Open Access to scientific information: facilitating knowledge transfer and technological innovation from the academic to the private sector

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October 2015

What is Open Access?

Open Access (OA) is the practice of making scientific information (peer-reviewed articles, conference proceedings, monographs, research data, theses, working papers, etc.) available online for free with a public copyright license that enables the use and exploitation of research outputs by researchers, public and private sector individuals, and the society at large. In the last decade, Open Access policies have been adopted by national governments, universities, research institutions and research funders with the objective to determine how access to scientific information must be provided. There are two main routes to make scientific information available on open access: self-archiving and open access publishing.

Self-archiving, commonly referred to as Green OA, designates the process through which authors publish their research findings in their preferred venue. Upon acceptance of the research output for publication, an electronic copy of the peer-reviewed output – and whenever possible the related research data – is deposited in an online repository (either an institutional or a subject repository) and made available on open access following the end of a determined embargo period.

Open access publishing, commonly referred to as Gold OA, designates that authors make scientific information such as peer-reviewed articles and monographs immediately available on open access. In the case of peer-reviewed articles, these may be published in pure open access journals or in hybrid journals. Publication in an open access form may be cost free but often authors are required to pay an Article Processing Charge (APC) to make research outputs immediately available online. In Europe, a few public and private research funders as well as universities provide specific funds to cover for APCs.

The benefits of Open Access to scientific information

National governments, universities, research institutions and research funder are growing increasingly aware of the importance of making scientific information available on Open Access. In Europe, more than 430 Open Access policies have been adopted and these have mainly been implemented by universities and research institutions. By and large, this results from institutional stakeholders and policymakers recognising the benefits of Open Access in:

- Making research **visible** and **accessible** to all;
- Advancing **academic research**;
- Fostering **knowledge and technology transfer** from the academic to the public, not-for-profit and private sectors;

- Enhancing the **innovative potential** of universities, research institutions and research-intensive organisations and companies;
- Enabling **new collaborations** and **interdisciplinary research**;
- Nurturing a **science-literate** and research-literate **society**; and
- Delivering increased **returns on investment in publicly funded research**.

Research funders, in similitude to universities and research institutions have also been paving the way towards promoting open access to scientific information. The most relevant example is the European Commission whose strategy towards Open Science seeks 'to make research more open, global, collaborative, creative and closer to society' by changing the way in which 'research is carried out, disseminated, deployed and transformed'[1] through the use of digital technologies, networks and the media (Figure 1). Open Science is a process which seeks to promote ways in which scientific information is shared more widely between academic communities and with the society in general. It involves the dissemination of scientific publications (peer-reviewed articles) and research data in open forms which make it more easily accessible and re-usable.

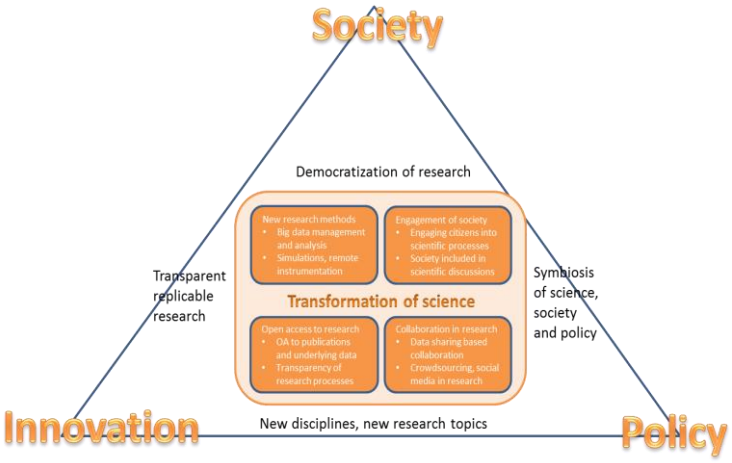

Figure 1: The European Commission's vision for Open Science

Accordingly, the EC considers that open access to scientific publications and research data leads to:

- 'Accelerat[ing] **innovation** (faster to market = faster growth);
- Foster[ing] **collaboration** and avoid[ing] duplication of effort (greater efficiency);
- Build[ing] on previous **research** results (improved quality of results);
- Involv[ing] **citizens and society** (improved transparency of the scientific process)'[2].

