Impact of Scientific Research beyond Academia: An Alternative Classification Schema

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Abstract

The actual or anticipated impact of research projects can be documented in scientific publications and project reports. While project reports are available at varying level of accessibility, they might be rarely used or shared outside of academia. Moreover, a connection between outcomes of actual research project and potential secondary use might not be explicated in a project report. This paper outlines two methods for classifying and extracting the impact of publicly funded research projects. The first method is concerned with identifying impact categories and assigning these categories to research projects and their reports by extension by using subject matter experts; not considering the content of research reports. This process resulted in a classification schema that we describe in this paper. With the second method which is still work in progress, impact categories are extracted from the actual text data.

Keywords: research reports, impact assessment, impact categories, corpus analysis

1. Introduction

The disciplinary field and activity of "impact assessment" (IA) are concerned with identifying, estimating, or understanding the consequences of infrastructures, objects, actions, and information on individuals, groups, or society (Latane, 1981). One application domain of IA is scientific research. Research results are mostly available as scientific textual products, e.g., research publications and project reports. It might be challenging for academic institutions, funding organizations[1], and other stakeholders of academic research to reliably identify methods or outcomes mentioned in project reports that have led to additional benefits of the work beyond the project, especially outside of academia. In other words, while academic impact is often achieved through publications and presentations by the researchers who did the work, the impact of research on society might be less obvious and hard to measure. Doing so matters though as the transfer of academic knowledge becomes increasingly important to researchers, funders, and society.

Due to a lack of standardized structure and language use in written descriptions of research projects and results across disciplines, studying and analyzing the impact or impact opportunities of research outcomes requires human domain experts and/or advanced technical solutions to go through the texts and extract the relevant information. For humans, this task is expensive in terms of time and expertise, and automated solutions are yet to be developed. Additionally, manual evaluation is limited by the large and growing number of research papers. As research papers are heterogeneous linguistic products, analyzing them semantically or developing automatic procedures to impact measurement or prediction are challenging and complex tasks.

To address these limitations, in our joint collaborative project TextTransfer[2], we aim to evaluate the impact of publicly funded research projects beyond academia by using an interdisciplinary, mixed-methods approach. The impact evaluation in this project is based on final reports that are collected by the German National Library of Science and Technology (TIB)[3] upon projects completion.

In this paper, we propose a new methodology for capturing and classifying non-academic impact of research projects by combining subject matter expertise with computational techniques (natural language processing, machine learning). We use two methods to identify the impact of research projects: First, we identify external (to the project reports) and objective indicators of impact. Second, we analyze project reports for mentions or indicators of impact. We will compare the results from both methods to better understand the types and magnitude of impact of projects along various dimensions (e.g., monetary versus non-monetary, sociopolitical vs. non-sociopolitical, etc.).

The rest of the paper is organized as follows: in the second section, we synthesize the theoretical foundations of impact studies. In the third section, we explain our two approaches for defining and extracting impact (external versus text-based). In section four, we mention our

[1] Some funding organization have an explicit mission to develop methods for increasing impact and transferring research results.

[2] http://www1.ids-mannheim.de/direktion/fi/projekte/texttransfer.html

[3] https://www.tib.eu/de/

preliminary outcomes and next steps. Finally, section 5 outlines potential future uses for the project final outcomes.

2. Theory and background on impact

Impact assessment (IA) has been studied and practiced for several decades in various disciplines and application domains, e.g., environmental studies (D. R. Becker, Harris, McLaughlin, & Nielsen, 2003; H. A. Becker, 2001; Vanclay, 2003), psychology (Latane, 1981), and media studies (Nisbet & Aufderheide, 2009; Whiteman, 2004). Across fields, the benefits of IA include facilitating decision-making processes, and minimizing risks while maximizing returns of investments.

The goals with IA are typically to broadly identify and precisely understand a project's future consequences. Gaining a clear and comprehensive understanding of a project is a precondition to be able to achieve these goals. Such an understanding is also key to designing methods for tackling anticipated problems or troubleshooting emerging issues. To gain such an understanding, after proposing a plan or project, scientists consult with domain experts, collect data, and study similar prior projects. As part of theses processes, assessors aim to get familiar with the domain-specific, local, and regional settings, norms, and regulations. Methods for gaining a localized and contextualized understanding of a situation include surveys and interviews. The resulting findings can then inform the planning of proper actions or adjusting plans. In the following sub-sections, we briefly discuss approaches to IA in the fields of environmental studies, information science, and library science.

