Advancing the open science movement through sustainable business model development

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Abstract:

The open science literature has focused on ways to increase the openness of research data at universities, while links with industry in the context of open innovation have received less attention. The aim of this paper is to increase understanding of how open science can lead to open innovation. The key research questions are: how can researchers be motivated to make open their research data and how can industry take advantage of the data? The authors explore this topic through a case study of a Finnish foundation and its closed database. In 14 semi-structured interviews with the database owners, potential users and open science experts, they identified opportunities, barriers and possible solutions to opening the database. The authors propose a generic process framework for developing sustainable business models to facilitate research data transfer from university to industry. The study contributes to the open science literature by shedding light on how the gap between open science and open innovation can be bridged through the development of sustainable business models.

Keywords:

Open innovation, open science, research data transfer, sustainable business models, university–industry collaboration

Open science can be defined as a movement to make scientific research, data and dissemination accessible to all levels of an inquiring society (FOSTER, 2016b). Despite many ongoing initiatives, such as the Open Research Data (ORD) Pilot and the European Data Infrastructure (EUDAT), the open science phenomenon is still at an early stage of development (McKiernan et al., 2016; Sadiku et al., 2016). Perceptions of data sharing differ from discipline to discipline, and researchers tend be cautious about it (Pampel and Dallmeier-Tiessen, 2014). There is a need for additional incentives and support for researchers to fuel the open science movement (Friesike et al., 2015).

Prior literature has underlined another major concern about recent open science initiatives – that they fail to assure the subsequent effective commercialization of scientific knowledge (Chesbrough, 2015). While open science and open innovation both focus on spreading and diffusing scientific knowledge to a wider community beyond organizational boundaries, the emphasis in open innovation is on the need for knowledge sharing to lead to the commercialization of that knowledge. This, in turn, requires the formulation and development of appropriate business models (Chesbrough, 2015).

Our aim in this paper is to shed light on these two aspects. The research questions are: how can researchers be motivated to make open their research data and how can industry take advantage of the data? We carried out an explorative case study with a Finnish foundation which owns a currently closed database. We investigated the underlying opportunities, barriers and possible solutions to opening the database, carrying out semi-structured interviews with the database owners, potential users and open science experts. As a key result of this investigation, we developed a generic framework to assist researchers in formulating sustainable business models based on the reuse of their

research data. The paper provides a step towards bridging the gap between open science and open innovation.

Literature review

In this section, we present key findings from the literature regarding the benefits of and barriers to research data sharing. We then describe existing models and initiatives to boost the open science movement and advance university–industry collaboration in knowledge sharing and transfer.

Benefits of open science

The scientific publishing landscape is being changed increasingly by governments and public institutes that require science to be open-access. This shift has been motivated by the belief that innovation is not best fuelled by patents, but rather by open science (Triggle and Triggle, 2017). Freely available scientific results before publication ensure early knowledge sharing and provide benefits for journals and publishers because papers receive citations at an earlier stage, increasing both the citation impact and the attractiveness of the journal (Friesike et al., 2015).

Viseur (2015) identifies several benefits for researchers in opening their own research data, arguing that open-access papers gain more citations and attention and the reproducibility of open research enhances the credibility of the researcher. By sharing experimental data, research results can be reproduced and may lead to new developments in the research field. The emergence of online communities and the semantic Web and linked data have brought additional benefits for researchers, accelerating the process of discovery and allowing rapid feedback on the research conducted. Researchers can also

use open research practices to gain media attention and find potential collaborators, as well as job and funding opportunities (McKiernan et al., 2016).

Cervantes and Meissner (2014) discuss the potential advantages for industry in collaborating with university researchers. In an environment of strong competition, collaboration offers companies the possibility to complement their own innovation activities, essentially applying an open innovation approach as their path to the market. The advantages, according to Minshall et al. (2007), of licensing university intellectual property (IP) lie in the low investment required, the potential for multiple revenue streams and the limited need to use complementary resources. While licensing university IP is one option, the creation of a spin-out firm brings the opportunity to capture a high proportion of the value generated. Cervantes and Meissner (2014) suggest that engaging in technology transfer has a positive effect on both the company's innovation capability and the scientific work, with patenting activity positively affecting the publication output and citation record of researchers.

