academic working conditions influence scientific productivity, when also controlling for other input factors. There is no evidence or theory that argues for a positive relationship between academic working conditions and scientific performance at micro or macro-levels. Good working conditions are

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probably closely related to other relevant input factors (economic resources, human resources) which influences scientific performance.

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Table 2: Research publications on working conditions in public research organizations and academic careers

Reference	RQs	Method/data	Findings	Impact on research and innovation?
Enders & Teichler 1997	Describes the employment and working conditions for academics in various European countries	Survey to sample in selected countries; comparative	Employment situation and satisfaction with work, functions and activities and time spent on different activities. Compares different occupational categories and countries	Impact on research productivity (publications)
Musselin 2005	Compares academic labour markets in France and Germany	Documentary analysis	Describes different characteristics of academic labour markets. Finds common trends towards increasing institutional management of academic work and working conditions	No
Bennion & Locke 2010	Compares working conditions and career trajectories of academic staff in 17 countries, also explores the influence of working conditions on mobility	Survey among academics in 17 countries	Compares the working conditions for academics in the early phase of their careers in 17 countries	Impact of mobility to careers and later mobility of academics Institutional support and salaries influence inflow of researchers
Cavalli & Moscati 2010	Investigates how differences in national academic systems have an impact on a number	Survey among academics in 5 countries	Compares career patterns and satisfaction with employment conditions in five countries. Rise in uncertain conditions and dissatisfaction among younger academics	No

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	of aspects of the working conditions of academic staff			
Kehm & Tecihler 2013	Presents results from the CAP-survey	Survey among academics in 8 countries	Different chapters presents results from the international survey of working conditions of academic staff and the changing academic profession	Mainly descriptive
Teichler et al 2013	Presents results from the CAP-survey	Survey among academics in 12 countries	Different chapters presents results from the international survey of working conditions of academic staff	Mainly descriptive
Idea consult et al 2013a;b	A: Higher education sector report based on indicators and survey to academics B: Final report of MORE2 project	Survey among academics in all European countries (150 different indicators)	Broad descriptive reports focusing on characteristics of the academic population in Europe, mobility of researchers, collaboration patters of academics and working conditions for academics in different countries, subject fields and institutional types. Also contains information on PhD training in Europe.	No, descriptive and comparative (by country, occupational categories, gender and fields of science)

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3. Commitment 2.1: University Rankings

Shifting to commitment 2, the first theme in this commitment addresses the need for new and improved university rankings to make better comparisons between countries and institutions. The main idea is that rankings need to take different activities and goals into account for the higher education institutions (i.e. not just research excellence), and the purpose is to create a new ranking that will incorporate multiple dimensions of inputs and outputs. As such this commitment is not directly or even indirectly about supporting innovation in Europe, it deals with a tool that ideally should help make better decisions in innovation, research and education policy areas.
The EU Innovation Union commitment has been followed up, especially in the form of the new ranking system U-Multirank which has been available since 2014. In this particular case, there may therefore be less reason to follow up with advanced data analysis to see whether the policy initiatives in the mechanism have had an impact. We have in this section chosen to discuss the literature on rankings in a slightly wider sense. We do this both to inform readers about the methodological and other challenges of rankings, but also in case some of the data used for the rankings will also be used in I3U or other projects as proxies for "quality" of a region's or country's higher education institutions.
There is a growing literature on the ranking of higher education institutions (HEIs), especially found within higher education studies. We have summarised the central ones in Table 3. Almost all of it deals with the problems and challenges of rankings, both related to their methodology and how they are used by policymakers and in HEIs. Some of the literature is inherently sceptical towards rankings in any case; other papers are concerned about how the creation and use of rankings can be improved. The scientific paper describing the U-Multirank approach claims that "none of the current ranking systems have the validity, rigour or meaning to be of real value" (van Vught & Ziegele 2011).
Many rankings are described and analysed in the literature, although the two most well-known ones dominate: the Times Higher Education Supplement (THES) ranking, based in the UK which incorporates data from publicly available registers, survey/reputational information and more, and the so-called Shanghai Ranking which is first and foremost oriented at various indicators of scientific excellence. Both have a global orientation and result in league tables with the "100 Best", "500 best" etc. universities in the world. Also most other rankings lead to league tables, although the tables resulting from the U-Multirank system are dynamic in the sense that they change depending on the selected focus variables.
The THES and Shanghai rankings, like most of the other ones, are proprietary and secret. This means that detailed information about the indicators used, as well as their

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weighting, is not known, and the underlying data are not publicly available. This is, naturally, an aspect that is criticised in the literature. Even for the U-Multirank system, where the weighting and indicators are fully disclosed, the underlying data are only available to members of the consortium behind the ranking. Some of the most commonly discussed problems in the literature (see Table 3) are:

- Unclear raw data
- Proprietary and secret algorithms inherent in the rankings
- Choice of qualitative versus quantitative indicators (peer review indicators do not always correlate well with bibliometric indicators)
- Relative weight of teaching, research and other activities (in general low weight on teaching in many of the rankings)
- Inclusion procedures (which universities are included; a general finding is that rankings are biased towards large institutions)
- Boundaries of HEIs (how do you deal with subsidiaries, multi-campus universities, mergers, attributions in the case of multiple co-authorships, multiple awards etc.)
- Publication language and coverage (general bias towards Anglo-American literature and countries)
- Inclusion of awards (some use e.g. Nobel Prizes that were awarded more than half a century ago)
- Use of third party data (employer, parent and student surveys)

The general message is that rankings should be treated with caution. Some argue that rankings are "meaningless" or "unsound" because they do not reflect differences between HEIs – the variation in the rankings are much better explained by country level factors (Bornmann et al. 2013; Saisana et al. 2011). Others are worried that rankings will lead to an "intrusion" in academic life leading to less freedom, new and problematic hiring procedures or less attention to teaching in general or the personal growth part of teaching (e.g. Amsler & Bolsmann 2012; Charon & Wauters 2008; Marginson & van der Wende 2007). Yet others describe how the use of rankings at the HEI level is "potentially harmful" or a "real threat" to quality development initiatives because institutions do not understand the many methodological flaws and the context of the rankings (Hazelkorn 2007; Harvey 2008). Finally, the rankings' place in the general media is discussed, where some comment that the most popular ones seem to be the ones with the largest problems of bias and methodology, and that the political and ideological aspects of rankings are under-communicated (Teichler 2011).

