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Europe’s twin deficits: Excellence and innovation in new sectors

Policy Paper by the Research, Innovation, and Science Policy Experts (RISE)

Frédérique Sachwald
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Contact: Katarzyna Bitka, Emanuele Barbarossa

E-mail: katarzyna.bitka@ec.europa.eu

emanuele.barbarossa@ec.europa.eu

RTD-RISE@ec.europa.eu

RTD-PUBLICATIONS@ec.europa.eu

European Commission
B-1049 Brussels

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Frédérique Sachwald

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EXECUTIVE SUMMARY

Main results

- Firms have opened their innovation processes and cooperate with different types of partners. Academic research institutions tend to be preferred partners for exploration and new to market innovation. As a result, the amount and quality of academic research remains one of the fundamental inputs to the long term innovation performance of firms and countries.
- Business R&D is a major input into the innovation process, but it is not a direct policy variable since it depends on the sector distribution of countries. As a result, more R&D and innovation in existing sectors have to be combined with the development of start-ups in new sectors to generate dynamic knowledge intensive growth.
- The significance of recent scientific results differs widely across technologies. Scientific publications are a major source for patents in biotechnology, pharmaceuticals, digital and basic communication, food or organic chemistry, while they play little role in other technological fields, such as transport, machine tools or civil engineering.
- Excellent researchers or academic institutions are more likely to engage in knowledge transformation, either through contract research with firms or through commercialisation. Moreover, firms that cooperate with high impact researchers generate more innovation and better market performance.
- The US has the world strongest science base for sectors related to information and communication technologies as well as in disciplines and sectors related to medicine and health. The transatlantic "excellence gap" is thus wider in the scientific disciplines with most innovation potential.
- These stylised facts are at odds with the notion of a "European paradox": the EU actually suffers from twin deficits in excellent research and in innovation in new high growth sectors. Europe as a whole is good at producing research results, but those may be of insufficient quality to meet the needs of the knowledge-based economy and society.

Policy recommendations

- In order to promote innovation, the policy mix should address Europe's twin deficits by strengthening both knowledge production and knowledge transformation.
- The EU contributes to the global excellence of European research, in particular through the ERC. It should precisely monitor the impact of ERC on the performance of European research and step up its capacity to analyse the interactions between excellence and innovation.
- In order to update the diagnosis on European innovation systems and integrate new evidence into policy making, the EU should develop the analysis of the nexus of research, knowledge transformation and innovation. Detailed knowledge of scientific production seems particularly important. Relatedly, efforts to evaluate the impact of research and the impact of innovation policies should take the quality of scientific production into account. In particular, the efficiency of policies in favour of public-private interfaces depends on the quality of research.
- The observation of countries' innovation performance should explicitly take into account countries' sector composition, which has a strong impact on some of the main indicators used to analyse innovation performance like R&D intensity and the propensity to patent or to export. A statistical analysis of the *Innovation Union Scoreboard* could in particular be conducted to generate a typology of countries and better adapt innovation policy design to the diversity of situations. It could also help reflect on the relevance of the indicators that are not correlated to the synthetic innovation index.
- The new evidence should generate a set of consistent stylised facts on the relationship between R&D intensity, research specialisation and innovation performance. It would provide a better basis to develop policies aimed at adapting the EU industrial structure to the knowledge based economy. At the regional level, similar evidence would be useful to monitor smart specialisation strategies.
- The European commission could launch the definition of a roadmap to produce new policy relevant data and indicators with a conference on the impact of research and its interactions with innovation.

INTRODUCTION

The perception of the interactions between R&D spending and economic performance during the second half of the 1990s has had a deep and enduring influence on research and innovation policies in Europe. The then increasing transatlantic gap in innovation and growth has been attributed to a combination of more business investment in R&D and a better ability of the US to generate innovation from research results (EU 1995). Policy conclusions seemed quite straightforward: increase R&D spending and improve technology transfer. These conclusions were drawn both at the European and country levels.

During the first decade of the XXIst century, both explanations of the lower European innovation performance have been questioned and studies have developed a better understanding of interactions within innovation systems. Firstly, private R&D intensity is to a large extent determined by the national economic structure, which, as a consequence, also commands firms' demand for innovation and interactions with academic research. Secondly, countries scientific performance should not be evaluated only by the number of publications, but also by scientific impact. Thirdly, interactions between scientific, technological and economic specialisation contribute to the dynamics of innovation systems. Since the early 2000s, a number of studies have shown that the scientific performance of Europe was not as excellent as that of the US. But since the number of European publications was catching up with that of the US, the notion of a European paradox was maintained (EU 2003). As a consequence, a strong policy focus was put on increasing science and technology linkages. This focus has been developed for example when considering the European performance in new generic technologies such as ICT and biotechnology.

Over the last decade, the increasing diffusion of open innovation practices and the need to take on global challenges have increased the policy focus on the issue of the impact of research. Stronger social and economic expectations being placed on innovation make it even more important to understand which are the weak points European countries should improve to upgrade their performance.

This paper argues that the diagnosis on the European innovation performance should be thoroughly re-examined: the EU suffers from twin deficits, in research excellence and in innovation in new sectors. The EU is insufficiently R&D intensive to a large extent because its structure is not that of a knowledge-based economy. And this is not only about manufacturing, but also about the digital economy and knowledge intensive services. The economic structure being endogenous, the challenge is to accelerate the transition towards a knowledge-intensive economy, which requires both sustained R&D spending and an efficient research and innovation system. The paper shows that improvement should not be sought only in the process of knowledge transformation but also in the production of high impact research. The paper also points to significant differences among EU countries. The conclusion draws policy recommendations to address Europe's twin deficits.

1. Open innovation, science and public policies

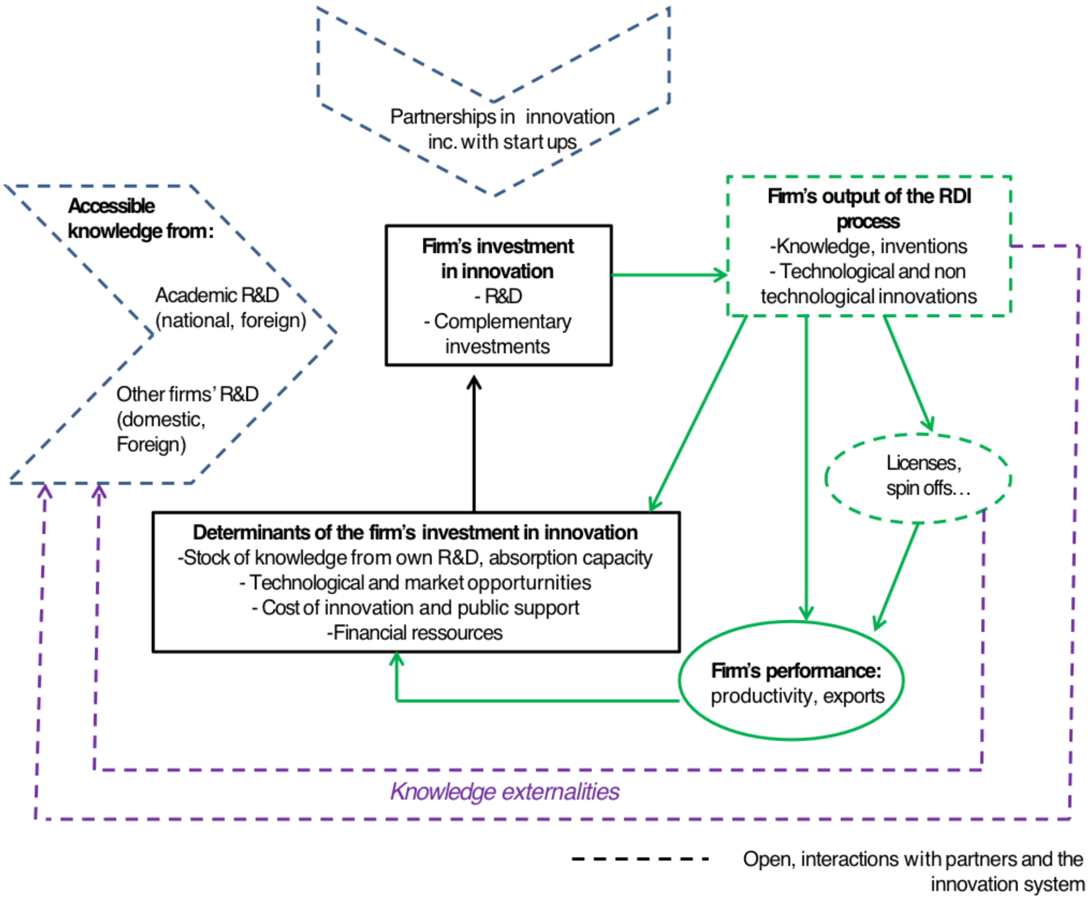
Business R&D has long been recognised as a major input to the innovation process. At the firm level, conducting R&D is causing product innovation a couple of years later (Raymond *et al*; 2013). Across industries, business R&D intensity is correlated to proximity to science and new knowledge creation fuelling technological opportunities (Klevorick *et al*. 1995). At the sector and country levels, business R&D intensity is correlated to productivity performance (Guellec and van Pottelsberghe 2001, Haskel *et al*. 2014). Empirical studies have also found high rates of return to private R&D as well as substantial social returns through externalities (Hall *et al*. 2009, Frontier Economics 2014).

Over the last couple of year, as R&D cooperation and open innovation practices have become widely diffused, the role of R&D for innovation has sometimes been questioned. Actually, as firms internalize a smaller share of the R&D activities on which their innovation relies, they organize connections to science through various partnerships, including with start-ups (1.1). Public policies have, at least implicitly, adapted to this evolution of the division of innovation processes between different institutions and types of firms. In Europe in particular, policies addressing the R&D deficit have changed as the impact of sector distribution on R&D intensity and the potential impact of start-ups on this distribution have been recognized (1.2).

1.1.Open innovation implies new connections to science

A firm's amount and type of investment in research, development and innovation (RDI) depend on its profile, which includes both its capabilities and the opportunities it perceives. In turn, these depend in particular of the sector in which the firm operates. Figure 1 identifies the determinants of firms' investment in R&D and other innovation expenses.

Figure 1. Open innovation and the firm's RDI capabilities



Source : Elaboration from the literature

Firms invest in both their own knowledge capabilities and in means to access external research results and partners. The empirical literature shows that firms in high tech sectors as well as large firms rely more on R&D and access to public science than firms from other sectors or small firms. This is related to their stronger absorption capacity, which results from previous investments and human resources decisions, like hiring Ph.D. holders in their R&D teams (Simeth and Lhuillery 2015). Large firms are able to devote resources to reading scientific publications, participate to conferences and connect with academic researchers. They also devote resources to identify new technologies and to partner with start-ups.

The need to connect to science has always meant a certain degree of openness of firms' research activities on the broader scientific community, but since the 1980s, openness has increased. Henry Chesbrough (2003) has summarized the systematic organization of interactions between internal R&D efforts and partners by the notion of open innovation. This trend results from a set of converging determinants, including more competitive pressures, more focused companies and increasing R&D capabilities around the world (Sachwald 2009). In this context, since the 1980s, both American and European firms have reduced their investment in internal scientific capability (Arora *et al.* 2015). These investments can be proxied by the proportion of fundamental and applied research in R&D activities or the publication of scientific articles.