Barriers to open science

In the current landscape, scientific knowledge and its application are still dominated by rather monopolistic and rent-seeking practices that limit public access to science (Triggle and Triggle, 2017). There is a lack of incentives for researchers to share and reuse their data (Giannoutakis and Tzovaras, 2017). While most researchers favour open-access journals, only a few actually publish in them (Friesike et al., 2015). Among the factors that negatively influence researchers' attitudes towards data sharing are the perceived career risks and the additional effort required to share the data (Kim and Adler, 2015; Kim and Zhang, 2015). Tenopir et al. (2011) note that researchers are also reluctant to

share their data due to concerns about legal issues, misuse and incompatible data types. It appears that researchers' perception of the available data repositories and guidelines for data sharing are that they are not compatible with the complexity of their data.

Cervantes and Meissner (2014) explain that weak commercialization of research can be the result of various bottlenecks. They argue that information on university inventions is not adequately available to potential users. Concerns about risk and an unwillingness to engage with university inventions on the part of potential industrial partners are compounded by the unclear ownership of inventions and by the distinct missions of firms and universities, which lead to misaligned incentives and coordination problems. According to Minshall et al. (2007), the disadvantages in licensing university IP relate to the need for companies to manage multiple licences and the limited engagement with actual value creation. For the university, there is the possibility that, by encouraging the creation of spin-outs based on academic IP, it will engage in high-risk activities and may lose 'star' researchers, weakening its scientific output. These considerations can result in an unwillingness in universities to support the opening of datasets.

Fostering open science and university–industry collaboration for open innovation

Prior research has suggested using a virtual research environment (VRE) to foster the transfer of research data from university to industry and its exploitation to generate new datasets, information and knowledge. A VRE acts as an online system, enabling collaborative research activities beyond geographical borders and providing researchers with tools to manage complex tasks (Grayling, 2009; Candela et al., 2013; Zuiderwijk et

al., 2016). The online system should have integrated tools for searching, accessing, integrating data and fostering collaboration among researchers (Zuiderwijk et al., 2016). We propose several key requirements for this kind of VRE: data storage, data accessing, data computational services, data curation and data cataloguing. These facilities would enable the VRE to provide researchers and industrial stakeholders with integrated open data from different domains and to offer open government data in combination with open research data. An example of such a VRE model is the European Cloud Initiative, which aims to boost Europe's data-driven innovations and competitiveness by providing a world-class virtual environment for researchers and science and technology professionals to store and manage their data (European Commission, 2017).

Another approach is the use of boundary organizations. According to Perkmann and Schildt (2015), boundary organizations can be deployed effectively to facilitate open data collaboration between industry and academia. The authors highlight a case study of such an organization in the Structural Genomics Consortium (SGC), which practised an open data approach and encouraged innovators to build on the work of others through a common databank. The SGC enables pharma industry partners to disclose their research problems to an audience of innovators from academia by shaping the organization's research programme. Each pharma company compiles a wish-list of proteins they want resolved by scientists. These lists are combined and anonymized into a master list that is submitted for approval to a Board of Directors from the sponsoring organizations and a scientific committee. Confidentiality is a key requirement for the companies as they want to avoid their R&D priorities becoming public knowledge. In addition to appealing to firms, the SGC also pursues strategies to attract and motivate participating scientists.

First, it promotes the opportunity to work on previously uncharacterized proteins in a state-of-the-art programme. Second, it encourages researchers to engage in follow-on research, beyond the proteins master list, to pursue their scientific curiosity, leading to more demanding research and higher scientific impact. This freedom allows scientists to publish high-impact articles and facilitates the career progression of participants. The SGC also adopts academic practices by distributing funding to universities so they can employ the researchers on academic terms.