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Indicators and secondary data sources on university rankings

As mentioned, all the ranking systems may be considered data sources in themselves, but it is arguably difficult to get hold of the raw data. In a study of innovation across Europe, most of the rankings will have limited value because only a small number of European HEIs are included in the league tables. An exception might be the U-Multirank database, but the output here is not a number but rather a visual representation of the scores of a university.

When using rankings as an indicator of the "quality" of a city, region or country's HEIs, many of the methodological challenges described in the literature will apply. Bias towards English-speaking countries, bias towards research (excellence) rather than teaching, bias towards large institutions are all factors that may distort analyses based on the rankings. The rankings could possibly also be taken as a signal of "talent attractiveness", with some care, since rankings seem to matter somewhat for mobility and attraction of talent (see commitment 4 and 30 below).

Summary on commitment 2.1

The literature on university rankings is highly critical, both of the rankings themselves, the way they are constructed including which data they use, and the way the rankings are applied in specific socio-economic and political settings. The most fundamental critique relevant for the innovation union is that the link between the rankings and the innovative performance of countries and regions is unclear. There are most likely several ways in which higher education institutions can be good for innovation, but this does not mean that they get a spot at all in the most popular rankings.

Partly some of these problems are sought solved through the development of the U-Multirank database and approach which focuses on many different variables and includes a wider set of higher education institutions than the typical global rankings. U-Multirank can be seen as a direct result of the innovation union commitment. It is, however, a bit early to assess whether this ranking approach is of sufficient quality and organised in a sufficiently open way as to be used in investigations of innovation. On the whole, we assess it will not be feasible to carry out an analysis of the impacts of this commitment, because of both the lack of relevant empirical data, as well as the unclear conceptual impact that the construction of a University ranking system may may have on European countries' scientific and innovation performance.

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Table 3: Selected references on university rankings

Reference	Goal/research questions	Methods/data	Findings
Al-Jubori et al. undated	Presents an overview of trends in ranking systems	Review	Rankings are controversial because they are not objective and definite, but they are still used in crucial policy decisions and decision by students and their parents
Amsler & Bolsmann 2012	Discuss the policy effects of rankings	Conceptual, policy-oriented	Rankings change the way we view "good" and "meaningful" education and it enrolls the university system into a global capitalist competition system in a way that is detrimental to the democratic values inherent in the universities
Bornmann et al. 2013	Uses the bibliometrics based Leiden ranking to discuss differences between universities	Methodological development	Only 5 per cent of the variation between universities in the ranking is explained by differences at the university level; 80 per cent explained by country factors; making some rankings "meaningless"
Boulton 2011	Discuss new rankings supported by the EU's Innovation Union (U-Map and U-Multirank)	Conceptual, policy-oriented	The new rankings are supposed to deal with the deficiencies of the "old" ones, but they have many of the same problems; and the problems will just be related to multiple rather than a single dimension; both have "serious defects" when it comes to providing comparable data
Charon & Wauters 2008	Discussion of rankings	Essayistic	Rankings will change the global university landscape and constitute an intrusion in academic life at the individual level
Clarke 2007	Focus on how rankings are used by students	Survey	Use of rankings may have negative consequences for disadvantaged and minority students; we may need rankings that are based on how well they train students, not on how exclusive the selection process is
Dill & Soo 2005	Discusses whether there is an emerging consensus on rankings, impact of rankings on behavior	Comparative analysis	Convergence in the definition of academic quality in five different rankings and potential for creating useful information for students and policymakers, but divergent policy interests and increasing laissez-faire

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	and public policy interests not covered in rankings		policies may lead to decreased validity
Federkeil 2008	Discusses how rankings can be used for institutional level quality assurance purposes	Conceptual discussion	Rankings are problematic for use at the institutional level without a deep understanding of how they are made and how they compare to other evaluation efforts
Frey & Rost 2009	Discusses whether rankings reflect research quality	Discussion of publicly available rankings	Different citation ranking systems produce entirely different results; measures are far from objective and new rankings must be based on multiple criteria and involve independent experts
Guarino et al. 2005	Discuss the variables in different rankings and contribute to methodological development	Comparative analysis	Latent variable analysis highlights the great degree of uncertainty in rankings and can contribute to improved comparability
Harvey, L. 2008	Editorial (very long, like a scientific article) about ranking systems for a leading higher education journal	Critical discussion	Rankings are a "real threat" to institutional processes of developing quality, due to the many methodological flaws and the lack of contextual understanding
Hazelkorn 2007	Looks at how rankings are used by university leadership worldwide	Survey	Rankings are "potentially harmful" and lead to a variety of responses that do not match what the rankings are actually saying
Jarocka 2012	Wants to review the literature on rankings and discuss the EU initiatives related to CHE, U-Multirank and U-Map	Literature review	Suggests that rankings need to be structured in a different way; not as hierarchies from "best" to "worse" but multidimensional using cluster analysis techniques
Jöns & Hoyler 2013	Contribute to the debate on rankings, seen from a geography perspective	Discussion of publicly available rankings	Geographical bias in many of the university rankings, giving preference to specific places in the world; substantial variation in ranking criteria; tension between established knowledge hubs and emerging centers of research and training
Liu & Cheng 2011	Discuss the methodological	Conceptual and	Challenges related to: definition and selection of indicators, research