2.1 Environmental Studies

Vanclay defines "social impact assessment" (SIA) as the study and analysis of the consequences of a planned or unplanned event, the steps that practitioners take to assess the impact of an event, and the development of strategies for monitoring and managing those impacts (Vanclay, 2003). After identifying probable impacts on humans, the economy, or the environment, a plan will be designed and shared with the public. That plan might then be changed due to suggestions and feedback. The updated plan will be delivered to participating organizations. Post-project monitoring may also be conducted (H. A. Becker, 2001; Vanclay, 2006).

SIA was first introduced in the National Environment Policy Act (NEPA) around 1960. Later, scientists formed a committee for "Social Impact Assessment" in order to meet the requirements defined in NEPA for private sector organizations ("Guidelines and principles for social impact assessment," 1995).

The IA approach presented for our study differs from SIA as we conduct assessment ex post facto to identify indicators for or correlations of text-based or project-based features, respectively, with secondary and subsequent (typically after project completion) outcomes of research projects. In the long run, academic research practices could adopt lessons learned from SIA to proactively anticipate lateral or subsequent consequences of their work on society. In fact, some funding agencies require grant applicants to specify the "broader impacts" of their work. For example, the National Science Foundation of the U.S. defines broader impacts as "the potential of the proposed activity - beyond the research, *per se* - to benefit the Nation", which may include promoting education, broadening the "participation of underrepresented groups", enhancing "infrastructure for research and education", advance "scientific and technological understanding", and benefits to society ("Broader impacts review criterion," n.d.).

2.2 Information Science

As IA in environmental studies aims to anticipate potential effects of future actions, IA of media and information focuses on the influence of information on people and society. This perspective has gained attention in recent years as funders and producers aim to measure the impact of information products on people (Diesner, Kim, & Pak, 2014; Diesner & Rezapour, 2015; John & James, 2011; Karlin & Johnson, 2011). A primary goal of information products, producers, and funders is often to raise awareness about issues in the general public (Clark & Abrash, 2011). Data collection and analysis approaches in this area can entail mixed-data and mixed-methods studies, for example, they may combine 1) qualitative analysis of interviews with 2) quantitative analyses of surveys or web metrics.

Impact of information can be divided into influence on the macro, meso, and micro level as explained next.

Macro-level impact refers to changes on the societal level, e.g., legislative and policy changes that result in raised awareness ("Impact glossary," n.d.). Impact of user-generated (e.g., social media) or professionally-generated (e.g., mainstream media) information on society may also entail changes in discourse and culture.

Meso-level impact refers to changes on the corporate and institutional level (Chattoo, 2014; "Impact glossary," n.d.), and can also include change in the structure of communities or the formation of new communities (Chattoo, 2014).

Micro-level impact refers to influence on individual people, such as 1) changes in awareness, 2) affecting behavior, cognition, and emotions, and 3) motivating civic engagement (Barrett & Leddy, 2008; Chattoo, 2014; Clark & Abrash, 2011; Karlin & Johnson, 2011). The aggregate of these effects can also result in the aforementioned higher-level types of impact. Based on surveys, closed group interviews, and data mining techniques, it was found that individuals indicated change in behavior and knowledge associated with watching films (Blakley, Huang, Nahm, & Shin, n.d.; Schiffrin, 2014; Schiffrin & Zuckerman, 2015). Rezapour and Diesner (2017) studied the impact of information products on individuals by analyzing film reviews and identifying and measuring different types of micro-level impact, such as changes versus reaffirmation in personal behavior, cognition, and emotions.

Relating these insights to measuring the impact of research reports, we acknowledge that research outcomes may intend to or potentially have an impact on all of these levels (macro, meso, micro).

2.3 Library Science

IA in the field of library science focuses on designing and creating efficient systems to meet the needs of customers and enhancing customer experience. Additional goals include increasing the influence of libraries, e.g., via outreach activities. To assess library services and systems based on this conceptualization of impact, one needs to 1) understand library or information users and their needs, and 2) employ a combination of qualitative and quantitative research methods (Connaway & Radford, 2016).

In the areas of bibliometrics and scientometrics, the impact of scholarly work on the scientific community has traditionally been measured by considering citation counts, and calculating metrics over these counts, such as the h-index (Bornmann & Daniel, 2005; Hirsch, 2005). More recent efforts, such as the altmetrics movement, also consider the impact on research beyond academic, e.g., by analyzing mentions of research on social and traditional media, or tracking the sharing and reuse of resources and data (Piwowar, 2013; Priem, Taraborelli, Groth, & Neylon, 2010).

The project described in this paper builds upon prior insights from various disciplines as outlined above, and expands alternative ways to study the impact of scholarly work. Our work is based on the assumption that regardless of the type and application domain of impact, information products can affect people, communities or society in a direct or indirect manner. We acknowledge that while the findings from research projects, especially from basic research, may not directly influence people's daily lives, they can lead to fundamental changes and restructurings of different aspects of society in the long run. Making this transition may require transfer from fundamental research to applications, moving from illustrative applications and limited samples to findings of general applicability and scalable performance, etc. Our project aims at identifying text-based indicators for or correlations with such subsequent outcomes.