The European Commission (EC) has many ongoing initiatives to strengthen the open science movement. These include the Open Research Data Pilot (ORD), OpenAIRE, European Data Infrastructure (EUDAT) and European Open Science Cloud (EOSC). ORD aims to improve access to and the reuse of research data generated by Horizon 2020 research projects (OpenAIRE, 2017). Furthermore, the EC has set up OpenAIRE as a key infrastructure for monitoring H2020 outputs. EUDAT and EOSC support the accelerated reuse of scientific data by making research data openly available and providing the necessary computing infrastructure (Giannoutakis and Tzovaras, 2017). Furthermore, the EC believes that, by increasing the transparency of evidence-based policymaking, open science can strengthen the link between science and society while allowing service providers to curate the data for interested users (Ramjoué, 2015). The aim of EUDAT is to make it possible to move, share and reuse big data seamlessly across markets and borders to foster open innovation. There are also many Europe-wide projects, such as Fostering the practical implementation of Open Science in Horizon 2020 and beyond (FOSTER Plus), Fostering improved training tools for responsible research and innovation (FIT4RRI), Responsible research and innovation tools (RRI Tools) and

Science2Society, that provide practical support for European stakeholders to adopt open science principles and practices. Table 1 provides a summary of key ongoing open science initiatives and projects at the European level. The list is not exhaustive and it excludes numerous national and institute-level initiatives taking place around Europe and elsewhere.

Table 1. Key ongoing open science initiatives

Name of initiative/ project	Main content	Key objectives
Open Research Data Pilot (OpenAIRE, 2017)	Obligation for Horizon 2020 projects to prepare a data management plan and to publish research data (e.g. related to open access papers) in a data repository.	To improve and maximize access to and re-use of research data generated by Horizon 2020 projects.
OpenAIRE (OpenAire, 2018)	European research and innovation project (2015–2019), assists in monitoring H2020 research outputs and provides a key infrastructure for reporting H2020's scientific publications.	To promote open scholarship and substantially improve the discoverability and reusability of research publications and data.
European Data Infrastructure (EUDAT), (EUDAT, 2017)	This initiative was launched to target a pan-European solution to the challenge of data proliferation in Europe's scientific and research communities.	To design, develop, implement and offer 'Common Data Services' to all interested researchers and research communities characterized by a high degree of openness.
European Open Science Cloud (EOSC), (European Commission, 2017)	The initiative reinforces open science, open innovation and open to the world policies. It is based on the EUDAT initiative.	Aims to create a trusted environment for hosting and processing research data to support EU science in its global leading role.
FOSTER Plus (Foster	H2020 project (2017–2019),	To contribute to a real and

2016a)	creates training material, delivers training and consolidates open science trainers network.	lasting shift in the behaviour of European researchers to ensure that open science becomes the norm.
FIT4RRI: Fostering improved training tools for responsible research and innovation (RRI), (FIT4RRI, 2018)	H2020 project (2017–2020), analyses general trends, barriers and drivers to RRI and OS, observes RRI/OS in action through 4 co-creation experiments and promotes changes and develops training tools and guidelines.	Enhancing competencies and skills in RRI and open science, and supporting research funding and performing organizations (RFPOs) to employ them.
RRI Tools (RRI Tools, 2016)	7th Framework Programme (FP7) project (2014–2016) that gathered a wealth of online resources for the RRI Toolkit and trained stakeholders to use it.	To support stakeholders across Europe to put responsible research and innovation into practice.
Science2Society (Science2Society, 2018)	H2020 project (2016–2018), creates pilots and shares good practices, guidelines and training materials that improve awareness and practical performance in seven concrete university–industry–society interfacing schemes especially affected by Science 2.0 and open innovation.	To improve the efficiency of the European innovation system and the ways it creates new businesses, turns technology into products and services, attracts financing and generally creates value from academic research.

While the potential benefits of open data have led to many initiatives and models in Europe and elsewhere, the motivations for researchers to share their research data have rarely been addressed. Furthermore, the link between open science and open innovation is lacking in most open science initiatives. Our case study is part of the H2020 research project Science2Society, and forms one of its seven co-creation schemes. Our work aims

to reveal ways of motivating researchers to share their research data and of fostering the link between open science and open innovation.