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	problems of the Shanghai ranking	methodological	versus education, attribution, language and databases for publications, selection of awards, boundaries of institutions (naming, merging, splitting); all these are known to the ranking developers who try to improve accordingly (?)
Lukman et al. 2010	Introduces a new ranking system where "sustainability" is one of the criteria	Test on 35 universities	Fairly low correlation between the traditional rankings and the proposed new one called "TUR" (three-dimensional university ranking)
Marginson & van der Wende 2007	Discuss methodological problems of the two most widespread rankings	Conceptual and methodological	The rankings barely pay any attention at all to quality of teaching, which is one of the most important missions and effects of universities; rankings are part of a global search for excellence which gives priority to only one type of higher education institution
Mesnard 2012	Discuss the SCImago ranking to improve it/discuss problems	Test of one ranking	Many problems detected related to nomenclature, double affiliation, aggregation and bias towards large institutions. Only detailed contextual knowledge can help make sense of the ranking.
Montesinos et al. 2008	Discuss how you can rank the "third mission" for "world class universities"	Conceptual discussion	Practical suggestions about which indicators to include if the third mission is taken seriously in development of rankings
Pouris & Pouris 2010	Develop a new ranking system for South African universities	Conceptual	Bibliometric approach (number of citations) shows promise but also difficult to assess all disciplines and universities that are not 'world class'
Proulx 2007	Discuss different ranking systems when used for benchmarking purposes	Test on 10 research intensive Canadian universities	Ranking systems are yet not good enough for benchmarking because of lack of comparability, divergent sets of indicators and unclear choices of data; rankings themselves are seen as "arbitrary choice of indicators and weights"
Saisana et al. 2011	Compare the two most popular world ranking systems (THES and Shanghai)	Methodological, conceptual, statistical	The institutional level and country level statistics are "unsound" and none of the rankings should be used to compare universities; but the rankings can say something useful about world regions

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Soo & Dill 2007	Review the German ranking system CHE	Conceptual	Ranking is fairly costly, has a number of methodological challenges and is often used only for "infotainment" value, although there may still be a potential for using the CHE in quality assurance processes
Tambi et al. 2008	Review of how performance indicators are used in total quality management	Case study	Proposes a new management model for universities in line with Total Quality Management and ISO9000
Taylor & Braddock 2008	Discuss theoretical and methodological issues related to rankings	Conceptual, comparing THES and Shanghai	Shanghai ranking better suited to judging academic excellence than the Times Higher Education Supplement ranking; but both are very limited tools for national and institutional level decision making
Teichler 2011	Discuss the methodological and policy implications of ranking systems	Conceptual	Highly critical; rankings are "primitive", the lower the quality and higher the bias, the more popular the ranking seems to be; rankings are ideological and political and carry a number of (negative, unintended) consequences
Usher & Savino 2007	Discuss 17 different university rankings and league tables from across the world	Survey	Ranking systems are still in their infancy and researchers need to work to create better practices for data collection and reporting if such rankings are to be used for quality assurance purposes
Van der Wende 2008	Review the dilemmas, trends and promises of university rankings and their impact on institutional behavior, system-level diversity and their relation to classification	Conceptual	Many methodological problems in global rankings and strong bias in favor of the research-intensive university although most countries need a wider diversity in higher education institutions; rankings should be used with caution if at all, the German CHE one is the best
van Raan 2005	Discuss recent developments in university rankings	Conceptual discussion	Correlation of expert scores and bibliometric scores close to zero, new and better methodologies are needed.
van Vught & Ziegele 2011	Propose a new ranking system	Conceptual and methodological discussion	This is the report that in fact answers the Innovation Union call for a new ranking system, proposing the U-Multirank system which is now the main link on the web site of the IU

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4. Commitment 2.2: Knowledge alliances and partnerships between business and higher education

The second theme in commitment 2 points out the need to stimulate closer collaboration between higher education institutions and businesses, with the purpose of creating innovative educational offerings and curriculum and to support the development of innovation skills among university graduates. As formulated by the European Commission, the role of such partnerships is to create innovation among higher education institutions, rather than seeing such partnerships as a way of transferring scientific knowledge to industry and thereby influencing innovation outcomes in industry.

There is a significant research literature on university-industry partnerships and knowledge transfer from universities to industry in general, but this literature has been more preoccupied with research partnerships and knowledge transfer between universities and industry. The agenda stressed by the Innovation Union is however different. In reviewing research, we have focused on finding publications that target education and student-related collaborations between academia and businesses. We summarise below some of the findings from the general literature on university-industry partnerships, before looking specifically at published research on education related partnerships between education and business.[1]

There is a considerable research literature describing the extent and mode of collaboration between the private sector and the higher education sector (for example Abreu & Grinevich 2013, Schartinger et al. 2002, Perkman et al. 2013). For the main part this literature has been preoccupied with research partnerships, knowledge transfer or commercialization activities. The role of education in university-industry partnerships is much less frequently addressed, although education related activities, competence programs, consultancy services and knowledge transfer in the form of university graduates represent – in volume – probably the largest share of collaborative activities between higher education institutions and the private sector (see table 3 for an overview of studies).

This lack of research interest is also in contrast to current policy focus that emphasizes increasing connection between education and innovation. This policy focus has been built on research that demonstrates that overall investments in tertiary education impacts on countries and regions capacity to innovate. At the European level, interaction between education, research and innovation has been conceptualized as a "knowledge triangle", and the vital importance of education and training for innovation has been repeatedly been emphasized. As a response,

[1] Some of the following text is a modified version of a prior review of this literature, published in Thune & Støren (2015).

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increased participation in tertiary education, focus on skills, entrepreneurship and employability of higher education graduates, and bringing education and business closer together are policy initiatives pursued in many European countries and regions. This development has also been spurred by broader perspectives on innovation. Research increasingly recognizes that innovation is carried out in new ways; through complex partnerships models, in intersection between sectors (service and industry), within the service sector, the public sector and non-technological sectors. Within this context, the importance of competences broadly defined rather than R&D investments are seen as relevant inputs in innovation (Lundvall & Lorenz 2006). One consequence is that education and training systems become central factors when policy makers seek to stimulate innovation.

Education-related collaborations can include many different activities and can take place between stakeholders at different levels. The main aims of such collaborations are to increase the students' work relevant competencies and skills, making them more employable, fostering entrepreneurial attitudes and mind-sets, increasing the flow of knowledge across sectors and stimulating the development of new networks.

Recent research offer several different classifications of business – higher education interaction activities (Jackson 2015, Lee et al 2010, Lester & Costley 2010, Tynjala et al. 2003). One form is interaction with private and public sector organisations to develop new, or change existing, educational courses or programs, to ensure that programs and courses are adapted to the needs to the local labour market A second form concerns collaboration to deliver parts of the educational programs, through practice periods, project work, joint supervision or teaching, and staff secondments. Third, private and public organisations can also support teaching without being directly involved in the programmes, by providing access to facilities and equipment, development of business case studies, development of projects and dissertation topics. Finally, there is extensive interaction with private and public organisations to facilitate transfer from education to work life in most subject fields, such as company visits, mentoring, career guidance, internships and summer jobs.