Overall, the advantages resultant from granting free access to scientific information have spillover effects in all sectors of society and play an important role in driving economic, social and technological progress.

'I am starting up a medical technology company. Open access to technical literature is extraordinarily useful to [non-academically] affiliated people'

1 Open Science, https://goo.gl/recyGk
2 Towards Better Access to Scientific Information: Boosting the Benefits of Public Investments in Research, http://goo.gl/JTmZ72

The role of Universities in transferring knowledge from the academic to the private sector

In the information age, knowledge and technology play a crucial role in advancing national economic growth. The advances made in digital information and communication technologies have also facilitated a greater **sharing of scientific information** inside and outside the academic sphere which have direct implications to national economies. In the last decades, the role of universities has extended beyond 'the traditional research and teaching mission'[3]. Universities contribution to the production, **transmission and dissemination of scientific knowledge** means that they are also perceived as economic agents[4]. The information revolution has also meant that academic researchers have wider access to information and possess a broader set of skills and expertise. Thus, researchers apply the knowledge acquired and the skills developed to investigate and generate new ideas that can result both in improving the quality and efficiency of products and processes but also in developing innovative solutions to address key societal challenges[5].

'The emerging era of science-based collaborations between academia and industry offers advantages to both entities and a means by which academic institutions and industry can address global challenges to their

The outputs resultant from publicly funded research are valuable to R&D performing companies, to companies with a strong technology base or with a strong innovation focus but also to non-research intensive companies. It has been observed that **research users from the private[6], public[7] and voluntary[8] sectors** can benefit from the research conducted in universities. For instance, by improving the quality of the products developed and services provided, by enabling the development of **new applications**, by experimenting with **new uses** for existing materials, by reducing **product development cycles**, or even by informing the development and adoption of new policies at the organisational or even governmental level. In 2011, a study on access to research and technical information in Danish knowledge-based SMEs showed that 'twenty-seven percent of the products and 19% of the processes developed or introduced during the last three years [2008-2011] would have been delayed or abandoned without access to academic research'. Ultimately, these '**new products contribute[d] to an average 46% of annual sales**'[9].

'I am a Ph.D. engineer at a U.S. telecommunications company. Having open access to research articles greatly enhances my ability to develop new products for the worldwide market'

Access to scientific information means that 'an increasing stock of useful knowledge'[10] becomes available to private sector companies (Figure 2). In some cases, private sector workers involved in industrial R&D activities '**employ science as a set of tools and stock knowledge** to be tapped in problem-solving'[11]. Accordingly, applied R&D starts with the need to address a particular problem or to achieve a particular objective and by applying scientific knowledge and research skills private sector workers are able to achieve a particular goal. In other cases, **new product ideas and process innovations** developed by private sector companies are a direct result from academic research. Overall, the transfer of knowledge from the academic to the private sector 'stimulates and enhances R&D performed by firms as well as expands the range of technologically exploitable opportunities'[12].

3 Indicators of University-Industry Knowledge Transfer Performance and their Implications for Universities: Evidence from the UK's HE-BCI Survey, p. 3, http://goo.gl/fYAo07
4 The Knowledge-Based Economy, http://goo.gl/vvYMB2
5 Europe's Societal Challenges: An Analysis of Global Societal Trends to 2030 and their Impact on the EU, http://goo.gl/Fp9kIm
6 Benefits to the Private Sector of Open Access to Higher Education and Scholarly Research, http://goo.gl/eqGHRD
7 Benefits of Open Access to Scholarly Research to the Public Sector, http://goo.gl/MfKJ8t
8 Benefits of Open Access to Scholarly Research for Voluntary and Charitable Sector Organisations, http://goo.gl/FoSGzl
9 Access to Research and Technical Information in Denmark, p. 8, http://goo.gl/n0cHbm
10 Access by UK Small and Medium-sized Enterprises to Professional and Academic Information, p. 5, http://goo.gl/5W2Lye
11 On the Sources and Significance of Inter-industry Differences in Technological Opportunities, p. 10, http://goo.gl/5TMdGR
12 The Benefits from Publicly Funded Research, p. 8, http://goo.gl/7N06lx