As a result, firms depend more upon their ecosystem of innovation, which includes prominently academic institutions and start-ups. The latter can be comparable to external projects, acting as transfer channels for research results and technologies in a number of sectors where large companies often buy out the promising start-ups (The Economist 2015). Overall, these richer innovation ecosystems do not rely less on science, but allow more specialized firms and institutions to collaborate to generate new products and services. Innovation may be accelerated, in particular for large companies, which operate a smaller number of steps than in the integrated or 'closed' model of innovation.

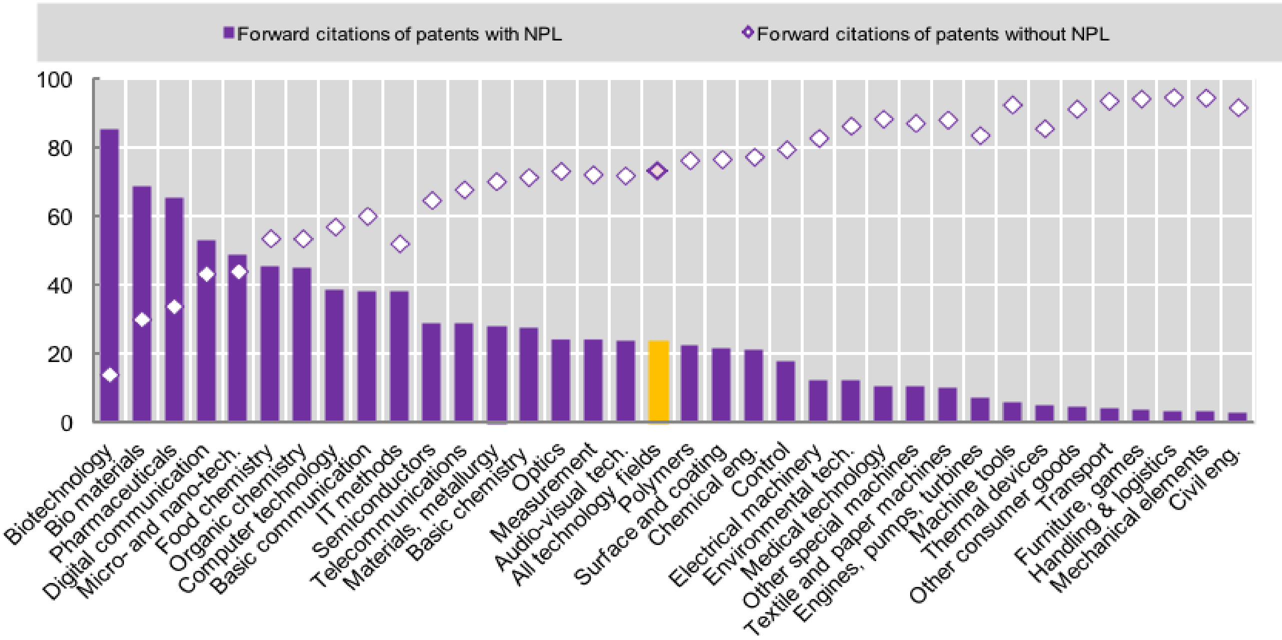
Indicators of knowledge flows between science and technology have been used to trace the use of science in innovation. Inventions seeking patent protection must disclose the prior knowledge on which they rely such as patents and scientific publications. The so-called backward citations are used to assess an invention's patentability and to define the legitimacy of its claims. They are also used to uncover the extent to which technology developments, in the form of patented inventions, rely on science contained in non-patent literature (NPL): scientific publications, conference proceedings, databases and other relevant literature. The rate NPL citations in patents may thus be used as one indicator of the openness of the innovation process, along with public-private co-publications or R&D collaborations (Cassiman *et al.* 2007).

The share of NPL citations of USPTO patents has strongly increased during the 1990s, when open innovation practices gathered speed and new sectors such as biotechnology developed (Narin *et al.* 1997, Mc Millan *et al*. 2000, EU 2003). Patents continue to cite science at the same rate and the age of cited publications is constant, indicating that new scientific results are similarly relevant for innovation (Arora *et al*. 2015).

The share of inventions that build on NPL varies widely across technology fields and, as a consequence, across industries. Figure 2, which is based on patents published by the European Patent Office, confirms that the connection to science varies widely across technology fields. More than 60% of biotechnology, biomaterials and pharmaceutical patents cite patents with NPL. More than 50% of patents in digital communication are in this case. Around 40% of patents in organic and food chemistry as well as nanotechnology and ICT related technologies are also in this case. On the contrary, engineering, mechanical and transport technologies hardly ever cite patents with NPL. These stark differences imply that industries nurture very different relationships with scientific institutions and academic researchers. Since inventors tend to cite papers from their own country (Narin *et al.* 1997), we can expect a correlation between industrial specialization and the intensity of science-technology relationships measured at the national level. The US and the UK have a stronger science-link position than Japan, Germany and France, which is the result of a tendency to cite more NPL in their patents and a specialization in highly science-linked technologies (Narin *et al*; 1997).

The contribution of countries to the production of patent-relevant science varies substantially. Scientific authors affiliated to US-based institutions account for more than a third of all scientific documents cited in patents in the areas of biotechnology, health, nanotechnology, ICT and environment (OECD 2013). No other country reaches 10% in these areas. The United States accounts for the highest share of scientific documents cited in ICT patents, with 41% of the world total. It is interesting to notice that ICT patents draw on various scientific fields, including clinical medicine, physics, chemistry, biology, engineering, material science and computer science.

Figure 2. Citations to patents that include non-patent literature, by technology field, 2007-12



Source : OECD (2013) based on EPO patents

Environment technologies are an important focus of patent-relevant science in Germany, while biotechnology and health-relevant science play an important role in the United Kingdom (OECD 2013). Environment technologies draw heavily on chemistry, but also on materials science, engineering and physics. They draw to a smaller extent on environment/ecology scientific field. China, Japan and Korea have relatively larger shares of science relevant to nanotechnology and the environment. Nanotechnology draws most on chemistry and materials science.

As suggested by figure 1 and the evidence on science-technology links, open innovation processes are designed to operate effective interactions between internal RDI capabilities with external resources. Thus, in the open innovation context, firms strongly depend on their research environment, which is composed of a mix of public research institutions, technology transfer operators and other firms. The latter include various types of innovation partners, including start-ups.

Successful open innovation thus depends on a sophisticated technological and service environment and on access to relevant research results. And this is also the case for non-technological innovation, which often makes use of sophisticated information and communication services.

Firms tend to interact preferably with close academic teams from the same country[1]. However, global innovation networks (GINs) develop and large firms as well as those relying most on science are able to identify relevant partners around the world (Sachwald 2013). Attraction to excellent science has been developing over the last decades. Arundel and Geuna (2004) using survey data from for the 1990s[2] calculated that about 30% of the R&D-weighted European responding firms in the telecom equipment sector considered that public science in North America was more important than domestic sources, compared to only 1.1% of firms active in basic metals. More generally, excellent research teams can attract firms' R&D location and collaborations from both domestic firms and foreign firms (Arundel and Geuna 2004, Abramosky *et al*. 2007, Hedge and Hicks 2008, Hausman 2012).

More open and rapid innovation processes are sometimes interpreted as a sign of diminished relevance of research for innovation. The above evidence shows that this interpretation results from a focus on part of the innovation process or on some categories of actors. Taken as a whole, the

1 But not necessarily from the same region, at least for strategic or important R&D partnerships (Dhont-Peltrault 2005).
2 PACE (Policies, appropriation and competitiveness in Europe) 1993 survey of Europe's largest firms.

innovation system still depends on science, especially in the most innovative sectors. However the ecosystem of innovation has become more complex with numerous actors.

1.2. Changing policies to address the European R&D deficit

The fundamental role of R&D in the innovation process does not mean that a country's R&D intensity, or even its business R&D intensity, is a direct policy variable. This is why the 3% target decided as part of the Lisbon Strategy has been questioned. Indeed, at the macroeconomic level, R&D intensity may be considered as an output of the innovation process (van Pottelsberghe 2008). Since R&D intensity depends on fundamental sector characteristics, each sector exhibits a set range of R&D intensity. In other words, in each country, R&D intensity depends on the sector distribution of value added. (Le Ru 2012a and 2012b), which remains true at the European level (Moncada-Paterno-Castello and Voigt 2013).

Table 1 shows the difference between R&D intensity as it is directly observed and R&D intensity adjusted for sector distribution. The reference is the average economic structure of OECD countries. It shows that the high business R&D intensity of Korea and Germany depends on their industry structure. The sector distribution of Norway and the Netherlands is on the contrary unfavorable. Norway is rich in natural resources, while the Netherlands is a service economy.

EU countries with either a large service sector or a large agriculture have a higher adjusted business R&D intensity (C>1) while the reverse is true for countries with a large manufacturing industry (C<1). The share of manufacturing industry in the economy is a stronger determinant than the level of development of the country: Spain, Italy and Slovakia have a higher adjusted intensity, while Slovenia and Hungary have a lower adjusted intensity.

Sector composition has thus been playing a fundamental role in the "R&D deficit" between the EU and the US. High tech sectors represent a much higher share of business R&D in the US. The share of high tech sectors has increased on both sides of the Atlantic during the 2000s, but the gap has remained: overall, the EU is specialised in mid-high tech sectors while the US has further increased its specialisation in high tech and knowledge intensive sectors. More generally, an analysis at the firm-level confirms that across-sector differences dominate over within-sector differences (Stancik and Biagi 2012). American high tech sectors and knowledge intensive service sectors are however particularly R&D intensive and the US corrected R&D intensity is higher than its observed intensity (table 1).

Since 2000, a number of European countries have engaged in policies to meet the 3% objective of the Lisbon strategy by stimulating business R&D spending. These policies have had some positive impacts on R&D intensity. In France for example, business R&D intensity has reverted its erosion since 2008 despite continuing desindustrialisation and the economic crisis. This means that R&D intensity has strongly increased in a number of sectors (MENESR 2014). Business R&D intensity has also increased in a number of European countries from the periphery (Rodriguez-Pose 2014, OECD 2014). At the EU level, these increases in R&D intensity are nevertheless relatively modest and will not be sufficient to meet the 3% objective if economic structures do not change more clearly in a number of countries.

The importance of the industrial structure to explain R&D intensity has led to consider the dynamics of structural change as a major issue for the development of the knowledge based economy and potential growth. Analyses dealing with these issues have underscored the role played by young high tech or knowledge intensive firms in this dynamics. In recent economic history the US has experienced larger and quicker changes in its industrial structure than a number of European countries. The US has in particular generated new product and service sectors based on new technologies. In Europe, some large companies manage to keep productivity and innovation up in their sectors, as illustrated by German companies in the car or machine tool industries. However, rapid growth in new sectors typically depends on innovation brought to the market by young companies.