Research methods

Our research adopts a case study approach (Eisenhardt, 1989) in order to explore the motivational factors that may lead researchers to share their research data, as these have not been fully addressed in prior studies. Our criterion for the selection of the case was that it needed to provide a means of identifying the real challenges of opening a database and ways of overcoming those challenges. We found that a Finnish foundation with a closed database fulfilled this criterion and that it was readily available for us to study. We therefore selected this organization as our case. The foundation's database contains over 20,000 applications for invention funding, as well as the characteristics and progress reports of the funded applications.

We first developed three distinct interview questionnaires: one for database owners, one for potential users of the database and one for open science experts. The questionnaires focused on the opportunities, barriers and alternative business models related to opening the currently closed database of the foundation. We invited all six Board Members of the foundation to the interviews. The Chairman and one Board Member, who were most familiar with the database, accepted the invitation. We also invited an old employee as an expert on the database, having worked with it for over 15 years, to identify the opportunities and constraints involved in opening it. We invited potential external users for interview, based on the convenience sample – the first author knew them as they were doing related research to clarify their interest in and needs for database. These potential users were professors or researchers in the field of innovation

and entrepreneurship. Furthermore, we invited experts in open science for interview so that they could give their views on possible barriers to opening the database and ways to overcome them.

In all, we conducted 11 interviews in March–April 2017 and three follow-up ones in May–June 2017. The interviews, which lasted between 30 and 60 minutes, were conducted face-to-face when convenient, and otherwise by phone. Interviewees received a memo of the interview notes, which they were able to verify and to which they could add further information. Table 2 presents a list of the interviews conducted.

Table 2. List of interviews

Title of interviewee	Organization	Interview date
Chairman of the Board	Foundation	23 March and 11 May 2017
Board member	Foundation	20 March 2017
Vice Executive Director	Tekes (Foundation until 2013)	4 April 2017
Associate Professor	Aalto University	23 March 2017
Research Scientist	VTT Technical Research Center	5 April 2017
Assistant Professor	Hanken School of Economics	21 March 2017
Postdoctoral Researcher	University of Jyväskylä	27 March 2017
Legal Counsel	Aalto University	4 April 2017
Grant Writer	Aalto University	5 April and 9 June 2017
Specialist	Aalto University	6 April and 19 June 2017
Senior Statistician	Statistics Finland	4 April 2017

We also collected secondary research data on the foundation from public sources to understand its current operations and resources, and we examined relevant internal

documents to build an appreciation of the full functionality of the database. With different data sources and through triangulation, we could increase the validity of our results (Yin, 2009).

We recorded all interviews and prepared interview notes. As mentioned above, the notes were sent to the interviewees so that they could verify that we had understood their views correctly to avoid interpretation bias. Following an analysis of the interviews, we developed a proposal that incorporated all the stakeholders' views regarding the opportunities and barriers and the possible solutions for opening the database. We asked for feedback on the proposal from the database owner (the Chairman of the Board in the foundation) and two open science experts. Based on additional feedback, we selected two of the solutions as sustainable business models, as they could bring value to both data owners and potential users.

Key findings from the case study

Motivation for opening the database

The owners see the database as a means of offering unique and valuable information for researchers in entrepreneurship and innovation. The information on Finnish inventions has been collected over 20 years and provides a basis for researchers to examine, for example, factors underlying the success of inventions. For policymakers, the database may help in the refining of innovation policies. For industrial firms, it could enable them to identify any inventions related to their own and to search for potential partners. The database also enables the foundation itself to collect conditional pay-back reimbursements.

The primary motivation for the database owners to share the data is the opportunity to share costs associated with the database maintenance. Another motivation is societal – to support the development of understanding on how best to promote invention activity that triggers innovation.

The barriers to data sharing were identified as confidentiality issues and technical matters.