In addition, higher education-industry partnerships is common in third cycle programmes, and many countries have developed particular PhD programs or funding regimes for PhD training that occurs as a collaboration between industry and universities (Thune 2009,2010, Borell-Damian 2009). According to Borell-Damian (2009) there is not a single model of doctoral collaboration with industry.

As education-related partnerships co focus on different activities, they likely lead to different results and produce different short- and long-term effects. For the firms, collaborating with universities might lead to increased access to relevant competences and development of relationships necessary for innovation activities in the firms (Thune & Børing 2015). Particularly addressing education-related collaborations, collaboration with universities is related to short and long-terms

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recruitment goals, and through collaborating with universities the firms have an opportunity of getting to know potential candidates and also to influence the content of the programs, so that the potential candidates have competences that fit industry's present and future needs (Thune 2009).

Education-related collaborations aim at ensuring that the core competences students develop during their studies are relevant for the world of work, to support development of work-related skills, and to support the transfer of knowledge from universities to business organizations. For students, closer collaboration with business organizations is expected to improve the quality and relevance of their studies, increase their motivation to complete education and ease the transition between their studies and working life (Thune & Støren 2015, Jackson 2015, Kessels & Kwakman 2008). For the higher education institutions, collaborating with industry might have a positive impact on the profile and quality of the educational programmes, and through this increase student recruitment to particular programmes of study.

There are very few studies that have looked at the impact of participating in knowledge alliances. Thune & Støren (2015) is one of the first empirical investigations of this issue, looking at the impact of having collaborated with industry during higher education for graduate students on several student outcome variables, including skills and transition to work. This study, based on a population-wide study of Norwegian university graduates, finds that interacting with industry during higher education increases the likelihood of finding relevant work after graduation. Person & Rosenbaum (2006) found that cooperating with industry also increases the likelihood for timely completion of studies; a finding that is also supported by Thune & Støren (2015). Empirical studies of PhD graduates, comparing students involved in and not-involved in partnerships, indicates positive labour market outcomes and positive commercial outputs (patents), and no negative impact found on research productivity (see Thune 2009 for an overview).

Indicators and secondary data sources on knowledge alliances for skills development

The studies reviewed on this commitment usually use qualitative data or are quantitative studies of particular institutions or student groups. To the best of our knowledge there does not exist broad-based quantitative indicators of knowledge alliances in the form addressed by this commitment. On university-industry partnerships, the R&D statistics in the OECD countries contain information on the level of private funding of R&D in public research organisations. Another commonly used measure for partnerships is co-publication between industry and academics. The CIS-survey also contains information about firms' propensity to engage in

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partnerships with universities and PROs. However, none of these data are adequate for measuring higher education-business partnerships related to education and skill formation. In some countries, there exists rather comprehensive surveys of students and academic staff, that also includes information about their external network activities, but probably not for all European countries and the data are not standardized. We therefore assess the availability of data on this commitment to be still unavailable at the moment.

Summary of commitment 2.2

The study of education-business partnerships for development of entreprenerurail skills as described by commitment 2.2 is an area with limited research and even less available statistical data. In our opinion, no relevant data source exists that can be used for either an implementation analysis or an impact assessment. Evidence on this commitment is qualitative, and there are very few studies that has measured the impact of business-university partnerships for development of skills at the micro-level in a systematic fashion (Thune & Storen 2015). We are not aware of any studies that have looked at this issue at macro-level.

If one wants to include in the direct impact assessment, the level of private investment in universities can possible serve as a proxy indicator, but this would have significant shortcomings as these data concerns R&D cooperation and not development of skills. Therefore scientific performance is a better outcome variable to analyse the impacts of this committment, whereas the impact on entrepreneurial skills can probably not be tested with the available data at this point in time.

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Table 4: Selected papers on higher education-business partnerships for skills development

Reference	RQs	Methods/data	Findings	Impact on research and innovation variables
Billett 2009	Presents an overview of trends in work-based learning approaches in higher education	Review	Focuses on trends and particularly describes learning theories underpinning work-integrated learning approaches in higher education	No
Borell-Damian 2009	Report that describes broad trends and examples of collaborative doctoral education in a number of European countries	Review and case studies	Uses case studies to develop a set of good practices in collaborative doctoral education	No
Butcher & Jeffrey 2007	Explores doctoral students persepctions on collaborative research prosjects	Survey	Characteristics of the collaboration process (supervision, management and communication) influences the perception of success positively	No/indirectly
Choy &Delahaye 2011	Addresses the challenges involved in developing a partnership between business and universities in connection with education offerings	Case study	Successful partnerships requires mutual understandings on the role of learning partnerships and its pedagogy; also address the changed role of academics and a transformation of identity	no
Jackson 2015	What are the good practices for work-integrated learning (placement of university	Survey of undergraduates in Australia	Learning at work through partnerships with businesses function as a complementary learning arena; positive for skills development and transition to work	Indirectly, focuses on skills for employment

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	graduates in employers)?			
Kessels & Kwakman 2006	To describe the features of cooperative education between business partners and universities	Conceptual and case study	Cooperative education programs challenges traditional notions of education. Its value is to bridge different forms of learning and contribute to development of skills. But it is hard to make it work.	No
Lee et al 2010	Describes a project where students and local businesses worked together to develop a new skills training course	Case study	Describes the pedagogy and learning experiences of the course, and how partnership with industry increase learning and development of complementary competencies	Indirectly, focuses on skills acquisition
Lester & Costley 2010	Presents an overview of trends in work-based learning approaches in higher education	Review paper	Describes trends, goals and practices in work-place learning arrangements and business-higher education partnerships	no
Person & Rosenbaum 2006	What are the educational outcomes of cooperating with work organisations during higher education?	Survey and longitudinal data on educational completion among college graduates in the US	Finds that work-placement for college graduates increases the likelihood of timely completion of degree	no
Thune 2009	Experience and effects of collaborating with industry during PhD training	Literature review	Prior research indicates that interacting with industry has limited impact on study effects and research productivity, but positive for commercial productivity and external orientation	Yes, on research commercialisation
Thune & Børing 2015	Does participation in Industry PhD schemes contribute to development of innovation	Survey to participating firms in industry PhD	Firms in general see industry PhD scheme funding as beneficial for building new skills in areas that support innovation. Contrary to expectations, both large and	Yes