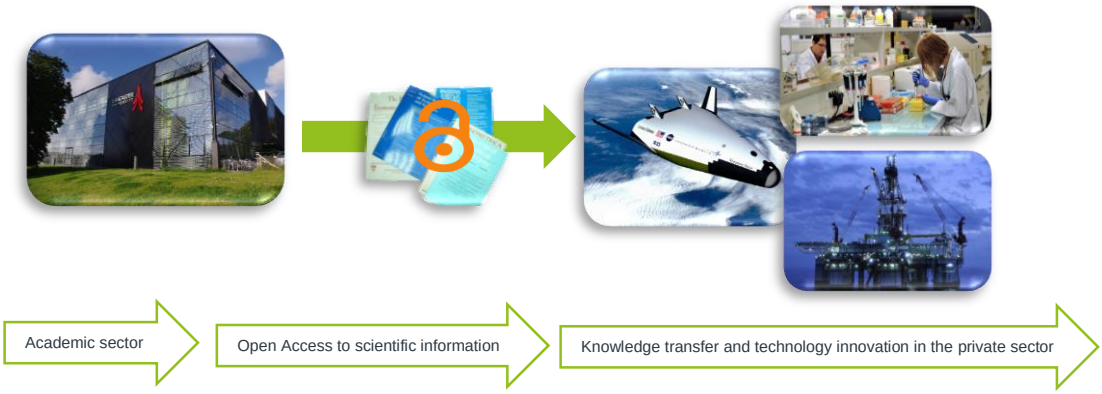

Figure 2: Open Access to scientific information enables a broader transfer of knowledge from the academic to the private sector and promotes technological innovation

How knowledge is transferred from the academic to the private sector

Knowledge can be transferred from the academic to the private sector through distinct routes[13]. The most common routes for knowledge and technology transfer include:

- **Publications** (e.g. scientific publications, co-publications);
- Participation in conferences, professional networks and boards;
- Mobility (e.g. temporary exchange/mobility of personnel from the public to the private sector);
- Informal contacts/networks (e.g. alumni groups);
- Cooperation in R&D (e.g. joint R&D projects, supervision of trainees or PhD students, financing PhD research);
- Sharing facilities (e.g. sharing laboratories or equipment, common work location);
- Cooperation in education (e.g. providing scholarships);
- Licensing (e.g. co-patenting, licenses of university-held patents);
- Entrepreneurships (e.g. spin-offs, start-ups, university incubators)[14].

Providing access to scientific publications can be an efficient mechanism to transfer knowledge from the academic to the private sector and it can subsequently foment technological innovation (Figure 3). Research has shown that access to grey literature and scientific publications[15] is relevant for Small and Medium-sized Enterprises (SMEs)[16].

13 Proximity and the Use of Public Science by Innovative European Firms, http://goo.gl/CgRVlV
14 The Different Channels of University-Industry Knowledge Transfer: Empirical Evidence from Biomedical Engineering, http://goo.gl/d2ay5m
15 Study on the Availability of UK Academic "Grey Literature" to UK SMEs: Report to the JISC Scholarly Communications Group, http://goo.gl/U1TYfB
Access by UK Small and Medium-sized Enterprises to Professional and Academic Information, http://goo.gl/dKQoBt
Access to Research and Technical Information in Denmark, http://goo.gl/0smE3N
16 SMEs represent the majority of European private sector companies and act as vehicles in the development of new ideas, competencies, products, strategies, innovations and technologies. For more information go to: http://goo.gl/l1lvlG

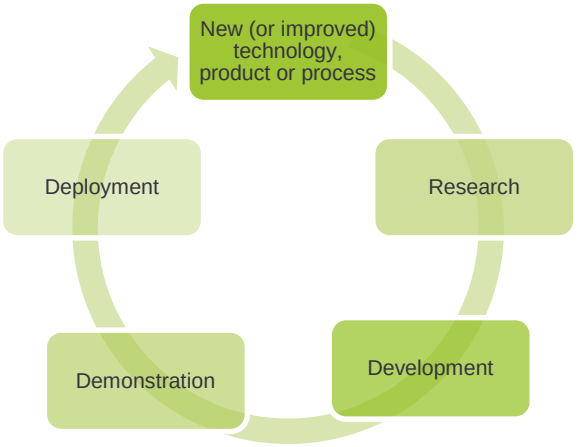

Figure 3: The technology innovation lifecycle[17].