End user needs for the database

Our interviews with potential users in the field of entrepreneurship and innovation revealed initial interest in the database. Potential users value the database because it is comprehensive, unique and large. The real research value would come from linking it with other datasets, such as those complied by Statistics Finland, with a view to understanding the connections between individuals and companies. The willingness to pay for the database depends on how well the data suit the researchers' specific research questions and objectives, and the ease of using it to collect the data needed. Typically, in commercial databases a member of staff is tasked with the administration, whom researchers can contact for guidance and further information. The data are anonymous to the researcher, and the administrator handles the confidential raw data. Our interviews revealed that when the key conditions were met – specifically, relevance to the user's research questions, ease-of-use and the availability of administrator support – researchers would be willing to pay for access, but they would be less interested if only the first criterion were fulfilled.

Alternative solutions for data sharing

Based on the interviews, we identified three distinct user groups for the database: (a) researchers and (b) policymakers in the field of innovation and entrepreneurship, and (c) entrepreneurial actors associated with a company or self-employed. The exploitation of the database offers different opportunities to these three groups. The researchers might wish to examine such questions as 'What determines the success of inventions?' or 'How does the geography of inventions evolve and why?', and to develop publications based on their findings. Policymakers may want to look at the impact of policy changes on the type and rate of inventions, and, in light of their findings, to refine current innovation policies. Entrepreneurs could exploit the database by investigating whether similar ideas to their own had been developed before and, if so, in what way. They would thus be able to enhance their own ideas. They might also look for information on who had developed inventions in similar areas to their own, and so to identify potential partners.

There are significant barriers (legal, intellectual property rights (IPR)-related and technical) to opening the foundation's database to external users. First, the database contains confidential information about individuals and companies. Second, technical barriers arise from the fact that the database was developed for internal purposes, and there are no proper guidelines, classification of the contents or separate copies of it, all of which are necessary requirements for the purposes of external use. These barriers lower the motivation of the foundation to share its database with external users, as there is a risk that the users would not treat confidential information confidentially and could accidentally destroy the database, as it is not possible to assign different usage rights to different user groups. Thus, the data owners emphasize that the database is available only

for research purposes and to researchers who sign a non-disclosure agreement (NDA) before using it.

Based on the interview results, we developed alternative solutions for overcoming these barriers. The first option is to give access rights to selected researchers who sign an NDA to use the database for research purposes (either for free or on payment of a fee). The second option is to develop a passive database with a separate copy holding anonymized data and restricted content. The third option is to transfer (sell or give) the database to an external stakeholder such as Statistics Finland or the National Archive. Figure 1 illustrates our findings from the interviews regarding the opportunities offered by the innovation database, the barriers to opening it to external users and alternative solutions.

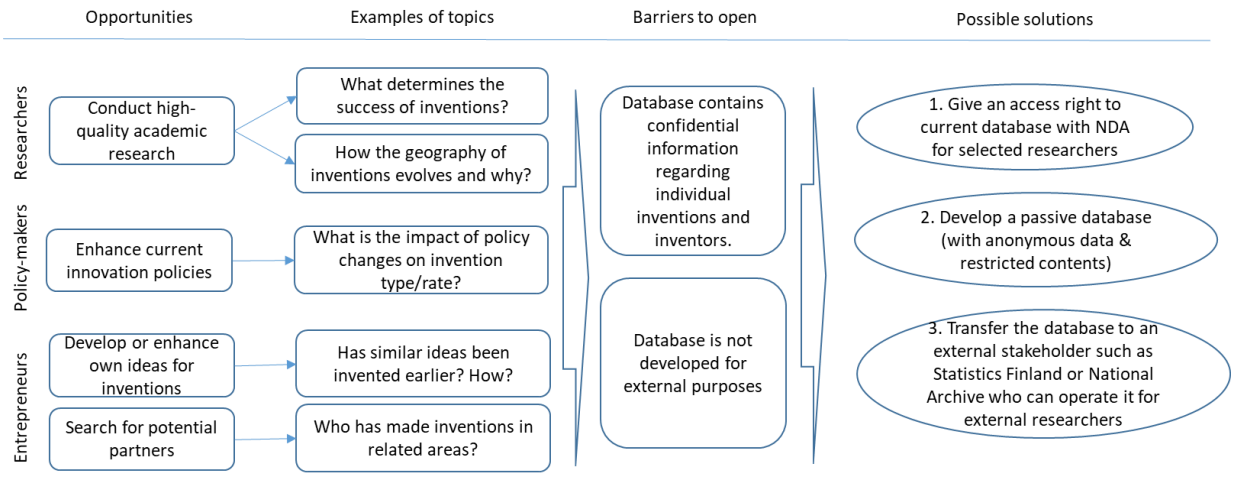

Figure 1. Opportunities, barriers and alternative solutions for opening the innovation database.