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	skills in firms?	schemes; interviews with firms	small firms value such schemes and use them for developing skills in both core and complementary technologies/areas of application	
Thune & Støren 2015	Do graduate students that collaborate with industry during education have more favorable study and labour market outcomes?	Survey to population of university graduates with master degree diplomas in Norway	Positive impact on study variables and transition to work, but only for committed forms of collaborations	No
Tynjala et al 2003	To examine the pedagogical aspects on collaboration with work-life during higher education	Literature review	Discusses four different perspectives on relationship between working life and education	No

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5. Commitment 3: E-skills

Commitment 3 seeks to propose an integrated framework for e-skills. The Commission declared that it intended to propose by 2011 an integrated framework for the development and promotion of e-skills for innovation and competitiveness, based on partnerships with stakeholders, and that this will be "based on supply and demand, pan-European guidelines for new curricula, quality labels for industry-based training and awareness-raising activities."

To search for relevant research literature on the theme of e-skills, we used the following four search strings (and variations and combinations of them): e-skills, e-leadership, e-business, ICT skills. We collected a total of 30 papers that we considered to be relevant for our literature review (including several reports from EC and EU projects). However, we also noticed that there is substantial repetition and overlap in the content of some of these papers, so that on the whole the content of the literature on commitment 3 is smaller than that for commitments 1 and 2 reviewed in the previous sections.

Further, the literature reviewed in this section presents a great number of research and policy reports funded by EU, basically presenting main empirical trends and policy prescriptions, but only a relatively minor number of academic contributions discussing analytical foundations of e-skills and theoretical and methodological aspects of interest. The few recent academic studies, briefly reviewed below, represent a rather fragmented literature spread across related fields such as business studies, information systems, and innovation studies.

The first important aspect to be pointed out is what e-skills means. Nearly all of the papers in the reviewed literature adopt the following five related concepts and definitions (which were initially formulated by the European Commission and thereby adopted by all subsequent papers and reports):

1. ICT user skills: this is the digital literacy of users, namely: "the capabilities required for effective application of ICT systems and devices by the individual. ICT users apply systems as tools in support of their own work, which is, in most cases, not ICT. User skills cover the utilisation of common generic software tools and the use of specialised tools supporting business functions within industries other than the ICT industry".

2. ICT practitioner skills: This concept refers specifically to employees working in ICT-related sectors and activities, i.e.: "the capabilities required for researching, developing and designing, managing, producing, consulting, marketing and selling,

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integrating, installing and administrating, maintaining, supporting and service of ICT systems".

3. E-business skills: This is a more general concept referring to the e-skills that are relevant for administering and managing organizations, namely: "the capabilities needed to exploit opportunities provided by ICT, notably the Internet, to ensure more efficient and effective performance of different types of organisations, to explore possibilities for new ways of conducting business and organisational processes, and to establish new businesses".

4. E-leadership skills: This type of skills relate specifically to leadership skills required in organizations, i.e. "the accomplishment of a goal that relies on ICT through the direction of human resources and uses of ICT. E-leaders are leaders who draw on technology to accomplish an ICT-enabled objective".

5. Digital entrepreneurship: Finally, this last concept has been put forward more recently by Husing et al. (2013) to denote e-skills that are useful in the context of entrepreneurship activities: "the accomplishment of a new organisation that relies on ICT for its operations and its products and services through the direction of human resources and uses of ICT. Digital entrepreneurs are leaders who create new ventures that rely on ICT for their operations, products and services".

In spite of adopting a set of clear definitions, the literature on e-skills has however not developed a thorough analytical understanding of the set of skills and capabilities that the five concepts noted above require, and how these contribute to innovative activities and performance in business companies. Coco Romani (2009) points out that e-competencies refer to five different levels and types of skills: E-awareness, technological literacy, informational literacy, digital literacy and media literacy.
Husing et al. (2013) presents an interesting report focusing on e-leadership, and points out that e-leaders are characterized by a T-shaped portfolio of skills. First, e-leaders obviously need literacy and basic skills (e.g. reading, writing, math, digital literacy); then, they need a set of vertical skills on how to use ICTs (customer and sector expertise, product expertise, function expertise, ICT expertise); finally, they also need a set of horizontal / transversal competencies needed to manage organizations (managing change and inventing; developing a compelling vision; building and aligning relationships across boundaries). The study by Husing et al. (2013) also argues that the number of e-leaders needed by companies is a function of the size of the organisation and the ICT intensity of a sector, and it uses this approach to estimate the total demand of e-leaders that firms in European countries have.

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A major issue investigated in the literature on e-skills refers to the potential mismatch between demand and supply of e-skills in Europe, which according to many may turn out to be an important factor hampering the competitiveness of the European ICT sector as well as other ICT-using industries. This is indeed one of the main policy motivations for the development of this literature in the first place. The European e-skills Forum (2004) clarifies the distinction between shortage, gap and mismatch of e-skills. A *shortage* is "a quantitative lack of skilled people in the labour market; i.e. there are not enough people in the workforce that can perform ICT jobs". A *gap* is instead "a competence shortfall between current and needed competence levels of (employed) personnel; hence, the ICT practitioners do not have the complete set of required competencies to an adequate level". Finally, a *mismatch* of e-skills is "a difference between the competence of the trainee or graduate and employers' expected competence needs. Mismatches are assumed to arise from inappropriate training or 'misaligned' course curricula, 'unrealistic' requirements of employers or rapid technological advances". Based on this distinction, Husing et al. (2013) emphasizes that a discrepancy between demand and supply could be due to a quantitative lack of skilled people (shortage) or to a qualitative discrepancy in terms of the required competencies (i.e. a gap and mismatch)., and that the policy implications of the two situations would be distinct.

Several studies have attempted to quantify the extent of these shortages and / or mismatches in e-skills in the European economy. On the one hand, there has been in recent years a rapid growth of employment both in ICT-producing and ICT-user industries. Some of the reasons for this high growth of demand are the increasing pervasiveness of ICTs; the attractiveness of ICT career; the growth of e-commerce; and that an e-skills strategy has recently become more important in the context of the European crisis; (Singh, 2012).