In 1995, the PACE report on innovation strategies in European large manufacturing and industrial firms showed that for **58.4%** of the survey respondents the most important source for learning about public research were scientific publications[18]. A study on the access to scientific information by UK high technology SMEs showed that respondents considered journal articles and review papers in journals as the most important sources of information[19]. The study also showed that only 2% of respondents had excellent access to research articles, 26% had good access to articles, 56% experienced some difficulties in accessing articles, and 14% had poor access to articles (Table 1).

	SMEs (n=186)	Large companies (n=111)	University/College (n=470)
Excellent (I have access to all the journal articles I need)	2%	7%	17%
Good (I have access to most of the journal articles I need)	26%	39%	55%
Varies (I sometimes have difficulty getting the journal articles I need)	56%	37%	22%
Poor (I frequently have difficulty getting the journal articles I need)	14%	13%	4%
Very poor (I always have great difficulty getting the journal articles I need)	3%	3%	1%

Table 1 - Level of access to research articles. Source: Access by UK SMEs to Professional and Academic Information.

Similarly, a study on access to research information by Danish knowledge-based SMEs showed that research articles, scientific and technical standards, and product or process technical information were the most important types of information[20]. For 48% of respondents, research articles were a very or extremely important source of information. However, 55% of respondents considered that access to research articles is very, fairly or sometimes difficult.

These and other studies have identified what the major benefits in private sector companies accessing scientific publications are. The key highlights include:

17 Adapted from Sagar, A. (2013), Technological Innovation, http://goo.gl/iUc8Ff
18 Arundel, A., Van de Paal, G., Soete, L., 1995. PACE Report: Innovation Strategies of Europe's Largest Firms: Results of the PACE Survey for Information Sources, Public Research, Protection of Innovations, and Government Programmes. Final Report, MERIT, University of Limburg, Maastricht.
19 Access by UK Small and Medium-sized Enterprises to Professional and Academic Information, http://goo.gl/ML0on5
20 Access to Research and Technical Information in Denmark, http://goo.gl/YhkGE9

- **Cost** savings;
- **Time** savings;
- Better and speedier **product development**;
- Increased product **sales**;
- Better tools to support **problem solving**;
- More information to assist in **addressing customers' requirements**;
- Support in making better and **more informed business decisions**;
- Contribution to the development of **new business ideas** or to expand current areas of work;
- Improvements in **internal work practices**.

However, barriers to access scientific publications still prevail and significantly hinder the potential for further technological innovation to take place in the private sector. The main barriers include:

- **Access**: the majority of scientific publications are not openly available online and private sector workers often have to use diverse routes to access scientific information[21];
- **Costs**: the majority of research articles are not freely available online and the costs to pay per view are high. These costs act as the major barrier to access information;
- **Licenses**: publishers' licenses act as barriers on how the content of scientific publications can be re-used;
- **Relevance and value:** in several cases, uninformative and ambiguous abstracts make it difficult to guarantee the relevance of the article and readers purchase articles blindly;
- **Public or academic libraries:** access via public and academic libraries is often insignificant due to the inexistence of relevant resources in public libraries as well as due to the costs associated to obtain walk-in access to academic libraries;
- **Discoverability**: uncertainty about how to find specific articles online and how to search for scientific information online effectively;
- **Time**: considerable amount of time spent trying to find relevant literature on a particular topic online and subsequent time spent in trying to access free full-text versions of the most relevant literature.