Table 1. Business R&D intensity* corrected for sector distribution, 2011

	A. Business R&D intensity	*Rank*	B. Business R&D intensity with OECD sector structure	*Rank*	C = B / A
Norway	1.34	*18*	2.32	*11*	1.734
Netherlands	1.78	*14*	2.67	*9*	1.497
Spain	1.07	*22*	1.56	*18*	1.461
France	2.46	*9*	3.51	*3*	1.425
UK	1.76	*15*	2.28	*12*	1.295
Portugal	1.21	*19*	1.57	*19*	1.292
Belgium	2.20	*11*	2.83	*8*	1.287
Poland	0.28	*24*	0.36	*24*	1.283
Italy	1.12	*21*	1.41	*20*	1.262
Slovakia	0.35	*23*	0.42	*23*	1.198
Ireland	1.69	*16*	1.91	*16*	1.127
Austria	2.82	*8*	3.17	*7*	1.127
USA	3.07	*6*	3.44	*4*	1.122
Australia	1.91	*13*	2.06	*15*	1.081
Estonia	2.33	*10*	2.41	*10*	1.034
OECD	*2.47*	-	*2.47*	-	*1.0*
Sweden	4.26	*3*	3.99	*2*	0.938
Finland	4.63	*1*	4.23	*1*	0.915
Denmark	3.76	*5*	3.38	*5*	0.901
Slovenia	2.20	*11*	1.86	*17*	0.848
Japan	3.88	*4*	3.26	*6*	0.839
Czech rep	1.58	*17*	1.18	*21*	0.747
Hungary	1.19	*20*	0.87	*22*	0.731
Germany	3.01	*7*	2.14	*13*	0.711
Korea	4.49	*2*	2.12	*14*	0.472

** For all countries, R&D spending over value added for commercial sectors (which is higher than the R&D intensity calculated in reference to total GDP).*

Source: OECD (2013)

These dynamics are confirmed by the age structure of R&D leaders of the *Industrial R&D Scoreboard* (EU 2011). The share of young firms[3] in R&D spending of the world innovation leaders tends to be larger in the US. It can have a large impact on the innovation and growth of activities such as biotechnology, computer hardware and software, leisure goods or internet. These activities correspond to sectors of technological specialization for the United States as measured by the relative technological advantage (Veugelers and Cincera 2010, OECD 2012). Besides, as described above, large incumbents draw more systematically on both academic teams and start-ups to speed up their innovation process and get access to new ideas and technologies.

As a result, policy makers have been increasingly reflecting on the way to promote the growth of start-ups in high tech and knowledge intensive sectors (Guellec and Sachwald 2008, Veugelers 2011).

3 Veugelers and Cincera (2010) have coined the term “yollies” for *young innovative firms* aged less than 25.

It has been the case in particular for start-up based on technology transfer from academic results. In a context of fiscal consolidation, policies also tend to try and increase the impact of all public funding of R&D expenses – public and private – on innovation and economic outcomes (OECD 2014). This trend is quite clear in a number of EU countries and at the European level. Related policies include more funding for applied research and experimental development as opposed to fundamental research, as well as various schemes to develop and speed up technology transfer of results from academic research.

The evidence on the division of innovation processes implemented through open innovation practices however suggest that firms rely more and more on public institutions to generate scientific results. They themselves do not invest in the most long term and risky phases of the process. They keep investing in their absorption capacity, but the scope of the latter has been redefined by open innovation practices. Major issues include the capacity to spot technological evolutions and to identify the best academic resources or the most promising start-ups. As a result, from a public policy point of view, it is crucial to nurture frontier research. The next section examines whether this is compatible with the objective to stimulate technology transfer.

2. Knowledge transformation depends on high impact research

Advances in scientific understanding represent a major source of technological opportunities for firms. Based on a detailed survey conducted in the 1980s, Klevorick *et al*. (1995) showed that these advances have two components. First new advances increase the pool of knowledge available to solve problems. This can explain the importance of applied disciplines for a large set of industries, including the automobile or defence industries. Second, in some cases, direct advances generate new opportunities, such as the emergence of biotechnology and its deep impact on the creation of new firms and a new set of actors in the pharmaceutical industry. In these less frequent cases, firms organize to be connected to academic research and not only rely on hiring well trained engineers or use disembodied knowledge through .publications for example.

These two types of impact of scientific results can be related to the distinction between two pathways from academic research to innovation, engagement through contract research on one hand, and commercialisation of new inventions and ideas on the other hand.

Empirical research indicates that productive and academically well assessed researchers engage more with technology transformation and cooperate more with firms. Conversely, firms tend to look for excellent researchers, with whom cooperation is more fruitful. In other words, excellent research generates higher economic returns.

2.1. Academics’ economic engagement increases with scientific impact

A number of empirical studies of the determinants of researchers’ engagement with firms have been able to use individual data. They cover countries with different types of innovation systems (US, UK, Sweden, Germany, Spain, Italy) and reach a number of converging conclusions. Table 2 summarises results from such studies, which are based on a variety of data sources (survey of researchers, CVs, bibliometric data). It distinguishes two pathways to technology transfer: engagement or contractual research on the one hand and commercialisation through patents or the creation of spin offs on the other hand.

A number of studies conclude that researchers with high scientific productivity and/or high impact tend to engage more in different activities of technology transfer (table 2). Productivity indicators are based on the number of articles produced by researchers. Studies use different proxies to build quality or impact indicators: volume of government grants based on peer review processes and impact of scientific publications in particular. Indicators of research quality generally have a positive impact on technology transfer, both at the individual and institutional levels and both through contract research and through commercialisation.

At the individual level, direct indicators of scientific productivity (number of publications) or impact as well as indirect indicators (government grants) have a positive impact on the researcher’s interactions with firms. One exception is researchers from social sciences. This may be due to the fact that those researchers may have less direct interest to interact with companies. Researchers in a number of applied disciplines for example are interested to cooperate with firms in order to use scientific equipment or to identify potential research questions.

Table 2. Academic engagement or commercialisation: summary results from the literature

Variable	**Engagement**				**Commercialisation**		
		Engineering	***Medical***	***Soc. Sc.***		***Spin offs***	***Patents***
Individual determinants							
Seniority	+				a		
Scientific productivity	+			*0*	+		
Scientific quality (assessment or publications)	+	+SMEs	+	-	+		
Grants awarded (government)	+				a		
Contracts awarded (industry)	+				a		
Previous commercialisation experience	a				+		
Institutional determinants							
Quality/productivity university/department	a				+	+	+
Size of the university	+					*0*	+
Applied discipline / Engineering in the university	+ / 0				+	*0/+**	+
Life science/biotech	a				+		
Country-specific regulations/policy	a				+		
Regional R&D intensity	0					+	*0*
Organisational determinants							
Size of TTO	0					+	*0*
Previous commercialisation experience	a				+		
Organisational support	a				+		
Peer effects	a				+		
Impact of engagement / commercialisation on:							
Scientific productivity / quality	a				+		
Shift towards applied research	a				0		
Collaborative behaviour	+				+		
Teaching	a				a		

0: no significant impact; a: ambiguous as the results vary according to different studies

** Positive impact in the case of universities specialised in engineering or applied sciences.*

Sources: Perkmann *et al*. (2011), Van Looy et al. (2011), Conti and Gaule (2011), Abramo *et al.* (2009), Abramo *et al*.(2012), Perkmann *et al*. (2013).

At the institutional level, research productivity or quality has a positive impact on the different commercialisation activities. The impact on contract research is more ambiguous. Van Looy et al. (2011) have found a positive impact of European universities scientific productivity on the level of contract research. The review of the literature by Perkmann *et al*. (2013) concludes on the contrary that the quality of university or department exerts a negative effect on the probability to engage in contractual research with firms. The authors suggest that good researchers (results from studies at the individual level) at academic institutions of lesser rank may engage with firms in order to compensate for the lack of public resources of their institution.

The determinants in technology transfer activities also depend quite strongly on the discipline of the researcher and, at the institutional level, the presence of certain disciplines. Applied sciences and in particular engineering have unsurprisingly the most consistently positive impact on both engagement and commercialisation. The impact of working in life sciences appears stronger for commercialisation than for engagement. This could be related to the more science-based character of life sciences and biotechnology. Patents in these fields are those citing non patent literature the most, which suggests a more direct impact of academic research on technology (see above).

Organisational issues seem to have more importance for commercialisation than for contract research. Previous commercialisation experience and organisational support have a positive impact on commercialisation. Seniority and previous contracts have a positive impact on engagement, but not on commercialisation. These observations suggest that engagement may be triggered by firms soliciting researchers, while commercialisation is decided by the researcher with support of her institution.

These results suggest that productive researchers, including those receiving public grants, also engage in technology transfer activities. Empirical results thus suggest that high impact research is connected to technology transfer activities and does not prevent it. It may be related to the fact that firms pick researchers with excellent track record.

Some studies suggest that there could exist an optimum degree of involvement with companies as they find that a high level of transfer activities negatively impact scientific productivity. But overall, there is a positive correlation between the quality of academic research and involvement in technology transfer.

From a policy perspective there is thus no need to compromise research quality to promote technology transfer.

2.2.Successful technology transfer depends on the quality of research

Empirical studies have analysed various technology transfer pathways, including R&D cooperation with firms, spin offs by researchers and licensing. For all pathways, studies conclude that research quality has a positive impact on transfer.

Studies on cooperation have shown that various agreements with academic research are about explorative R&D and novelty. Cooperation with academic research generates more patents or significant technology than for example cooperation with suppliers or customers (Cassiman *et al*. 2007). A study of collaboration between firms and universities in Japan showed that resulting patents had a higher quality than those flowing from firms' internal R&D (Motohashi and Muramatsu 2012). Firms entering in such public-private cooperative research tend to have a solid absorptive capacity and conduct exploratory research to serve an ambitious innovation strategy (Miotti and Sachwald 2003, Bercovitz and Feldmann 2007). Cooperation with academic research leads to higher levels of novelty while it does not represent risks in terms of value appropriation, which overall generate positive performance effects (Belderbos *et al.* 2004, Faems *et al*; 2005, Belderbos *et al*. 2014).

Some studies have been able to take into account the profile of the researchers or academic institutions involved. Overall, they tend conclude that high impact research leads to more productive relationships with firms in terms of innovation.

A study of the Japanese cluster policy, has estimated the impact of the *University-Industry Partnership* (UIP) scheme on innovation (Nishimura and Okamuro 2010). The policy did not provide incentives and services to further develop research and innovation networks within the selected clusters. It aimed more specifically at stimulating public-private research partnerships between SMEs and "national" universities, which are the excellent universities in the Japanese system[4]. Participation to a selected cluster (*Industrial Cluster Partnership,* ICP) aimed at allowing SMEs to choose the most appropriate partners within the cluster, in the region or neighbouring regions. The scheme provided for R&D funding, support to networking, start-ups, marketing and training. From 2001 to 2005, 19 clusters have benefitted from the scheme.