On the other hand, however, studies indicate that nearly 50% of "enterprises which recruit personnel with ICT specialist skills had hard to fill vacancies in this area" (Eurostat Enterprise survey, 2007). On the supply side, in fact, while enrolment in tertiary education in Europe have significantly increased since 2000, enrolment in computer science has decreased since 2006. As a consequence, there is currently both a shortange and a mismatch between demand and supply of e-skills in many European countries. EC (2014) estimates that "Europe could face a shortage of up to 560,000 ICT workers in 2015, which could exceed 1 million by 2020".

The fear that e-skills shortages may hamper the competitiveness of the European economy has therefore attracted substantial policy attention on this issue, and many policy initiatives have been developed at the European level during the last decade to raise awareness and promote actions in this field. In June 2005, the European Commission launched the *i2010 Strategy*, also known as the European Information Society 2010. This was followed by several other initiatives and events: an European

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e-skills conference in October 2006; the establishment in the same year of an ICT Task Force on competitiveness of the ICT sector, including a working group on skills and employability; the new EC strategy in 2007 on "e-skills for 21st century: fostering competitiveness, growth and jobs"; a European e-skills conference in 2009 on "Fostering ICT Professionalism". In March 2010, the Commission launched the Europe 2020 Strategy, which marks the intensification of policy action on e-skills and the incorporation of the e-skill issue in the Innovation Union programme. The Commission promoted in 2013 the European e-competence framework 3.0 (EU Standardisation Committee, 2013), and thereby developed proposals for quality labels for IT industry training and certification, followed by another major conference on e-skills and ICT professionalism in Brussels in March 2014.

In a recent appraisal of the state of the Innovation Union commitments, EC (2014) points out explicitly that the main priorities for the future (2014-2020) will be "the promotion of ICT professionalism and e-leadership and the generation of a larger talent pool of ICT professionals, entrepreneurs, business leaders, managers and advanced users with a focus on the strategic use of new information and communication technologies".

According to Singh (2012) and Husing et al. (2013), some of the key policy actions that should be implemented in the near future are the following:

- Continue to build awareness of e-leadership skills for innovation, competitiveness and employability
- Sharpen definitions and metrics for e-leadership skills
- Improve data, monitor demand and supply
- Upgrade and update curricula and educational programmes in computer science, math and engineering, as well as e-leadership curricula
- Establish an ICT Skill Certification Centre
- Foster e-leadership in the context of entrepreneurship and self-employment

In spite of the large policy interest and the substantial number of conferences and research policy reports on the subject in the last few years, academic research on e-skills is still at an infant stage. Most studies of e-competencies have been disseminated through policy and project reports, rather than through journals, books and other academic dissemination channels. Among the few published studies, summarized in table 5, Kolding and Kroa (2007) carried out a survey of over 600 employers in 10 European countries about their employees' e-skills level, and found that companies, although they recognize the relevance of e-competencies, are typically not investing time and resources for the development of these. Koellinger (2008) presents an empirical analysis of the relationships between Internet-based innovations and firm performance based on data on over 7000 European companies,

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showing that companies that make active use of Internet-related technologies grow as rapidly as those that do not do so. Battisti et al. (2009) estimated of a logistic diffusion model of ICT usage in UK firms using a cross-section of data from the UK CIS3 survey, and found substantial heterogeneity in e-business use across firms in terms of firm size and labour force skills. More recently, Youssef et al. (2015) studied the relationships between e-selling, e-banking and e-administration and new product development in a sample of 900 firms in Luxembourg, and found a positive effect of ICT usage on the probability of implementation of successful new projects.

It is interesting to notice that, apart from the few studies noted here, the majority of papers and reports on the topic of e-skills always assume the existence of a positive relationship between e-skills and innovation and firm performance, but typically do not provide any theoretical analysis of this relationship or empirical support for it. One of the reasons for this gap in the academic literature is arguably related to the available data on the subject.

Indicators and secondary data sources on e-skills

There are basically three main approaches to measure e-skills and three related sets of data sources and indicators to be used in analyses of e-competencies and their impacts on innovation and firm performance (Frinking et al., 2005).

The first is data on *occupational profiles*. Eurostat's Labour Force Survey, using ISCO-codes (International Standard Classification of Occupations), provides data that define what people in various occupations do (which do not necessarily correspond to the underlying skills required to perform the job in a competent manner, though). The relevant ISCO codes are 213, 312, 313 and 724. Some of the key indicators that could be used from this data source are in particular the level and growth of employment of ICT practitioners (split by gender and age), the unemployment in e-skilled occupations (split by gender and age), and the number of unfilled job vacancies in e-skilled occupations.

The Labour Force Survey is available by sector and for most EU countries, and it is thus possible to link it to other industry-level data sources (e.g. R&D statistics, CIS data). For instance, CIS data provide several well-known and widely used indicators of R&D and innovation, in both ICT-supplier and ICT-user industries, making it possible to carry out a cross-industry and cross-country comparative analysis of the relationships between e-skills (from the LFS) and innovation and economic performance (from CIS and related data sources).

A second data source that may be potentially relevant is data on *skills profile*. Skill-based classification systems have been developed for a few European countries (e.g. UK's Skills for the Information Age (SFIA)). However, at present, this data source would not enable a cross-country European study of e-skills.

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Finally, a third data source that is commonly used to trace the development of e-skills is on the supply-side is from statistics on *formal education and vocational training*. Some of the indicators that have been used in the literature are in particular the number of graduates in e-skilled educational fields, te enrolment ratio in computer science, the number of vocational graduates in computing, and, where available, the number of issued training certificates for training.

Summary of commitment 3

As noted in this section, the literature on e-skills is mostly made of a number of research and policy reports and only a relatively minor number of academic contributions. Academic research investigating the analytical foundations of e-skills is rather scant and fragmented, and there is a need of further research studying how e-skills are acquired by individuals and firms' employees, transferred and diffused among individuals, and what impacts they have on scientific and innovation output.

One of the main results in this literature is to highlight and provide estimates of the mismatch between demand and supply of e-skills in Europe, which according to many is an important issue hampering the competitiveness of the European ICT sector as well as other ICT-using industries.

It is noticeable that most works on this topic typically *assume* the existence of a positive relationship between e-skills, on the one hand, and research and innovation performance, on the other. However, there is a lack of research investigating theoretical underpinnings of this relationship, and its empirical relevance in European countries. In WP1 of this project, we argue that it will be interesting and feasible to assess the empirical relationship between e-skills and scientific / innovation performance in Europe, and that some of the data sources and indicators noted above – such as the Labor Force Survey – should make it possible to carry out this empirical assessment.

