Empirically Assessing Impact of Scholarly Research

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ABSTRACT

The impact of scholarly research can be manifested in many different ways, but conventional citation measures are often used to evaluate research impact without distinction. This paper attempts to analyze the misconception about what research impact is and what exactly citation data measures or cannot measure for impact. The author proposes a framework of impact assessment, in which research output makes intellectual, technological, and societal impact through knowledge diffusion. The extent of knowledge diffusion, adoption of technology and practices, and benefits from adoption constitute the overall impact of research. Although still in its preliminary form, the framework offers a more holistic view on the composite of research impact.

General Terms

Measurement

Keywords

Impact assessment, citation-based measures, scholarly research

1. INTRODUCTION

Citation data is empirical in nature and has been used to study the extent to which a paper or a journal was cited. It has been used to quantify a wide range of things, ranging from the evaluation of research quality and impact to the mapping of science. A large number of publications have been produced on all these topics since the *Science Citation Index* started half a century ago. While using citations to map science is considered a useful approach and can provide valuable "big picture" [11], the debate on the validity and reliability of citations as measures for impact assessment never reached an agreement. Concerns on citation measures for research performance and impact primarily come from the inherent limitations of citation database: inadequate or biased coverage for countries, disciplines, and languages of research publications [1] [9], as well as the ambiguities and confusions caused by name abbreviations and orders of author names. Such concerns and critiques, however, rarely question the meaning of impact: What does impact of scholarly research mean exactly? How does citation data measure the impact?

The word "impact" has been used loosely to refer several things. We frequently read in literature that the number of citations a paper received is considered as "research impact," thus the average number of citations received by a research group would be "average impact" [10], or "indices of scientific impact" [5]. These impact measures, however, are vague on what they mean exactly and lack elaboration on theoretical implications. While citation counts reflect the extent to which a research publication is known or visible to the research community, the data does not tell what role a cited work played in the creation of citing work, nor does it show whether it received criticisms or served as the "giant's shoulder" for the citing work. Citation counts may be a "proxy for the objective quality of an article" (Oswald, 2009), but far from telling the whole story of research impact.

What does research impact mean? How can it be measured? This paper attempts to analyze the composite of research impact with a focus on information science research. Unless specified, all discussion in this paper is placed in the context of information science research. In the framework proposed in this paper, three factors are discussed—extent, adoption, and benefits—along the intellectual, technological, and societal aspects of research impact.

2. THE COMPOSITE OF RESEARCH IMPACT

Impact implicates a strong influence, effect, or a forceful consequence. Impact from natural environment, such as that of invasive species on ecosystem, or hurricanes on affected regions, is concrete and visible, hence easier to measure in the economic, ecosystem, and health terms. Impact of scholarly research (and especially in information science), on the contrary, is not always easily measurable by economic gains or losses, or in countable figures. In addition, research impact requires some ingredients to brew: the utilization of research output, be it papers, data, patents, software, or otherwise, and a process of diffusion of these research outputs through humans and social and economic activities (Figure 1).

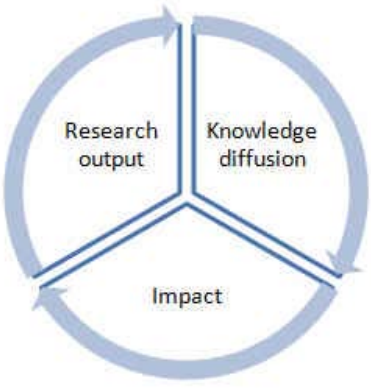

Figure 1. The research impact cycle

The boundaries between research output and knowledge diffusion are often not clear-cut and different models of impact assessment have been applied in various contexts. The impact assessment case studies at the Arts and Humanities Research Council (AHRC) (UK) apply a logic model of assumptions, resources, processes/activities, outputs, outcomes, and impact to evaluate the impact of their funded research projects [8]. Duryea, Hochmanand and Parfitt [4] define a similar model in which they specify research outputs, research transfer, research outcomes, and research impact. These models provide supportive footnotes to Figure 1 that knowledge diffusion does not start only when research output is produced; rather, it may well begin when a research idea is being formulated and the interaction between output from previous research and ideas/theories from current research lays the foundation for diffusion of knowledge and impact.

The orientation of research has a direct effect on what types of impact will result from research. Theory-based hypothesis-testing research, for example, would produce primarily intellectual impact, which may or may not trigger other types of impact later along the stages defined by the diffusion theory's adoption process—knowledge, persuasion, decision, trial, and adoption [7]. Another case is the practice-based research. Research with this orientation in information science typically involves developing algorithms, software, databases, standards, best-practice guidelines, etc. that can be applied or implemented to benefit work processes and/or customers. When output from practice-based research is diffused, the measures for research impact include productivity increased, time saved, or revenues gained/cost saved [4]. Even though these aspects of impact are relatively easy to quantify, the data is not always easy to collect. This is particularly true for information science research because the research output may be used by any sectors and the effects or benefits of using them are recorded elsewhere other than the institution where such output is produced.