The study has analysed 229 SMEs that engaged in a partnership with academic research between 2002 and 2004. Among those, 57 were involved in an ICP. R&D productivity has been measured through patent data (number of patents, claims and citations). Control for the quality of patents aimed at checking that an increase in the number of patents was not due to pressure from METI to

4 National universities are the most prestigious. The university system includes three types of universities: 86 national universities, several hundreds of private universities, 82 « public » universities (Nishimura and Okamuro 2010).

patent results firms would not have spontaneously protected in order to generate more favourable policy indicators. The analysis shows first that simple participation to an ICP does not increase R&D impact on patents. This can be explained by the fact that about a third of ICP participants have never actually used the specific services provided by the programme. Second, collaborations with academic research within one region or with the neighbouring region tend to reduce the number and quality of patents out of R&D spending. On the contrary, collaboration with more distant academic institutions tends to increase the number of patents without diminishing their quality. However, local collaboration through an ICP involving a « national » university has a positive impact on the number of patents. In other words, local collaborations only stimulate innovation when they involve an excellent academic partner.

These results confirm the importance of the choice of a relevant partner, even if it is located far away. National or international rather than regional relationships may be justified by relevance, complementarity and the search for excellent partners (Miotti and Sachwald 2003, D'Este and Iammarino 2010). Besides, the more general trend of scientific globalisation and global innovation networks makes collaboration at a distance easier (Tijssen *et al*. 2011).

The case of Norway illustrates the effectiveness of innovation through long-distance knowledge exchange of isolated areas (Fitjar and Rodriguez-Pose 2011). Norwegian firms have achieved a high level of innovation despite a number of disadvantages (small cities, distant between each other and from the economic core of Europe). The concentration of enterprises in these urban centres is not sufficient to give rise to knowledge externalities typical of large agglomerations. However, Norwegian cities have maintained their innovativeness through the development of international connections between the local industry and foreign firms. The number of enterprises' international partners is positively associated with their innovative capacity, and process, product and radical innovations have tended to come especially from those firms which have set up connections outside their clusters and immediate geographical surroundings. On the contrary, regional cooperation does not impact radical innovation.

The location of star scientists has been an important factor in the development of biotechnology companies during the 1990s as they play a central role in both the development of the science and its successful commercialisation. Zucker and Darby (2003) have shown that the location of scientists publishing breakthrough articles is correlated with firm entry in nanotechnology. These empirical results on the importance of proximity with outstanding researchers may be related to the fact that technology being transferred to the start-up is typically at an early stage and needs to be further developed in connexion with the researcher herself. In other words, technology transfer requires an interaction between codified knowledge (e.g. patents) and complementary un-codified knowledge.

More recent contributions have further explored the impact of proximity to an excellent university on the probability of the creation of new firms. An American study shows that university patents have a positive impact on the probability of firm creation in the neighbourhood (Hausman 2012). This impact is measured by establishing a correspondence between the technologies in which universities patent and the sectors in which new companies are created. The study is able to measure a positive impact of higher federal funding (from NIH and DOD).on the creation of new companies around beneficiaries. Overall, university patents have a positive impact on local employment (75 miles around the university) and a stronger impact close to the university. In this study, the new establishments may be subsidiaries of existing companies. As a result university attractiveness results in more companies, with a mix of start-ups and new establishments of existing companies. This is the case in particular in the pharmaceutical industry, where new R&D centres have been attracted to excellent academic centres. These establishments may represent numerous jobs, but start-ups tend to experience higher growth.

A recent study using data on new knowledge intensive firms (KIFs) in Italy investigates more directly the role of university knowledge with respect to start-up creation (Bonaccorsi *et al*. 2013). It shows that knowledge codified in academic patents from one Italian province positively affects new KIFs creation in other provinces, having a spatial range of 200km. Knowledge codified in publications and embedded in university graduates is more localized: their effect on new KIFs creation is confined within the boundaries of the province in which universities are located. Besides, the spatial range of university knowledge is shaped by the quality of the universities producing this knowledge. Here again, the quality of university knowledge appears to increase its economic impact.

Few studies have been able to analyse the differences between countries in technology transfer performance, but the few available results suggest that research performance can explain at least part of the differences.

A comparison of the propensity of universities to license in the US and in European countries confirms the positive impact of research excellence on technology transfer (Conti and Gaule 2011). They analyse the determinants of the transatlantic "licensing gap", which they measure both in terms of numbers of licenses and in terms of licensing revenues. Their empirical analysis shows that the number of licenses of a university depends positively on it having an engineering department and on its volume of scientific publications[5]. In the mid-2000s, it depended negatively on the country still enforcing the so called "professor privilege", which was the case then in Sweden, Finland and Norway. The "licensing gap" between American and European universities disappears when, on top of these determinants, the explanatory model includes the size and age of the technology transfer office (TTO). The income from licensing is also positively impacted by publications, but also by the presence of star researchers in biomedical disciplines[6]. The presence of an engineering department in the university does not impact income from licensing. These results are consistent with the difference between engineering disciplines, which generate numerous patents, and biomedical disciplines, which may lead to blockbuster in the pharmaceutical industry. Income from licensing is also positively impacted by the local GDP per capita[7], which the authors interpret as an indicator of demand for technology transfer. A transatlantic "licensing gap" persists when these factors are all taken into account. The qualitative analysis of the authors relates this remaining gap to the fact that US universities tend to employ more TTO staff with an industrial experience than their European counterparts.

This study confirms the importance of the characteristics of the academic institution in which a TTO operates for the performance in terms of licensing. In particular indicators of excellence have a strong positive impact on licensing performance. The impact of excellence on technology transfer is twofold. On the one hand, it is an indicator of the quality of the technology that is being produced and, on the other hand, it impacts the perception a firm has of this quality. The authors consider that these results lead to a reinterpretation of the European Paradox.

A comparison of the impact of public-private R&D co-operations in France and Germany found that they have a stronger positive effect on innovation in Germany (Robin and Schubert 2013). The authors have not explored the effect of differences in scientific quality on these results.

2.3. Innovation performance is correlated with high impact research

Firms rely on connections with science to innovate, in particular in a number of new and growing business areas (part 1). Moreover, successful technology transfer often depends on the involvement of high impact researchers (2.1 and 2.2). At the national level, innovation should thus be correlated with research excellence. This is actually what suggests the *Innovation Union Scoreboard*. Figure 3 indicates that high impact research is strongly correlated to the EU synthetic innovation index. The correlation is as strong as with business R&D (Appendix 1).

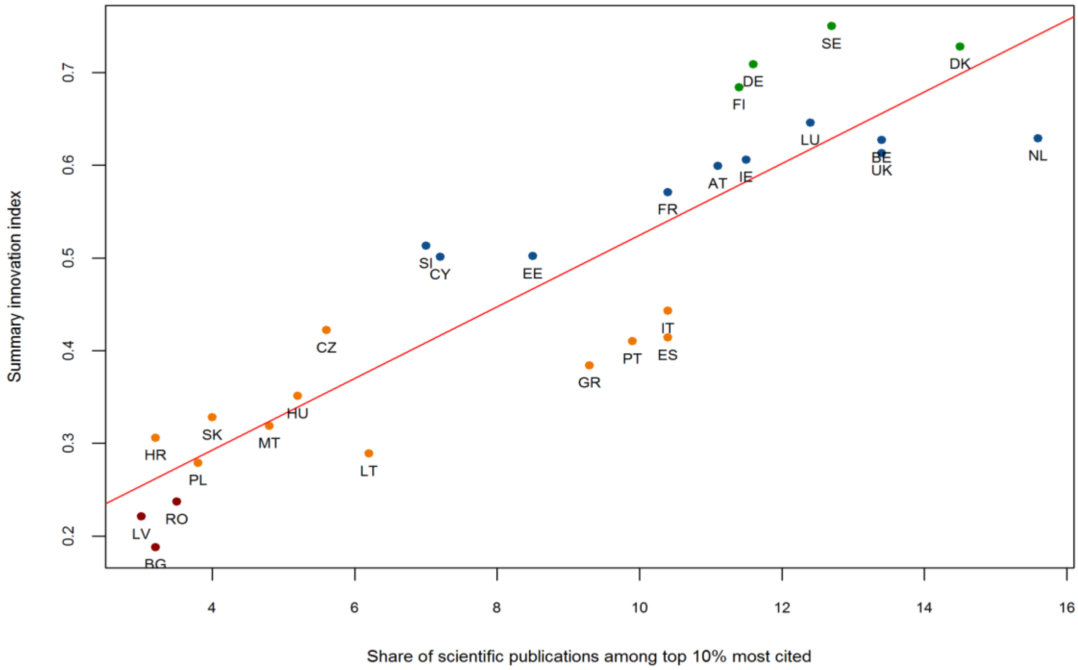
The precise position of countries is also influenced by the sector composition of their economies. As discussed above, countries with large high or mid-high tech sectors tend to exhibit high R&D intensity (table 1). Moreover, business R&D intensity is strongly correlated with the propensity to patent. As a result, these countries tend to have a high synthetic index of Innovation. Finland and Germany are in such a position: their performance in terms of business R&D intensity is better than their performance in terms of research excellence. The Netherlands, the UK and Belgium are in a symmetrical position with respect to these two indicators Denmark combines very strong positions in terms of business R&D and research excellence. Among modest innovating countries, Italy, Spain, Portugal, Greece have relatively high academic performance.

The indicator of high impact research and the indicator of public-private co-publications are highly correlated. The latter is also highly correlated with business R&D intensity and with the propensity to patent. More generally, the examination of the correlation table of the 25 indicators composing the *Innovation Union Scoreboard* suggests strong complementarities between the intensity of business

5 Number of articles in science and engineering published in 2004-2006 as reported in the ISI Web of Science.
6 A star is defined as appearing on the ISI Web of Science list of highly cited researchers.
7 Country level for Europe and state level for the US

R&D, the impact of academic research and public-private co-publications (see Appendix 1). Business R&D intensity can be considered as a proxy for demand for research results and high impact publications for high quality supply of results. A higher rate of public-private co-publications in a country could then be interpreted as an indicator of successful matching between supply and demand for research results.

Figure 3. High impact scientific publications and innovation performance, 2014



Source: Calculation from the Innovation Union Scoreboard 2014

Overall, the evidence discussed in this second part suggests that the transformation of research results is only one issue to deal with to boost the EU innovation performance. The quality of these research results also appears as a fundamental asset to stimulate both transfer and innovation in Europe.

3. The persistent transatlantic excellence gap

Since high impact research is one determinant of the intensity of technology transfer and innovation, it is important to measure to what extent EU scientific base generates such high impact or excellent research. International comparisons cannot be limited to the number of publications or even the number of highly cited publications. A full diagnosis of the contribution of the EU scientific base to knowledge transformation and innovation includes a combined analysis of specialisation and excellence of European research. Since star researchers are related to the creation of start-ups in emerging sectors, it is also relevant to compare performance for the research results with the highest impacts[8].

3.1. The transatlantic excellence gap in scientific production

Over the last decade, a number of empirical studies have actually pointed to what could be summarised as a "transatlantic excellence gap". Various authors have produced indicators to question the productivity and quality of European science and European universities (Dosi, et al., 2006, Bonaccorsi, 2007, Aghion et al, 2010). The EU generates a larger number of scientific publications than the United States, but these publications are on average of lesser quality. These results seem to

[8] In the previous section, high impact researchers were identified either through bibliometric indicators or through the propensity to get research grants. This section relies on bibliometric indicators which are more widely available and allow more comparisons between countries and disciplines.

be quite persistent. Albarran et al. (2011) found that the mean citation rate of EU publications was lower than in the US in all scientific fields studies between 1998 and 2002. The OECD (2013) has found that between 2003 and 2011 most European countries had a lower share of high impact scientific publications[9] than the US.