'[I am] a disabled engineer researching gravity and inertia… My research is hampered by one thing alone, paywalls'

"I have a PhD in math, and have picked up on the theory of machine-learning, but have had a hard time finding source material on how these algorithms might be applied in the banking industry. The high cost of computer science journal articles has definitely been an obstacle in my research'

The way forward

In Europe, there are roughly **21 million SMEs** in the non-financial business economy[22]. Private sector European companies (including large companies and SMEs) that are R&D-intensive or that perform research-based activities tend to concentrate on the following **sectors of activity**: pharmaceuticals & biotechnology; software & computer services; electronic & electrical equipment; automobiles & parts; chemicals; technology hardware

21 For instance, by using colleagues personal subscriptions to professional bodies/associations that grant access to some scientific content; by requesting access to articles via associates or collaborators based in universities; by approaching the author to request the full-text version of the article; or by obtaining access to the article via the library where the worker previously worked/studied (access through this route is time limited).

22 Key Figures on European Business - with a Special Feature on SMEs, http://goo.gl/E55qzc

& equipment; and aerospace & defence[23]. Importantly, it is in the **academic disciplines** of science, technology, engineering, mathematics and medicine where the vast majority of peer-reviewed articles are published[24].

In late 2014, there were **28,100 active peer-reviewed English journals** that collectively published some **2.5 million articles annually**. In October 2015, the Directory of Open Access Journals[25] listed a total of **10,582 open access journals** (7,691 in English). It is now estimated that 12% of the total articles published annually are made available on open access (including publications on open access or hybrid journals and publications deposited in institutional and subject repositories)[26]. The academic disciplines where most peer-reviewed articles are available on open access include: medicine; biochemistry, genetics and molecular biology; mathematics; earth sciences; chemistry and chemical engineering; engineering; physics and astronomy; and social sciences[27].

These findings demonstrate that there is scope for academic scientific publications to be consulted and re-used by private sector stakeholders which can ultimately foment technology innovation. On the one hand, there are significant **commonalities** in the areas where academic research is conducted and the industries where the majority of R&D-intensive activities are performed. On the other hand, there is a relative number of peer-reviewed articles available on open access that the private sector may not be aware of merely due to difficulties in **discovering** these resources online. Nonetheless, the overwhelming majority of scientific publications are still inaccessible to the private sector as a result of **paywalls**. Such a fact negatively impacts on the possibility for societal, environmental and health challenges to be addressed.

As a result of the potential for knowledge transfer from the academic to the private sector to lead towards technology innovation and job creation as well as to address key societal challenges, European governments and research funders are becoming increasingly committed to ensure that **publicly funded research outputs become freely available online**. For instance, the European Commission aims to 'mak[e] publicly-funded scientific information available online, at no extra cost, to European researchers, innovative industries and citizens'[28]. The Commission supports the principle that a speedier and free access to scientific information brings significant returns on R&D investment 'which has enormous potential for boosting productivity, competitiveness and growth'[29]. In the absence of a swift access to the latest research, firms are taking more time to develop or introduce new products in the market. In the UK, the government reinstated its commitment to ensure that publicly funded research outputs are made freely available online in a report issued in 2014. In the government's view, open access to scientific information 'encourage[s] collaboration and enable[s] SMEs in particular to access more […] high quality research'[30]. As a result, SMEs become more innovative and productive and there are spillover effects for social well-being and economic growth.

Private sector companies have also expressed that open access to scientific publications is the way forward. For instance, **AppliSci**, a micro-SME that delivers services to pharmaceutical and healthcare companies, has illustrated that 'as a new start business we can't afford to pay for papers. With **open access resources**, this time-consuming and wasteful process is unnecessary'[31]. **Think Associates**, an HR consultancy, has illustrated how open access to scientific publications enables the company to **save costs** in pay per views and how 'access to full text versions of papers would enable […] to make a **more rapid and accurate assessment of a paper's value** and […] avoid wasting time in looking for free alternatives. […] this **saving** in opportunity cost would be in the region of **£5,000 per annum'**[32]. **SLR Consulting**, an international environmental consultancy, has illustrated that 'the major benefit of Open Access would come through **easier and more immediate access**