Feedback from stakeholders on the alternative solutions

When we presented these possible solutions to the database owners and open science experts, they regarded only the first and third as being viable. The first could work as an

intermediate solution for the foundation as long as it has need of the database itself. Giving access rights to selected researchers with an NDA would provide support by enabling the foundation to share some of the database costs and would mean that it could develop a better understanding of the real value of the database for researchers and other stakeholders. Our second solution, the development of a passive database, was not of interest to the foundation, as it would be expensive to implement the required functionality. The solution was also not interesting to possible users, as they would need in-depth information at least provided by the database administrator to make useful connections and associations at the individual level. Our third solution, to sell or give the database to an external provider to administrate, was regarded as viable. In our interviews, two of the researchers saw this as a good solution and said they would be willing to pay for access when they had relevant research projects. If this option were adopted, the new owner of the database would act as an administrator, taking care of the confidentiality issues in accordance with high-quality standards. The owner of the foundation was also positive about this solution, and considered that they could transfer the database to a third party that would treat the information with confidentiality when the foundation itself no longer had a need for it.

Generic framework for sustainable business models

Based on the case study, we developed a generic process framework to help researchers develop sustainable business models for opening their research. The first step in the process is opportunity identification. This is a crucial step that ultimately determines whether the benefits of opening a research database would outweigh the effort and cost in doing so. If there are clear potential benefits for researchers, these will provide the key

motivation to share their research data. It is important, first, to understand who will be the potential users (academia, industry, government) of the database and what opportunities there are for them in database usage. Second, one needs to clarify the specific requirements of potential users and their willingness to pay for the access. Finally, an estimate is needed of the potential user base in order to gauge the market potential.

Once the opportunities and user requirements have been identified, it is important to investigate whether there are any legal, IPR-related or technical barriers that might constrain the sharing of the research data. These barriers may determine who can obtain permission to use the database and whether all content can be shared or only a restricted data set (e.g. anonymized data). Technical adaptation and the development of new functionality may be required to overcome the constraints of sharing research data with external users.

The final stage is the formulation of the business model. To be sustainable, the business model must provide benefits to both the data owner and the users. First, it is important to develop a value proposition that provides clear value for the external user and to specify the target user and the offering. The second issue is pricing – whether users need to pay for access and, if so, how and how much, or whether access is granted free of charge based on academic merit or propensity towards scientific collaboration. It is then important to test the business model developed with a few potential users to verify that it is sustainable and to adjust it if necessary. Finally, it is essential to consider the resources and processes that will be required to open and manage the database (these relate, for instance, to the decision on the data repository, the metadata catalogue and the licence). Maintenance will necessitate resources and processes to accept new user

requests, respond to user questions, etc. Figure 2 illustrates our generic process framework for developing sustainable business models.