Herranz and Ruiz-Castillo (2011) studied publication performance at a low aggregation level between 1998 and 2002. They found that, although the EU has more publications than the U.S. in 113 out of 219 sub-fields, the U.S. is ahead of the EU in 189 and 163 sub-fields in terms of the high-impact indicators. They also found that the US/EU gap tends to be larger for high-impact indicator than when using the mean citation rate. Bonaccorsi *et al*. (2013) pointed to the fragmentation of research in European universities to explain that the EU falls short of the critical masses of funding and talent needed to achieve global scientific and technological excellence.

Tables 3 and 4 confirm the general picture on recent data. Table 3 is based on scientific publications over the decade starting in 2000. The EU has a substantially larger number of scientific publications than the US and this number has been growing more rapidly over the decade. But both indicators of impact are lower for the EU than for the US. The indicators are also lower for EU countries than for non EU ERA countries[10]. The number of Chinese publications has increased by nearly 80% over the decade, but their impact remains low.

Table 4 provides indicators for the top 1% most cited scientific publications. The EU share of world publications is larger than the share of the US, but the reverse is true for the top 1% most cited publications. As a result, the index of highly cited articles is nearly 90% higher for the US (last column on the right). Comparing tables 3 and 4 indicates that the transatlantic gap is larger for more demanding impact indicators, which confirms the result by Herranz and Ruiz-Castillo (2011) cited above. Table 4 also indicates that the transatlantic excellence gap has been hardly reduced between 2002 and 2012. China and Japan exhibit much lower scores, but the two Asian countries have a very different dynamic profile. China has experienced a rapid increase in the impact of its publications, as opposed to Japan. As a result, China and Japan have the same index of highly cited publications in 2012; at 0.6 it is a third lower than the EU and two thirds lower than the US.

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9 Scientific publications among the 10% most cited.
[10] Switzerland, Norway and Israel in particular tend to produce publications with more impact than the EU.

Table 3. Publications in all disciplines and indicators of quality, 2000-2011

Geographical zone	Number of publications	Number of publications, fractional	Growth index	Average of relative citation*	Share of top 10% cited publications in total publications, %
ERA	6,673,485	5,920,382	1.19	1.08	12.7
EU	6,038,673	5,281,856	1.19	1.08	11.0
US	4,947,133	4,221,118	1.08	1.37	14.9
China	2,528,134	2,337,281	1.77	0.73	6.7
Japan	1,282,630	1,129,660	1.00	0.89	8.1
World	17,500,890	17,500,890	1.28	1	10

* The average of relative citation (ARC) is a field-normalized measure of the scientific impact of publications, based on the impact factors of the journals in which they were published.

Source: Data from Campbell *et al.* (2013)

Table 4. Share of all science and engineering articles, top 1% cited articles and index of highly cited articles, 2002 and 2012

	Share of articles in world total, %				Share of top 1% cited articles in world total, %				Index of highly cited articles*			
	EU	**US**	**Japan**	**China**	**EU**	**US**	**Japan**	**China**	**EU**	**US**	**Japan**	**China**
2002	35.6	30.8	9.0	2.6	28.2	57.0	5.0	0.3	0.8	1.8	0.6	0.1
2012	31.6	26.6	6.3	9.2	29.8	46.4	4.0	5.8	0.9	1.7	0.6	0.6

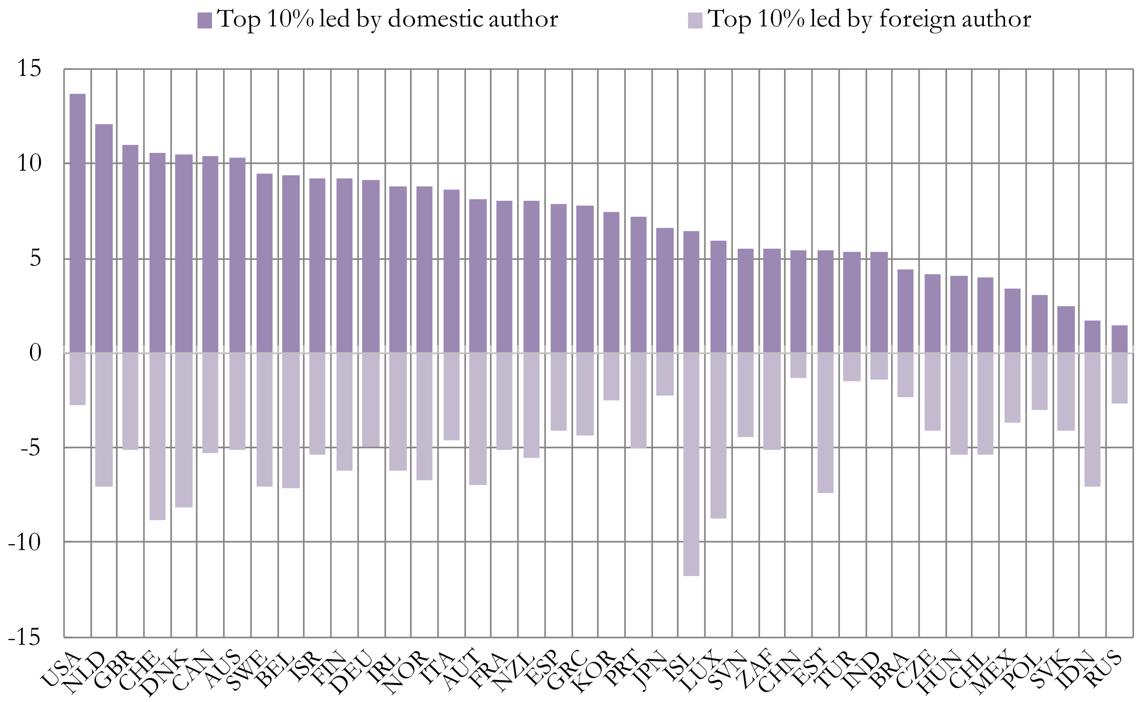
* *Share of the world top 1% cited articles divided by the share of world articles in the cited-year window.*

Source: National Science Board (2014)

International co-publications account for a substantial share of scientific articles and a leadership indicator has been devised to help understand the role of a given institution or country in the context of its collaboration activities. The scientific leadership indicator shows the share of scientific publications involving international collaborations by authors from a given country where an author from this country is listed as leading author.

Excellence and leadership information can be jointly analysed to gain further insights about the source of a country's highly cited publications. The United States, for example, accounts for 17% of the top 10% cited publications, of which 14% accounted for by documents where a US-based author is listed as the leading author, while only 3% are led by authors with affiliations abroad (Figure 4). This places the United States as the country with the largest share of top cited publications that are led by domestic authors, followed by the Netherlands and the United Kingdom. Other countries with higher overall excellence rates, like Switzerland, display lower scores on this metric because of the higher share of collaborative articles led by authors from other countries.

Figure 4. Top 10% most cited documents and scientific leading authorship, 2003-12,
% of all documents, whole counts



Source: OECD (2015)

Overall, bibliometric evidence underscores the leadership position of the United-States in terms of academic excellence. This type of data should be interpreted with caution, even when indicators are carefully designed and normalised to take into account differences between disciplines. In the above data, the contrast between Japan and China or between EU countries and non EU ERA countries, however suggests that the causes of the transatlantic excellence gap may not be mostly related either to English being the national language or to cultural aspects.

In an opinion piece published in the *European Journal of Information Systems*, four editors of high impact journals either educated or located in Europe asked "Why the old world cannot publish?" (Lyytinen *et al*. 2007). They attributed the low representation of European authors in top journals to a set of causes including characteristics of Ph.D training or research priorities. They mentioned, weak reviewing practices, inadequate Ph. D preparation for article publishing and lower command of research methods. They also mentioned a preference for long contributions and books in Europe, while top journals promote the ability to succinctly express the basis for reaching conclusions. Finally, they considered that European information systems researchers closer interactions with industry result in practical concerns dominating the agenda. Intense research-industry engagement may have contributed to the lower motivation of European researchers to publish in elite journals and generate long term impact. Such characteristics are related to national research and innovation system and as such may vary by country and by discipline. It is thus important to examine whether the transatlantic gap varies by discipline and whether there is a relation between specialization and excellence.

3.2. Specialisation and excellence in ICT and health related scientific fields

Table 5 provides data to analyse the evolution of the share of world publications and excellence indicators by disciplines over the last decade. It is ordered by the 2012 EU share of world publications. The overall share of the EU being 31.6% (table 4), it is specialised in astronomy, mathematics, social sciences, medical sciences and agricultural sciences. The US is also specialised in astronomy, social sciences and medical sciences. Besides, it is specialised in psychology, biological sciences and computer science. Neither the EU nor the US are specialised in physics, chemistry or engineering, where China has been increasing its specialisation. China has also increased its specialisation in computer science.

Excellence may be defined by an index of highly cited articles above one. Based on this metric, in 2012 the EU is excellent in two fields: physics and agricultural sciences. It is thus both specialised and excellent only in agricultural sciences. The US is excellent in all fields and its index of highly cited articles is always above that of the EU. The US index is above its overall 2012 average of 1.7 in physics, chemistry, mathematics and engineering.

Both the US and China are specialised in computer science, with an index of highly cited articles of respectively 1.6 and 1.3. The only other field in which China has an index above one is geosciences.

These observations are still at a quite aggregated level, but the conclusions are consistent with more detailed analyses based on data from the 1990s and 2000s (Herranz and Ruiz-Castillo 2011, Campbell *et al.* 2013). They confirm in particular that both the US and the ERA are specialised in health related fields, which generates a large share of world publications, but the US publications have a much higher impact.

Campbell *et al.* (2013) provides detailed data by using three different classifications for publications. When publications are classified on the basis of the FP7 thematic priorities, the US achieves one of its highest impact scores Information & Communication technologies (ICT), well above that of the EU[11]. The EU's best positions are in scientific fields which are more related to traditional manufacturing industries: Enabling & Strategic technologies and Engineering. These are the two fields in which the US impact is nevertheless slightly higher and China is strongly specialised with a substantial share of world publications.

Table 6 focuses on publications in ICT. It shows that European publications have increased more than the world total. As a result, the EU has become slightly specialised in ICT (SI equal to 1.05). Publications from the US have been less dynamic and the country has moved from a specialised to a non specialised country in ICT. Indicators of excellence have evolved in the opposite direction. Both the EU and the US have improved the impact of their publications in ICT, but the transatlantic excellence gap[12] remains (it decreases slightly when measured with the top 10% indicator).

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[11] The share of top 10% most cited publications is 16% in the US total and 11.2% in that of the EU (Table VI, page 23).

[12] Ratio of the US quality indicator to the EU same indicator (either ARC or top 10%).