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Table 5: Papers on e-skills: a selection of recent academic contributions

Reference	RQ	Data sources/method	Key findings	Addresses impact on research and innovation related variables?
Kolding and Kroa (2007)	Assess present ICT competencies of staff and future needs	Survey of 600 employers in 10 European countries	Lack of resources and working time devoted to systematic development of e-skills in business companis	No
Koellinger (2008)	Analyse the relationship between use of Internet-based technologies, innovation and firm performance	Sample of 7032 European enterprises from the 2003 e-business Market W@tch survey. Estimation of an error component model	Firms that rely on Internet-enabled innovations grow as fast as those that rely on non-Internet-enabled innovations	Yes
Battisti et al. (2009)	Develop a model of e-business use and diffusion within and across firms	Third UK CIS survey	Substantial heterogeneity in e-business use across firms in terms of size, labour force skills and generated externalities	Yes
Phillips and Wright (2009)	Study how e-business processes adjust to customer preferences (flexibility)	Five case studies and factor analysis on a new survey dataset	A seven factor typology that describes the influences of flexibility on organizational effectiveness in e-business environments	No
Mitrovic (2010)	Position e-skills and e-competences within	Conceptual discussion adopting an information systems	Mapping of e-skills and e-competences to various areas and activities of organisations	No

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	organisations	perspective		
Singh (2012)	Summarize recent trends and challenges related to e-skills focused on a European perspective	Survey of policy and academic literature on e-skills	Policy recommendations are developed on the basis of the conceptual discussion and critical review of the literature	No
Youssef et al. (2015)	Analyse the relationships between e-selling, e-banking and e-administration and new product development	A sample of 900 manufacturing and service firms in Luxembourg. Estimation of an ordered logit model	Positive effect of ICT usage on the probability of implementation of successful new projects	Yes

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6. Summary and further research

This report has collected and summarized relevant literature on themes related to work packages 1, 2 and 3 of the I3U project. These three commitments all relate to promoting scientific capabilities and human capital in Europe, and intend to foster these capabilities in European public research organizations and business companies in order to close the skill gap with other regions in the world. Specifically, the commitments aim at developing strategies for training enough researchers to meet national R&D targets, promoting of attractive employment conditions in public research institutions, developing a benchmarking and ranking system of European universities, fostering knowledge alliances between education and business to develop new curricula addressing innovation and skills gaps, and particularly e-skills for innovation. Sections 2 to 6 have summarized the relevant literature that we have collected on research themes related to these three commitments, and briefly indicated the data sources and indicators that may be used for the empirical studies to be undertaken by WP1 in the next phase of the I3U project – specifically for the implementation analysis and direct impact assessment.

Table 6 provides an overview of some of the main data sources and indicators that could be used in the empirical phase of the project during 2016 and 2017.

Table 6: Summary of key data sources and indicators relevant for the empirical studies to be carried out in WP1

Indicator	Source	Country	Sector
Number of researchers	OECD	All OECD	No
Government researchers	OECD	All OECD	No
Public spending on education	OECD	All OECD	No
Total researchers (FTE), by sectors of performance	Eurostat	All EU	Yes
Research and development personnel, by sectors of performance	Eurostat	All EU	Yes
Doctorate students in science and technology fields	Eurostat	All EU	No
Graduation rates at doctorate level, 2000 and 2009	OECD	All OECD	No
Government budget appropriations or outlays for RD	OECD	All OECD	Yes
Other national R-D expenditure by field of science and by source of funds	OECD	All OECD	Yes
Other national R&D expenditure by field of science and by type of cost	OECD	All OECD	Yes

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R-D personnel by sector of employment and occupation	OECD	All OECD	Yes
R-D personnel by sector of employment and qualification	OECD	All OECD	Yes
R-D personnel by sector of employment and field of science	OECD	All OECD	Yes
R-D expenditure by sector of performance and type of R-D (1963-1980)	OECD	All OECD	Yes
R-D personnel by sector of employment and occupation (1963-1980)	OECD	All OECD	Yes
Researchers	OECD	All OECD	No
ICT specialists by gender	Eurostat	All EU	No
ICT specialists by level of education	Eurostat	All EU	No
ICT specialists - total	Eurostat	All EU	No
ICT specialists by age	Eurostat	All EU	No
Mobile students from abroad enrolled by education, sex and country of origin	Eurostat	All EU	No
Distribution of students enrolled in tertiary education by sex and educ. field	Eurostat	All EU	No
Percentage of persons employed with ICT user skills	Eurostat	All EU	No
Enterprises with training to develop/upgrade ICT skills of their personnel	Eurostat	All EU	No
Doctorate holders by sex and age group	Eurostat	All EU	Yes
Non-EU doctorate holders in total doctorate holders (%)	Eurostat	All EU	No
GMC1 - Current international mobility based on citizenship - Share of researchers currently employed in another country than their country (countries) of citizenship, in % and by country of current employment / Total	MORE2	All EU	No
GMC1 - Current international mobility based on citizenship / Field of science	MORE2	All EU	Yes
GMC1 - Current international mobility based on citizenship / Gender	MORE2	All EU	Yes
WC5.1 - Satisfaction in current academic position with academic aspects - Share of researchers that is satisfied with academic aspects in the current academic position, in % and by country of current employment / Total	MORE2	All EU	No
WC5.1 - Satisfaction in current academic position with academic aspects / Field of science	MORE2	All EU	Yes
WC5.1 - Satisfaction in current academic position with academic aspects / Gender	MORE2	All EU	Yes
WC5.2 - Satisfaction in current academic position with employment aspects / Total	MORE2	All EU	No
WC5.2 - Satisfaction in current academic position with employment aspects / Field of science	MORE2	All EU	Yes
WC5.2 - Satisfaction in current academic position with employment aspects / Gender	MORE2	All EU	Yes
WC5.3 - Satisfaction in current academic position with personal	MORE2	All EU	No

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aspects / Total			
WC5.3 - Satisfaction in current academic position with personal aspects / Field of science	MORE2	All EU	Yes
WC5.3 - Satisfaction in current academic position with personal aspects / Gender	MORE2	All EU	Yes
WC5.4 - Satisfaction in current academic position with career-related aspects / Total	MORE2	All EU	No
WC5.4 - Satisfaction in current academic position with career-related aspects / Field of science	MORE2	All EU	Yes
WC5.4 - Satisfaction in current academic position with career-related aspects / Gender	MORE2	All EU	Yes

Before concluding this report, it is important to summarize the key point of this literature review, and how this work will be used in the empirical research in the continuation of this project.