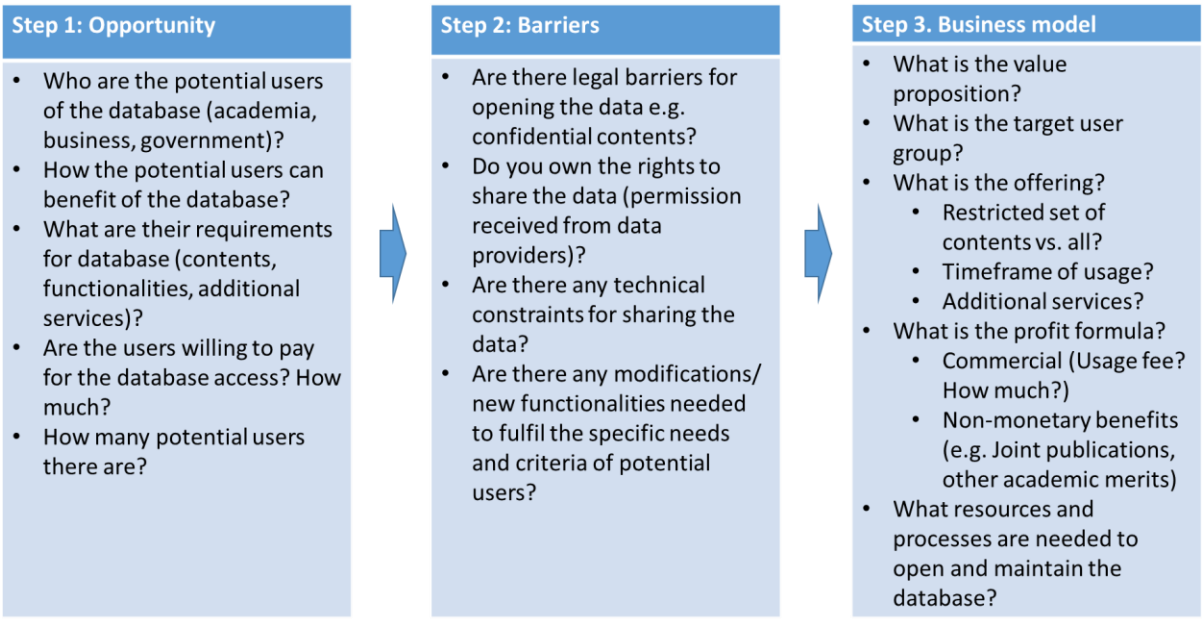

Figure 2. Framework for developing sustainable business models.

Conclusions

While the potential of open research data has pushed initiatives and models on a European level and elsewhere (e.g. OpenAIRE, 2017), the open science movement is still in its infancy (McKiernan et al., 2016; Sadiku et al., 2016). One reason for this is that scientists' personal motivations, the factors that drive their data-sharing behaviour, have not been adequately addressed (Giannoutakis and Tzovaras, 2017). The reluctance to open research data stems from the unknown returns and worries about data sharing (Tenopir et al., 2011). Although organizations that provide research funds have been pushing for research data sharing, there need to be additional incentives to encourage researchers to support the open science movement (Friesike et al., 2014; Giannoutakis

and Tzovaras, 2017). Our approach departs from other open science initiatives in that we suggest shifting attention from a pure open research data obligation to the recognition of underlying opportunities and the development of business models to capture them. This is an essential enabler for open science to lead to open innovation.

The paper contributes to the advancement of the open science movement and the literature with its increased focus on the underlying opportunities of open research data and their realization through sustainable business model development. When there are clear potential benefits for the data owner, they are motivated to share the data. Similarly, there needs to be clear value for external users so that they are motivated to exploit open research data. Only then will it be possible develop sustainable business models. We offer a generic framework for the development of such models and thus provide an additional step to bridge the gap between open science and open innovation highlighted in the literature.

Prior literature has identified virtual research environments and boundary organizations as key enablers of university–industry collaboration for research data sharing and commercialization (Grayling, 2009; Candela et al., 2013; Perkmann and Schildt, 2015; Zuiderwijk et al., 2016). Both these enablers allow scientists to share their data with stakeholders from academia, government and industry, to integrate datasets and to make new scientific discoveries, potentially leading to open innovation in the form of commercialized new products and services. Communities and ecosystems in specific fields provide the means for university researchers to implement sustainable business models by connecting them with potential users in research institutes and industry.

A major limitation of our study is the focus on only one case, which is related to the field of entrepreneurship and innovation. Prior research has emphasized that data sharing differs from discipline to discipline (Pampel and Dallmeier-Tiessen, 2014). We have mitigated this concern by covering additional cases in the interviews with open science experts and researchers. We also used existing literature on open data strategies and business models to complement our framework with information on additional studies and cases in other contexts. For future research, we recommend testing the validity of our framework and possibly identifying additional issues in other contexts. It will also be important for practice to demonstrate successful cases of opening research data that have led to open innovation in different research fields. This will serve as a model for researchers and will encourage them to share their research data.

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