Table 5. Share of science and engineering articles, top 1% cited articles and index of highly cited articles by field, 2002 and 2012

		Share of articles in world total*, %				Share of top 1% cited articles in world total, %				Index of highly cited articles**			
		EU	**US**	**Japan**	**China**	**EU**	**US**	**Japan**	**China**	**EU**	**US**	**Japan**	**China**
Astronomy	**2002**	39.2	33.3	5.9	1.9	34.4	54.9	1.2	0.0	0.9	1.6	0.2	0.0
	2012	38.8	31.1	4.9	4.7	39.3	48.5	3.6	0.7	1.0	1.6	0.7	0.1
Mathematics	**2002**	40.4	29.0	4.6	4.7	32.0	54.8	1.3	3.1	0.8	1.9	0.3	0.7
	2012	37.7	22.0	4.1	12.4	34.3	44.1	1.6	7.3	0.9	2.0	0.4	0.6
Social sciences	**2002**	30.6	48.0	1.5	0.9	22.9	70.0	0.4	0.2	0.7	1.5	0.1	0.5
	2012	35.6	37.4	1.6	1.9	32.5	49.3	0.4	1.0	0.9	1.3	0.2	0.5
Medical sciences	**2002**	38.6	34.6	8.5	0.9	30.2	56.8	3.1	0.4	0.8	1.6	0.4	0.4
	2012	34.5	32.9	5.9	4.0	32.1	51.0	2.2	1.5	0.9	1.6	0.4	0.4
Agricultural. sciences	**2002**	35.0	26.2	8.6	0.9	41.9	37.2	4.1	0.5	1.2	1.4	0.5	0.5
	2012	32.9	19.6	6.7	7.9	38.6	27.6	1.9	5.9	1.2	1.4	0.3	0.7
Geosciences	**2002**	34.6	32.0	5.3	1.9	27.7	53.2	1.8	0.5	0.8	1.7	0.3	0.2
	2012	31.7	26.6	4.8	7.6	26.9	43.4	2.2	8.4	0.8	1.6	0.5	1.1
Psychology	**2002**	26.6	53.6	2.0	0.7	18.8	71.7	0.5	0.1	0.7	1.3	0.2	0.1
	2012	31.7	45.2	1.6	1.3	25.0	63.7	0.3	0.2	0.8	1.4	0.1	0.2
Biological sciences	**2002**	34.6	35.3	8.7	1.4	24.1	62.4	5.3	0.1	0.7	1.8	0.6	0.1
	2012	31.5	31.6	6.6	6.6	26.5	56.0	3.6	2.0	0.8	1.8	0.5	0.3
Computer science	**2002**	28.9	39.8	4.2	4.3	20.6	63.3	1.3	0.9	0.7	1.6	0.3	0.2
	2012	30.6	27.2	2.0	13.0	21.6	43.6	0.5	16.7	0.7	1.6	0.3	1.3
Physics	**2002**	35.9	20.6	12.2	4.7	36.8	42.4	8.3	0.8	1.0	2.1	0.7	0.2
	2012	30.2	17.4	8.7	14.8	36.2	37.8	6.4	5.2	1.2	2.2	0.7	0.4
Chemistry	**2002**	37.9	19.1	11.6	5.3	32.7	44.2	9.4	1.9	0.9	2.3	0.8	0.4
	2012	29.6	16.2	7.9	16.9	28.4	33.5	5.6	16.3	1.0	2.1	0.7	1.0
Engineering	**2002**	31.5	24.4	12.2	5.0	29.9	42.7	10.1	2.5	1.0	1.7	0.8	0.5
	2012	26.4	18.4	6.7	15.2	24.6	37.5	4.3	12.2	0.9	2.0	0.6	0.8

** Descending order for 2012 EU share. ** Share of the world top 1% cited articles divided by the share of world articles in the cited-year window.*

Source: Adapted from National Science Board (2014)

Table 6. Publications[1] in ICT[2], specialisation and excellence indicators, 2000 and 2013[3]

	Number of publications (fractional)		Specialisation index (SI)		Average of relative citations (ARC)		Share of top 10% most cited publications (fractional)	
	2000	**2013**	**2000**	**2013**	**2000**	**2010[3]**	**2000**	**2010[3]**
Austria	203.9	1 215.5	0.83	1.83	1.11	1.23	12.50	12.52
France	1 607.7	4 654.6	0.86	1.16	1.04	1.32	9.30	11.86
Germany	2 053.2	5 733.3	0.81	1.03	1.03	1.25	9.54	11.34
Greece	442.8	1 122.6	2.29	1.76	0.91	1.32	7.67	12.88
Italy	1 466.8	3 810.2	1.11	1.04	1.12	1.46	10.98	14.99
Netherlands	573.4	1 567.4	0.83	0.87	1.76	1.54	14.16	13.89
Poland	221.0	1 227.9	0.50	0.77	0.61	0.83	2.41	8.52
Portugal	177.9	1 068.0	1.48	1.46	0.80	1.03	6.15	7.92
Spain	807.9	3 879.7	0.87	1.22	0.83	1.36	7.80	14.15
Sweden	430.3	1 131.4	0.79	1.00	1.36	1.23	9.79	11.78
United Kingdom	2 296.0	4 734.0	0.80	0.82	1.16	1.53	10.27	14.22
Total EU-28	**11 980.4**	**36 025.4**	**0.88**	**1.05**	**1.04**	**1.22**	**9.53**	**12.18**
China	3 575.4	32 068.9	1.48	1.28	0.66	0.68	5.64	5.66
Japan	3 322.0	4 858.7	0.94	0.86	0.58	0.69	4.65	5.36
Rep. of Korea	1 077.0	4 549.5	1.83	1.36	0.78	1.20	6.30	11.39
United States	12 712.2	18 885.2	1.12	0.78	1.45	1.79	14.28	17.31
World	**39 875.0**	**124 242.0**	**1.00**	**1.00**	**1.00**	**1.00**	**10.00**	**10.00**

1. *In the EU, countries with more than 1 000 publications in 2013 only*
2. *Information and Communication Technologies corresponding to the FP7 priority*
3. *Publications from 2010, citations in a three year window.*

Source: Sciencemetrix based on Scopus data base

Table 6 shows the indicators for the EU countries with more than 1,000 publications in 2013. Specialisation in ICT has increased in all countries except Greece and the Netherlands. Performance in terms of quality is more diverse. The excellence gap with the US has slightly increased in Austria and the Netherlands, the performance of which remains among the best in the EU. The gap has on the contrary substantially decreased in some countries with low impact indicators: it has decreased by more than 25% for Greece and Spain and by more than 60% for Poland. Among those, Poland and Spain have also substantially increased their specialisation in ICT publications. Among countries with relatively high impact performance, Italy and the UK have simultaneously increased their specialisation and reduced the excellence gap with the US. All three Asian countries in the table have reduced their specialisation in ICT and Korea has substantially improved its impact performance.

Overall, the above data confirm results from previous empirical work. Evidence based on various indicators, periods and levels of aggregation indicate that the US has the world strongest science base in fields related to ICT. The US also has the strongest science base in disciplines related to health and medicine. By contrast, the EU strongest scientific fields are related to traditional industrial sectors or agriculture. As a consequence, the US is in a stronger scientific position to generate innovations in the coming converging technologies and the exploitation of big data. The detailed data on ICT nevertheless suggest that some EU countries have managed to simultaneously progress both in terms of specialisation and impact of their ICT scientific base.

3.3. Does the EU suffer from 'mismatches' between science and technology ?

The most recent report on research and innovation in the EU (EU 2014) combines data on publication and patents to suggest that there are "strong S&T mismatches" in Europe but not in the US. The report concludes that "*consideration should be given in the EU to better articulating supply and demand-side policies in these areas and improving the exploitation of research results"* (p. 14). In other words, the Commission identifies European paradoxes at the sector level and suggests adopting policies to stimulate knowledge transformation in specific domains. The evidence however does not support this conclusion. The report underscores a "*strong mismatch between scientific and technological specialisations in the EU"* in five areas related to the FP7 priorities: health, ICT, energy, other transport technologies and aeronautics and space (EU 2014, p. 14).

Actually, the "S&T mismatches" are not in the same direction in the different areas. In aeronautics & space and in automobiles, the EU is much more specialised in terms of technology than in terms of publications. This can be explained by the combination of EU production profile and the relation to science of these sectors. The EU is specialised in these two sectors, which explains that European companies file numerous patents in related technologies. Besides, as discussed above these technologies do not relate directly to recent scientific publications (figure 2). In other words, technological progress and innovation in the automobile sector does not closely rely on excellence of the recent scientific contributions. It is much more dependent on the quality of the training system and on firms' strong absorption capacity.

Moreover, the analysis of ICT and health areas is at odds with the available data. The report notes that in "*the areas of health and ICT, there is a relatively strong scientific specialisation (coupled with citation rates which are slightly above average) but a weak technological specialisation. This situation compares unfavourably to the US and China where health and ICT, respectively, are areas of strong S&T co-specialisation"* (EU 2014, p. 14). Actually, the evidence does not support this analysis.

In the case of ICT, during the first decade of the century, the EU was not specialised, neither scientifically nor technologically, as indicated on figure 3 of the report (EU 2014, p. 15). The EU has become specialised in ICT related publications recently, while the US lost their specialisation (Table 5, section 3.2). Besides, a citation rate slightly above average should not be used to claim that the EU has a strong scientific base in ICT. As argued above, the EU has a substantially weaker or "less excellent" scientific base than the US in ICT: the US share of top 10% most cited publications was 50% higher than that of the EU in 2000 and is still 42% higher in 2013 (based on table 5). The US is hardly technologically specialised. In conclusion, the US is not scientifically specialised in ICT but has excellent academic performance. The mismatch is then on the US side, its slight technological specialisation being probably due to a thriving ICT business sector[13].

In health, both the US and the EU are specialised, but the scientific performance of the US is substantially higher. Over the last decade, the top 10% most cited publications indicator is 50% higher for the US[14]. The gap was similar for the scientific publications related to medical and surgical equipment[15]Table 4 above shows that in 2013, the US index of highly cited publications in medical sciences and biological sciences remains much higher than that of the EU. In order to evaluate the innovation potential in a number of health technologies, which rely heavily on recent scientific results (figure 2 above), the European academic performance should not be compared to the world average, but to the leading countries and the US in particular.

The combined analysis of scientific and technological performance is relevant to design evidence based policies and the EU innovation report 2014 rightly started to tackle this issue. As the discussion above suggests, it would however need to consider additional indicators, go into more details and consider recent evolutions. At this stage, it cannot be said that the EU suffers from "S&T mismatches" that would suggest policies focusing on "*better articulating supply and demand-side policies in these areas and improving the exploitation of research results"* (EU 2014, p. 14). The data discussed above suggests that in ICT and health related fields, policies should also consider improving the quality of scientific production which may be the missing link in the analysis. In more traditional industrial sectors like the automobile, the EU technological specialisation does not suffer from its lack of related scientific specialisation.

Conclusions: Twin deficits and policy challenges

The identification of the EU's innovation twin deficits calls for a renewed reflection on the mix of public policies to stimulate research and innovation. These policies would benefit from more precise and detailed evidence on the interactions between research and innovation across scientific disciplines, technological areas and industrial sectors.