Implementation analysis and direct impact assessment

We will use the data described in the table and data available from the Innovation Union monitoring exercises to analyse the extent to which European countries have implemented (or are in the process of implementing) the commitments. Not all of the commitments can be measured through indicators available in panel data format to identify changes than can be the result of implementation of commitments, as described above.

For the direct impact assessment, we will perform one analysis that will simultaneously consider all the input factors described by the commitments 1 and 2. These concern the quality of the science system and scientific manpower, and we will investigate the extent to which these characteristics of national S&T systems in Europe are empirically related to the scientific performance of European countries, and the changes of this over time.

Economic mechanisms and relevance for the NEMESIS model

A key message of this study is that the three commitments reviewed in this report do actually refer to two quite distinct economic mechanisms, and hence will have to be represented in different ways in the NEMESIS model adopted in this project and the related empirical analyses. Commitments 1 and 2 do on the whole seek to improve the quality of *public* R&D, i.e. they have a focus on scientific capabilities in public research organizations; by contrast, commitment 3 aims at strengthening e-skills of *private* firms' employees (and individual ICT users more in general), thus targeting a specific form of human capital currently required by the business sector of the economy.

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Figure 1 depicts a summary of these distinct economic mechanisms. First, as noted above, commitments 1 and 2 seek to improve the quality and increase the effectiveness of public R&D. In terms of the project's NEMESIS model, these policy actions are expected to have three direct effects on R&D and innovation: (1) they will increase Government's expenditure on public R&D (which is an exogenous parameter in the NEMESIS model); (2) they will spur the productivity of R&D activities in private companies (since firms' knowledge stock will increase); (3) there will also be an increase in the supply of high-skilled, some of which will be employed in private R&D. Policy efforts linked to commitments 1 and 2 will thereby also have some indirect effects on firms' economic performance. First, they will enhance firms' productivity via increases in turnover and demand, lower input costs and higher quality index and export performance. Second, they will enhance human capital (and thereby firms' performance) by increasing the number of skilled workers employed by business firms, and hence also lead to strengthen their absorptive capacity (which in turn will lead to higher innovation and productivity).

Second, commitment 3 calls for a set of policy actions that will strengthen e-skills of private firms' employees and corporate leaders. The direct effects that these policy actions will have on firms' economic performance are twofold, both related to firms' human capital: they will increase the number of highly skilled workers employed by business firms in Europe; and they will also increase companies' absorptive capacity, which as noted above is expected to lead to higher innovation and productivity. Further, according to the NEMESIS model, we should also expect two types of indirect effects in the public sector of the economy, namely: (1) an increase in the quality and productivity of public R&D (which will in turn lead to further productivity gains in firms, see above); (2) an increase in the quality and productivity of other public services. The next phase of the I3U project will aim at investigating these various mechanisms both conceptually, through the NEMESIS modelling framework, and empirically, through statistical analyses of the relationships between public and private innovative capabilities, on the one hand, and innovation and economic performance of European countries, on the other.

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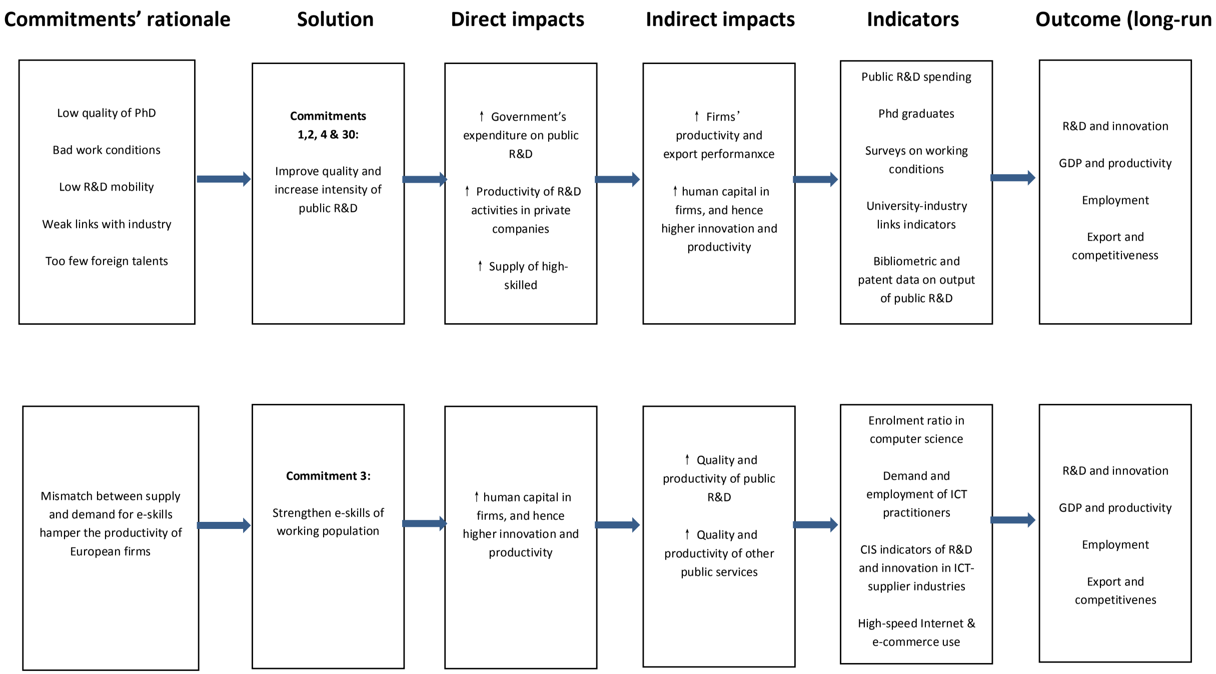
Figure 1: Summary: Economic mechanisms and map of commitments



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