3. Impact of research projects beyond academia

As mentioned before, the TextTransfer project is concerned with evaluating the impact of research projects based on their final reports. These reports are collected by the TIB after project completion. We do not study the academic impact of these reports or projects, but their impact beyond academia.

Our text corpus for analysis consists of the text version (PDF) of project reports, meta-data about the project (e.g., duration, partners), and meta-data on the reports (e.g., number of pages).

Our work is based on the assumption that reports on projects with subsequent impact beyond academia have text-level characteristics or indicators that can be distinguished from reports of projects with no or little proven effects after completion. For the later intended stage of building a classifier, we also assume that these indicative features not only occur in the reports that we examine, but also generalize to other reports.

Our goal is to develop a computational methodology for detecting and classify impact indicators in large amounts of texts in a short amount of time and with high accuracy. We aim for this work to help libraries and funders to efficiently assess potential future uses of research projects. We hope that this work can also inform efforts to develop automated processes for identifying the potential usages of projects based on scientific texts. Our work is not intended to motivate the reverse engineering of impact (from hopes to texts).

3.1 Dataset

We analyze final reports of publicly funded projects with the specific focus on the question if the results of the projects have been put to usage outside of science after the project ended. A project can have one or more reports; the latter applies for example to projects with multiple independent but collaborating partners. Since the number of reports available in TIB is large[4], we selected a sample based on the following criteria, which all projects in the sample must meet:

- report(s) digitally available in the TIB library (PDFs and metadata),
- project domain: electro-mobility,
- project profile: technology and promotion of innovation,
- project completion: between 2005 and 2015,
- at least two partners,
- at least one academic project partner.

The resulting sample contained about 450 projects. Since the reports are in PDF format, they must be converted into a format suitable for automatic processing. We chose to convert them into both plain text and TEI-I5 format. Since we are only interested in the text content, non-textual data like pictures, complex mathematical typesetting, and table layouts are not being remodeled in the destination formats as doing so is error-prone and of no avail for textual analysis. We acknowledge that these elements might be of use for analysis at some point, but multi-modal data analysis is beyond the scope of the current work on this project.

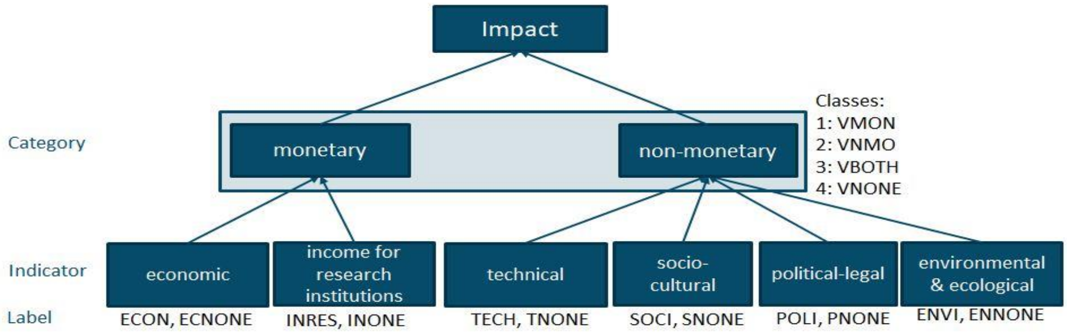
Next, we need to classify the projects with respect to impact on the non-academic community. We do this in two ways: First, by identifying objective evidence of project impact regardless of the reports (detailed in section 3.3). Second, by assessing impact only based on the text content of the project reports (detailed in section 3.4).

3.2 Impact definition and measurement

As mentioned in section 2, IA has been studied and/or practiced for decades in various fields and application domains. For some of these fields and domains, defining impact may be a clear and straightforward task. Also, assessing impact may involve qualitative and quantitative research.

[4] In November 2016 the TIB collection comprised about 256000 printed and 75000 electronic documents of which 65097 are openly accessible in PDF format.

Figure 1: Classification scheme for external impact categories



The process of defining and measuring impact of research projects beyond academia is challenging for the following reasons. The first issue is timing: it might take time after project completion to convert research findings and other outcomes into knowledge, activities, services, products, etc. that affect society. The time span between project completion and impact can vary widely. Also, we are solely relying on project reports of the completed projects. These reports may describe impact that has already been realized (which is easy to identify), or anticipate future impact, which might not be realized (which requires careful distinction between potential and actual impact).