The challenges of innovation policies in Europe

A decade ago, the third *European Report on Science and Technology indicators* was wondering about the origins of the perceived "European paradox":

"The perceived gap between Europe's strong science base and its poor performance in terms of technological and industrial competitiveness (sometimes referred to as the "European Paradox") has led policy-makers to seek additional insights into how, where, and why this "paradox" occurs, and the measures that might be taken to address this phenomenon. Does the European science system fail to produce the kind of research upon which advanced industrial economies have become increasingly dependent, or does its industry lack the ability and/or absorptive capacity to use the knowledge produced in the science sector effectively? In either case, the interfaces between public research, technological development and commercial exploitation have to be better understood if improvements are to be made (e.g. through intermediary structures)" (EU 2003, p. 413).

In this citation the report rightly mentioned both knowledge production and knowledge exploitation as potential sources of European difficulties, but focused its policy recommendations on intermediary structures to improve knowledge transformation. This paper has argued that Europe's difficulties come both from the public research and business sides, but, more fundamentally, that the notion of a "European paradox" should not inform the design of innovation policies anymore. Yes, the European science system fails to produce the kind of research upon which advanced industrial economies have become increasingly dependent, but it is at least partly because it is of insufficient quality. And, yes the European industry lacks the ability and/or absorptive capacity to use the knowledge produced in

[13] Recent data published by the OECD shows that the technological specialisation of the US in ICT has been decreasing somewhat since the early 2000s, but its revealed technological advantage remains above1 (OECD 2014).
[14] 15.3% of total publications between 2000 and 2011, versus 10.2% for the EU (Campbell *et al*. 2013, Table III, p. 17).
[15] 14.9% of total publications between 2000 and 2011, versus 10.7% for the EU (Campbell *et al*. 2013, Table LXI, p. 114).

the science sector effectively, partly because it is less specialised in high tech and knowledge intensive activities than the US industry. The EU is not caught in a science vs technology paradox, but actually suffers from twin deficits in excellent research and innovation in new high growth sectors.

The evidence produced here to support this argument can be summarised with three sets of stylised facts. First, the significance of recent scientific results differs widely across technologies. It is essential in biotechnology, pharmaceuticals, digital and basic communication, food or organic chemistry, while it is of much less importance for patents in the fields of transport, machine tools or civil engineering. Second, high impact researchers or academic institutions tend to engage more in knowledge transformation than others. Moreover, firms that cooperate with excellent researchers generate more innovation and better market performance. Third, the persistent transatlantic "excellence gap" is wider in the scientific disciplines with most innovation potential. The US has the world strongest science base for sectors related to ICT as well as in disciplines and sectors related to health and medicine.

Reinforce the production of evidence for policy making

Innovation depends on a complex set of drivers and can be hampered by a number of obstacles, including to general conditions of the business environment or the social acceptance of technologies. National and EU policies address a number of these drivers and obstacles, but this paper suggests that they should better monitor the production of high impact research. More evidence is needed to develop a complete diagnosis on the determinants of the innovation performance of European countries in relation with the performance of their scientific base. The EU could contribute to develop such evidence.

First, in order to thoroughly revisit the European paradox and draw policy conclusions from detailed evidence, the EU should invest in relevant capacities to analyse the nexus of research, knowledge transformation and innovation. Publications and research results are intermediary products of the innovation system and both their quantity and quality should be monitored. The related issue of the quality of higher education is also particularly important[16] since open innovation processes depend on a combination of a strong science base, creative human resources and high quality infrastructures and intermediaries. Innovation in new and high growth activities may not only depend on excellence, as suggested by many recent analyses, but does also depend on excellence in relevant scientific fields.

Second, the observation of innovation performance should be based on a sound and updated framework of analysis. This paper has underscored in particular the importance of taking into account the role of countries' sector composition, which has a strong impact on some of the main indicators used to analyse innovation performance like R&D intensity and the propensity to patent or to export. The value of the new "innovation output indicator"[17] of the EU also strongly depends on the sector composition of countries. In order to update the EU framework of analysis, it would be useful to conduct a statistical analysis of the *Innovation Union Scoreboard* in order to produce a typology of countries. This would increase the capability to connect country characteristics to policy design. It could also help reflect on the relevance of some indicators which are not correlated to the synthetic innovation index (see Appendix 1). Overall, these new analyses could lead to a fruitful revision of the Scoreboard, which is also suggested by a recent contribution based on the analysis of the case of Sweden[18].

Third, efforts to evaluate the impact of research should take the quality of scientific production into account. Evaluation of the impact of the numerous public-private co-operative schemes should also take the quality of research into account. It would for example be interesting to examine impact indicators for patent relevant publications. During the 1990s, the scientific literature cited in patents was often produced by the best research institutions (Narin *et al.* 1997): is it still true and does it depend on the technological area?

Overall the suggested new data and typologies should generate a set of consistent stylised facts on the relationship between R&D intensity, research specialisation and innovation performance. Such

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16 On this issue and the relationship between the quality of research and teaching, see Aghion *et al*. (2010), Bonaccorsi *et al;* (2013b).
17 Used in particular in the 2014 edition of *Research and Innovation Performance in the EU* (EU 2014).
18 The proposed statistical analysis is different and more generic than the method adopted by Edquist. and Zabala-Iturriagagoitia (2015) in the case of Sweden.

evidence would provide a better basis to develop policies aimed at adapting the EU industrial structure to the knowledge based economy. At the regional level, similar evidence would provide a sound basis to design smart specialisation strategies.

The European commission could launch the definition of a roadmap to produce this set of policy relevant data and indicators with a conference on the impact of research and its interactions with innovation. This conference could specifically focus on the evidence policy makers need to promote both open science and open innovation.

REFERENCES

Abramo, G, C. D'Angelo, M. Ferretti and A. Parmentola, 2012, "An individual-level assessment of the relationship between spin-off activities and research performance in universities", *R&D Management*, 42: 225-242

Abramo, G, C. D'Angelo, F. DiCosta and M. Solazzi, 2009, "University–industry collaboration in Italy: A bibliometric examination", *Technovation* 29, 498–507

Abramovsky, L., R. Harrison and H. Simpson, 2007, *University research and the location of business R&D*, The Institute for Fiscal Studies, WP 07/02.

Aghion, P., Dewatripont, M., Hoxby, C., Mas-Colell, A., Sapir, A., 2010, The governance and performance of research universities. Evidence from Europe and the US. *Economic Policy*, 25 (61), 7-59.

Albarran, P, J Crespo, I Ortuño and J Ruiz-Castillo, 2010, 'A comparison of the scientific performance of the U.S. and the European Union at the turn of the 21st century'. *Scientometrics*, 85, 329–344.

Arora, A., S. Belenzon and A. Patacconi, 2015, Killing the Golden Goose? The Decline of Science in Corporate R&D, NBER Working Paper 20902

Arundel, A. and A. Geuna, 2004, "Proximity and the use of public science by innovative European firms", *Economics of Innovation and New Technology*, vol. 13, 559-580

Belderbos, R, M., Carree and M. Lokshin, 2004, 'Cooperative R&D and firm performance', *Research policy* 33, 1477-92

Belderbos, R., B. Cassiman, D. Faems, B. Leten and B. Van Looy, 2014, "Co-ownership of intellectual property: Exploring the value-appropriation and value-creation implications of co-patenting with different partners, *Research policy,* 43, 841-52

Bonaccorsi, A., 2009, *Linking industrial competitiveness, R&D specialisation and the dynamics of knowledge in science: a look at remote influences*, JRC Scientific and Technical Reports.

Bonaccorsi A., 2011, European competitiveness in Information Technology and long term scientific performance,. *Science and Public Policy*, vol. 38(7), August, 521-540.

Bonaccorsi, A. *et al*., 2013, Are European universities facing the Asian Challenge in excellent S&T research? Innovation for Growth–i4g Policy Brief N°10.

Bonaccorsi, A., M.G. Colombo, M. Guerini, C. Rossi Lamastra, 2013b, The impact of local and external university knowledge on the creation of knowledge intensive firms: evidence from the Italian case, *Small Business Economics*

Campbell, D., Lefebvre C., Picard-Aitken M., Côté G., Ventimiglia A., Roberge G., and Archambault E., 2013, *Country and regional scientific production profiles*, Directorate-General for Research and Innovation,: Publications Office of the European Union,

Cassiman, B., R. Veugelers and P. Zuniga, 2007, Science linkages and innovation performance : An analysis on CIS-3 firms in Belgium, IESE Research Papers

Chesbrough, H., 2003, *Open Innovation: The new imperative for creating and profiting from technology*, Harvard Business School Press

Conti, A. and P. Gaule, 2011 "Is the US outperforming Europe in university technology licensing ? A new perspective on the European paradox", Research Policy, 40

Council of Canadian Academies, 2013. *Paradox Lost: Explaining Canada's Research Strength and Innovation Weakness*, Council of Canadian Academies,

D'Este, P., Iammarino, S., 2010. « The spatial profile of university-business research partnerships », *Papers in Regional Science*

Dhont-Peltrault 2005, « Les relations interentreprises en R&D », *Note Recherche* 05.01, Ministère de l'Education nationale, Paris

Dosi, G, P. Llerena and M. Sylos-Labini, 2006, "The relation between Science, Technology and their industrial exploitation: an illustration through the myths and realities of the so-called 'European Paradox'", *Research Policy*, Vol 35, pp. 1450-1464

Edquist, C. and J-M. Zabala-Iturriagagoitia, 2015, The Innovation Union Scoreboard is Flawed: The case of Sweden –not being the innovation leader of the EU, Papers in Innovation Studies, CIRCLE, Lund University

EU, 1995, *The Green Paper on Innovation*, European Commission

EU, 2003, *Third European Report on Science & Technology indicators*, European Commission

EU, 2011, *2011 EU Industrial R&D Investment Scoreboard,* Joint Research Centre (JRC) - Institute for Prospective Technological Studies (IPTS) and Directorate General for Research and Innovation

EU, 2014, *Research and Innovation performance in EU Member States 2014, Innovation Union progress at Coutnry level*

EU, 2014b*, The Innovation Union Scoreboard 2014*

Faems, D., B. Van Looy and K. Debackere, 2005, The role of inter-organizational collaboration within innovation strategies: toward a portfolio approach, Department of Applied economics, University of Leuven

Fitjar, R. D., & Rodríguez-Pose, A. (2011). "When local interaction does not suffice: Sources of firm innovation in urban Norway",. *Environment and Planning* , A, 43, 1248–1267.

Frontier Economics, 2014, *Rates of return to investment in science and innovation*, Report for the department for Business, Innovation and Skills

Hall, B., J. Mairesse and P. Mohnen, 2009, Measuring the returns to R&D, NBER working paper series, 15622

Haskel, J., A. Hughes and E. Bascavusoglu-Moreau, 2014, *The Economic Significance of the UK Science Base*, UK Innovation research Centre, March

Hausman, N., 2012, University Innovation, Local Economic Growth, and Entrepreneurship, US Census Bureau Center for Economic Studies Paper 12-10

Hedge and Hicks 2008, 'The maturation of global corporate R&D: Evidence from the activity of U.S.foreign subsidiaries', *Research Policy*, 37(3), pp. 390-406.