23 The 2014 EU Industrial R&D Investment Scoreboard, p. 49, http://goo.gl/KPJrU5
24 The STM Report: An Overview of Scientific and Scholarly Journal Publishing, http://goo.gl/hY8Z8c
25 Directory of Open Access Journals, https://doaj.org/
26 The STM Report: An Overview of Scientific and Scholarly Journal Publishing, p. 10, http://goo.gl/p9t0iU
27 Ibid, p. 34.
28 Guidelines on Open Access to Scientific Publications and Research Data in Horizon 2020, p. 4, http://goo.gl/P9pZq3
29 Towards Better Access to Scientific Information: Boosting the Benefits of Public Investments in Research, p. 3, http://goo.gl/PxtOCY
30 BIS Innovation Report 2014: Innovation, Research and Growth, https://goo.gl/12UG3v
31 Benefits to the Private Sector of Open Access to Higher Education and Scholarly Research, p. 20, http://goo.gl/V1tv6y
32 Ibid: 20

to the full content of papers, saving time and effort in working around payment barrier. Such **savings** could be significant […] around **£100,000 per annum**'[33].

Open Science success stories: Open Source Malaria Consortium

The **Open Source Malaria Consortium** is an international collaborative and open source project that 'uses a crowdsourcing model to accelerate drug discovery to fight deadly malaria, by sharing and discussing open data with scientists around the world, in real time'[34]. This project has benefited from contributions from researchers from across the globe and from a combination of synergies resultant from the transfer of knowledge between stakeholders in the academic, governmental and private sectors.

Open Science success stories: HIV Self-Test

The **HIV Self-Test** project focused on developing 'a strategy based on the synergy of the Internet, an oral fluid-based self-test and a cell phone'[35] to test whether patients have contracted HIV. The project resulted from a perceived global challenge in testing marginalised populations for HIV. By publishing the project's research outputs in Open Access journals, this information has contributed to enhance a speedier dissemination of the research findings, to inform a widespread 'uptake of new knowledge' and to improve patients' health. This project has benefited healthcare workers and policymakers worldwide and contributed to interactions with the private sector.

Steps towards widening the access to scientific information

Some of the practical steps that universities and the private sector can take to further advance open access to scientific information include:

Universities:

- **Access and discoverability**: provide information in the university's Open Access web pages that is targeted to the private sector and that explains what is open access, what are open access repositories, how the repositories can be found, what resources can be consulted in the repositories, and what academic disciplines they cover;
- **Advice and support**: establish a point of contact in the university for private sector stakeholders to contact with any queries on how to access scientific publications and the institutional repository;
- **Promotion of scientific information**: create a portfolio of research conducted in different academic disciplines in the university, highlight the value of such research is and what research outputs are available for private sector stakeholders to consult and re-use. The development of academic research portfolios can be done in collaboration between academic librarians and the universities' knowledge transfer centres or business/enterprise centres.

Private sector:

- **Engage**: explore routes to engage with and build trust with universities;

33 Ibid: 20
34 Accelerating Science Award Program: Accelerating Impact, p. 14-15, http://goo.gl/UvUVQr
35 Accelerating Science Award Program: Accelerating Impact, p. 16-17, http://goo.gl/UvUVQr

» **Share**: involve universities on the purposes for accessing scientific information and share examples on how open access to scientific publications and research data contribute to the company's work.

Initiatives to increase access to scientific information

In 2013, the **Accelerating Science Award Program (ASAP)**, recognised the importance of Open Access in stimulating economic, technological and social progress. The ASAP awards sought to raise 'awareness and encourage the use of scientific research – published through Open Access – in transformative ways'. It also sought to inspire and 'encourage a new generation of individuals to embrace the application of scientific research published through Open Access'[36]. The major sponsors of this initiative included Google, PLOS and the Wellcome Trust.

In 2015, **Open Science Prize** was announced as an initiative that will 'unleash the power of open content and data to advance biomedical research and its application for health benefit'. The Prize will grant funding to 'support the prototyping and development of services, tools or platforms that enable open content – including publications, datasets, codes and other research outputs – to be discovered, accessed and re-used in ways that will advance discovery and spark innovation'[37]. The Open Science Prize is an initiative of the Wellcome Trust, the National Institutes of Health, and the Howard Hughes Medical Institute.

Note: Quotes retrieved from 'Towards Better Access to Scientific Information: Boosting the Benefits of Public Investments in Research', http://goo.gl/JTmZ72

36 Accelerating Science Award Program, http://goo.gl/dYKkq4
37 Open Science Prize, https://goo.gl/dKMk2n