The second issue is defining impact of research projects. Impact can be direct (e.g., a new online service), immediate (within the project lifetime and reporting), indirect (the contribution of the project is not obvious to the public), or delayed (after project completion and reporting). In order to be be able to distinguish these aspects, we use two different approaches to define and measure impact. We will also test the congruence of these approaches.

The first approach is deductive: we define external impact categories of research projects, and let experts assess the impact for every project in our project sample regardless of the project reports. We then perform text analysis techniques to find correlations between the texts and externally defined and identified impact of the related projects. This approach is based on the assumption that some text features in the project reports might correlate with impact categories, which are detailed in section 3.3.

The second approach is to let human coders analyze project reports from our sample of reports, and identify and mark up text-based indicators of impact. We will then use the analysis results for deductive learning. This step is described in section 3.4.

In the final step, we will compare the results from both approaches in order to find out if text-level impact aligns with expert judgment on the project level impact.

3.3 Externally defined impact categories and measurement

Our first approach is to define external impact categories of research projects, and to let experts assign applicable categories to the projects in our sample. In a first step, we defined six objective impact indicators/criteria for research projects in general:

- Economic impact: refers to the use of research results in the private sector, e.g., the development of a business model.
- Income impact: refers to additional income for research institutions, e.g., selling licenses or establishing research contracts.
- Technical impact: refers to technologies that are used outside of the original project, e.g., prototype development or process development.
- Socio-cultural impact: occurs when a project influences societal groups or institutions like schools, local authorities, foundations, or clubs. Also includes activities such as starting a grass-root initiative.
- Political impact: refers to using the project results in political or jurisdictional contexts, e.g., contributions to a new law, or informing political advice.
- Environmental and ecological impact: refers to changes of ecological or environmental aspects, e.g. environmental reports or weather data collection.

We then created two higher-order categories that we associated with these six categories: “monetary impact” and “non-monetary impact”, and based on that, four classes: "monetary impact" (VMON), “non-monetary impact” (VNMO), “monetary and non-monetary impact” (VBOTH) and “no impact” (VNONE), see Figure 1.

Monetary impact of a project considers the indicators for economic impact and income impact. The non-monetary impact considers the other four indicators. Any given project must be categorized with one of two possible labels for each of the six indicators: the first label is the positive one (e.g., “ECON” means the project has economic impact), and the second label is the negative one (e.g., “ECNONE” means the project has no economic impact). According to our impact type classification schema (Figure 1), the categories of “monetary impact” and “non-monetary” impact are not collected separately, but derived from the six pre-defined indicators.

In order to label the projects in our sample according to this schema, we tried two methods: First, we did a web search on several projects to find objective evidence for our impact indicators. This process turned out to be heavily time consuming, and not all relevant information about a project's impact could be found online. Therefore, we used a second method: Based on the project reports, the main person per project was identified, contacted via email, the purpose of the contact was explained to them, and they were asked for their permission to perform an interview with them regarding the project. If they agreed, they were asked to answer questions about ten aspects of the project impact. Based on their answers, the project was classified accordingly. For projects with multiple reports, we assigned the impact classes to each report on the project.

3.4 Text-based definition and measurement of impact categories

The impact categories described in the previous section are external to the project reports. While we assume the resulting labels to relate to the project reports, they might be independent of the reports. For this reason, we also pursue a second approach, i.e., identifying impact solely based on the project reports. For this task, we first asked human annotators to read a sample of project reports, and based on that, suggest impact categories that they see in the data. These annotators are not aware of the externally defined classification schema. Hence, the text-based impact categories may or may not overlap with the external ones. In the next step, we will review the suggested categories and synthesize them into a formal system of categories, resulting in a codebook. The codebook will then be used by at least two independent annotators to mark up a larger set of project reports from our sample. After finishing the document annotation and measuring intercoder reliability, we plan to train a classifier for impact types and categories using the annotated data for training, so that we can use the resulting model to label projects automatically for their potential impact.

4. Preliminary outcomes

We have completed the definition of external impact categories, and the project reports in our sample are being labeled accordingly. Identifying the text-based impact categories is work in progress that we will report on in the workshop presentation.

As soon as all projects are labeled using the two different methods, we will extract features, train classifiers, evaluate their accuracy, and conduct an error analysis. Finally, we will test the congruence of the two selected methods for measuring impact.

5. Discussion

Ideally, the outcomes of research projects include or lead to broader impacts, i.e., benefits to society beyond the research project *per se*. With our approach, we hope to allow researchers as well as other stakeholders of publicly funded research to assess how research projects might have different kinds of impact (economic, sociopolitical, environmental, etc.).

By enhancing the meta-data of the project reports with our impact categories, we also want to provide a valuable resource for the interested community. We aim for the approach described in this paper to be applicable to research and application areas beyond electro-mobility. The impact categories might need to be customized for other application domains, but the overall research design should still be applicable.

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