Herranz, N, and J.Ruiz-Castillo, 2011, *The end of the European paradox*, Working Paper Economic Series 11-27, University Carlos III, Madrid

Le Ru, 2012a, Dans une économie tournée vers les services, la recherche industrielle reste dynamique, *Note d'information*, Ministère de l'enseignement supérieur et de la recherché, Paris

Le Ru, 2012b, Un déficit d'effort de recherché des entreprises françaises ? Comparaison France – Allemagne, *Note d'information*, Ministère de l'enseignement supérieur et de la recherché, Paris

Lyytinen, K., R. Baskerville, J. Livari and D. Te'eni, 2007, 'Why the old world cannot publish? Overcoming challenges in publishing high-impact IS research', *European Journal of Information Systems*, 16, 317-26

Mc Millan, F. S., F. Narin and D. Deeds, 2000, « An analysis of the critical role of public science in innovation : the case of biotechnology », *Research Policy*

MENESR, 2014, *Développement et impact du credit d'impôt recherché: 1983-2011*, Ministère de l'enseignement supérieur et de la recherché, Paris.

Miotti, L. and F. Sachwald, 2003, « Co-operative R&D: why and with whom ? : An integrated framework of analysis », Research Policy, 32, 1481–99

Moncada-Paterno-Castello, P. and P. Voigt, 2013, *The effect of innovative SMEs' growth to the structural renewal of the EU economy*, Policy Brief, Joint Research Center

Motohashi and Muramatsu, 2012, "Examining the university industry collaboration policy in Japan: Patent analysis", *Research Policy*

Narin, F., K. Hamilton, D. Olivastro, 1997, "The increasing linkage between U.S. technology and public science", *Research Policy*

Nishimura, J. and H. Okamuro, 2010, "R&D productivity and the organization of cluster policy: an empirical evaluation of the industrial cluster project in Japan", *Journal of Technology Transfer*,

National Science Board, 2014. *Science and Engineering Indicators 2014*, National Science Foundation

OECD, 2011, *Science, Technology and Industry Scoreboard.*

OECD, 2013, *Science, Technology and Industry Scoreboard.*

OECD, 2014, *Science, Technology and Industry Outlook 2014*

OECD, 2015, *Compendium of bibliometric* scientific *indicators 2014* (Chapter 1), Directorate for Science, Technology and Innovation, *March*

Polt, W., Rammer, C., Schartingner, D., Gassler, H., and Schibany, A., 2000, Benchmarking Industry-Science Relations in Europe – The role of Framework Conditions, Conference on: 'Benchmarking Europe's Industrial Competitiveness'

Raymond, W., J. Mairesse, J., P. Mohnen, and F. Palm, 2013, Dynamic models of R&D, innovation and productivity : Panel data evidence for Dutch and French manufacturing', UN University, Maastricht

Robin, S. and T. Schubert, 2013, 2013. "Cooperation with public research institutions and success in innovation: Evidence from France and Germany", *Research Policy*, vol. 42(1), pp. 149-166.

Rodriguez-Pose, A., 2014, Reconciling innovation, growth and cohesion in the periphery of the EU, RISE Background paper, EU Commission.

Sachwald, F., 2009, *Global networks of open innovation, national systems and public policies*, Ministère de l'Enseignement supérieur et de la recherche, Paris, http://cache.media.enseignementsup-recherche.gouv.fr/file/2009/68/5/Open-innovation-sachwald-2009_122685.pdf

Sachwald, F., 2013, The Development of *Global Innovation Networks*, Innovation for Growth–i4g Policy Brief N°22, https://ec.europa.eu/research/innovation-union/pdf/expert-groups/i4g-reports/i4g_policy_brief__22_-_development_global_innovation_networks.pdf

Simeth, M. and S. Lhuillery, 2015, "How do firms develop capabilities for scientific disclosure?", Research Policy, 44 : 1283-95

Stančík, J. and F. Biagi, 2012, Characterizing the evolution of the EU R&D intensity gap using data from top R&D performers, IPTS-JRC

Tijssen, R; Waltman, L.; van Eck, N. (2011): Collaborations span 1,553 kilometres, *Nature* 473, 154

Van Pottelsberghe, B., 2008. *Europe's R&D: missing the wrong targets?* Bruegel Policy Brief

Veugelers, R., 2011, Mind Europe's early-stage equity gap , Bruegel Policy contribution

Veugelers, R and M. Cincera, 2010, Young Leading Innovators and the EU's R&D intensity gap, Bruegel Policy Contribution

APPENDIX 1.

Correlation table: Innovation Union Scoreboard indicators, 2014

		1.1.1	1.1.2	1.1.3	1.2.1	1.2.2	1.2.3	1.3.1	1.3.2	2.1.1	2.1.2	2.2.1	2.2.2	2.2.3	2.3.1	2.3.2	2.3.3	2.3.4	3.1.1	3.1.2	3.1.3	3.2.1	3.2.2	3.2.3	3.2.4	3.2.5
1.1.1	New doctorate graduates per 000 hab	1,00																								
1.1.2	Population with completed tertiary education	0,25	1,00																							
1.1.3	Youth with upper secondary education	0,00	0,01	1,00																						
1.2.1	International scientific co-publications	0,60	0,70	-0,19	1,00																					
1.2.2	Most cited scientific publications (10%)	0,60	0,66	-0,27	0,92	1,00																				
1.2.3	Non EU doctorate students	0,43	0,65	-0,25	0,70	0,76	1,00																			
1.3.1	R&D expenditures in the public sector, % GDP	0,77	0,36	0,06	0,70	0,67	0,47	1,00																		
1.3.2	Venture capital investments	0,23	0,74	-0,24	0,64	0,63	0,58	0,46	1,00																	
2.1.1	Business R&D expenditures, % GDP	0,76	0,52	0,10	0,79	0,75	0,59	0,86	0,56	1,00																
2.1.2	Non R&D innovation expenditures	0,13	-0,22	0,16	-0,07	0,03	-0,29	0,32	-0,11	-0,01	1,00															
2.2.1	SMEs innovating in house	0,54	0,49	-0,31	0,82	0,90	0,61	0,53	0,44	0,66	0,06	1,00														
2.2.2	SMEs innovating in collaboration	0,60	0,54	0,08	0,87	0,81	0,52	0,71	0,48	0,83	0,04	0,74	1,00													
2.2.3	Public-private co-publications	0,73	0,54	-0,06	0,87	0,91	0,68	0,82	0,62	0,92	0,03	0,76	0,87	1,00												
2.3.1	PCT patent applications	0,78	0,53	-0,03	0,77	0,82	0,63	0,86	0,57	0,93	0,06	0,68	0,77	0,92	1,00											
2.3.2	PCT patent applications in societal challenges	0,78	0,49	-0,11	0,78	0,84	0,66	0,83	0,51	0,90	0,07	0,72	0,76	0,93	0,98	1,00										
2.3.3	Community trademarks	0,52	0,45	-0,26	0,75	0,75	0,59	0,55	0,37	0,65	-0,21	0,75	0,64	0,67	0,70	0,69	1,00									
2.3.4	Community designs	0,37	0,13	-0,25	0,59	0,54	0,32	0,56	0,39	0,55	0,07	0,65	0,50	0,54	0,54	0,52	0,73	1,00								
3.1.1	SMEs with product or process innovations	0,53	0,52	-0,24	0,79	0,83	0,62	0,54	0,48	0,65	0,15	0,90	0,75	0,69	0,64	0,65	0,68	0,58	1,00							
3.1.2	SMEs with organisation of marketing innovations	0,32	0,23	-0,30	0,44	0,44	0,33	0,19	0,13	0,26	0,05	0,68	0,39	0,29	0,28	0,31	0,32	0,43	0,64	1,00						
3.1.3	Emp. of fast growing firms of innovative sectors	0,59	0,72	0,01	0,66	0,69	0,62	0,53	0,58	0,74	-0,14	0,58	0,59	0,75	0,73	0,73	0,49	0,21	0,51	0,34	1,00					
3.2.1	Employment in knowledge intensive activities	0,53	0,75	0,00	0,80	0,84	0,63	0,54	0,62	0,77	-0,09	0,81	0,73	0,80	0,78	0,75	0,69	0,48	0,76	0,53	0,86	1,00				
3.2.2	Medium and high tech contribution to trade balance	0,23	-0,12	0,09	-0,12	0,07	0,22	0,27	0,05	0,33	0,05	0,03	0,06	0,24	0,39	0,38	0,04	0,07	0,08	0,04	0,30	0,19	1,00			
3.2.3	Knowlege intensive service exports	0,35	0,53	-0,11	0,44	0,44	0,24	0,11	0,36	0,25	0,04	0,55	0,34	0,32	0,19	0,19	0,18	0,10	0,49	0,61	0,58	0,58	-0,29	1,00		
3.2.4	Sales of new to market or firm innovation	0,22	-0,23	-0,29	-0,06	-0,01	-0,17	0,24	-0,17	0,04	0,28	0,00	0,02	0,05	0,12	0,12	-0,18	-0,11	-0,04	0,30	0,05	-0,09	0,27	0,07	1,00	
3.2.5	Licence and patent revenues from abroad	0,48	0,70	0,09	0,62	0,65	0,52	0,38	0,65	0,69	-0,29	0,50	0,55	0,72	0,68	0,64	0,47	0,20	0,47	0,13	0,84	0,84	0,23	0,43	-0,21	1,00
	Synthetic innovation index	0,73	0,64	-0,13	0,90	0,92	0,66	0,79	0,62	0,88	0,07	0,85	0,82	0,93	0,91	0,89	0,77	0,62	0,80	0,48	0,80	0,91	0,17	0,49	0,08	0,71

Spearman coefficient.

Legend: positive correlation above 0.50 in blue and correlation below 0.50 in pink to red.

Source: Calculations based on the data from the *Innovation Union Scoreboard 2014*

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Over the last 15 years, open innovation has become mainstream and both public and private actors from many countries are involved in global innovation networks. This paper argues that research and innovation policies in Europe have not fully adapted to the challenges and opportunities of this global context.

The paper reviews empirical evidence and concludes that the EU does not suffer from the so called "European paradox", but rather from twin deficits in excellent research and in innovation in new high growth sectors. Europe as a whole is good at producing research results, but those may be of insufficient quality to meet the needs of knowledge-based growth. In order to promote innovation, the policy mix should address Europe's twin deficits by strengthening both the production of high impact research and knowledge transformation.

To this end, updated evidence on a set of related stylised facts should be produced and integrated in national and EU policy making.

- In order to stimulate knowledge intensive growth, more R&D and innovation in existing sectors should be combined with the development of start-ups in new sectors.

- As part of open innovation processes, firms tend to prefer academic partners for exploration and new to market innovation. Hence, the amount and quality of academic research remains fundamental to the innovation performance of firms and countries.

- Excellent researchers or academic institutions are more likely to engage in knowledge transformation, either through contract research or through commercialisation. Moreover, firms that cooperate with high impact researchers tend to generate more innovation.

- The US has the world strongest science base for sectors related to information and communication technologies as well as in disciplines and sectors related to medicine and health. The transatlantic "excellence gap" thus appears wider in the scientific disciplines with high innovation and growth potential.

Studies and reports

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