The field of research can also determine how research output might make an impact. The Backer Medical Library at Washington University in St. Louis developed a model for faculty to assess the impact of their research, in which the impact of their research can be measured by community benefits from the diffusion and adoption of their research output. Such community benefits include 1) economic outcomes indicated by a cost-effective intervention for a disease, condition or disorder among other things, 2) health care outcomes as reflected in clinically effective approach in the management and treatment of a disease, disorder or condition, and 3) enhancement of quality of life [2]. In the impact case study by Sheppard [8], the research impact included encouraging scientists to look beyond the current aesthetic of digital images and helping patients to communicate their experiences individually and collectively through artist exhibitions. Obviously, citation measures in these cases would have been unable to capture such qualitative effects.

On a macro-level of research impact, three factors will determine the overall impact of research: the geographical and disciplinary extent to which research output has been diffused, the adoption rate, and the societal benefits. The units and implications of this statement can be more formally expressed with the equation[1]:

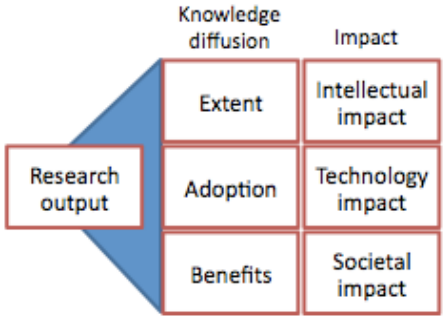

Figure 2. The research impact framework

$$I = E \times A \times B \qquad \text{[Equation 1]}$$

where the overall impact I is defined as the product of the extent (E) of knowledge diffusion, in which citation data can be utilized to analyze the rate and scope of knowledge diffusion, the rate of adoption (A) as represented by the proportion of intellectual property that has been licensed or purchased among all produced, and the benefits (B) to society in both quantitative and qualitative terms.

Figure 2 visualizes Equation 1 as a framework for evaluating the impact of research, which was created with information science in mind in particular. Through knowledge diffusion, various types of research output make impact at intellectual, technological, and societal levels. At each stage of diffusion, the kinds of impact that research output has are assumed to be different: the geographical and disciplinary extent of knowledge diffusion produces mostly intellectual impact, the adoption of inventions or innovations makes impact mainly on technology and implementation, and benefits to communities and society would impact the society as a whole in much broader and deeper ways. While these assumptions are yet to be proved, differentiating between the kinds of impact would help us clarify what measures are appropriate for assessing which types of impact and thus address the long-time concerns on the validity and reliability of impact measures.

2.1 Extent

So far citation counts have been the most widely used measure for impact at either individual or collective levels for papers, journals, or institutions (Given its wide use in science research performance and impact assessment, it exemplifies an excellent case in intellectual impact, to say the least). For reasons mentioned in the introduction section, citation measures are not without problems: they may be inaccurate, misleading for interpretation; non-experts may use them inappropriately in evaluating research quality and

[1] The equation idea comes from Parker, I.M. et al. (1999). Impact: toward a framework for understanding the ecological effects of invaders. *Biological Invasions*, 1: 3-19. While the variables are different in this equation from the one in Parker et al.'s article, the way the authors describe the impact of biological invaders on ecological systems and economy helped formulate the equation in my paper.

performance [10]. While citation data has its advantages in research evaluation, its role lies mainly in measuring the extent of knowledge diffusion only in formal scholarly communication, rather than measuring the whole spectrum of research impact as many bibliometric studies have taken for granted. It translates the quantity of citations into one type of impact—the intellectual impact—and such impact is only in proxy. As for the qualitative aspects—whether the research had an impact on others in terms of methods, hypotheses, theories, or experiments, or whether it served a supportive role or otherwise for the citing work, the assessment must go beyond citation data and quantitative methods to obtain a holistic picture of research impact.

2.2 Adoption

Adoption is a term used in the diffusion of innovations theory. Diffusion is defined as "the process by which an innovation is communicated through certain channels over time among the members of a social system" [7, p.5]. While diffusion research centers on how (diffusion process) and why (adopter studies) innovations are diffused, impact assessment is targeted in the outcomes of such processes and their impact. Some of the outcomes from adoption are countable, e.g., number of license agreements signed, number of patents applied or approved, or academic-industrial research partnerships established. Others, however, are not so direct and easily countable. The impact of adoption is not always immediately obvious. A good example would be the involvement of science librarians in managing datasets for scientists. While science metadata and datasets management result from practice-based research, the adoption of science metadata standards and best practices in supporting eScience is a typical stage of diffusion. The impact of this adoption may not be immediately clear in the short term nor easily measurable within the information science field, but anecdotal evidence has shown that such an adoption is changing the curriculum structure and guiding principles for educational programs in some institutions. A systematic assessment of such an impact would require data collection from outside of research field itself.

Here again disciplinary differences affect the kinds of impact resulted from adoption. For example, the impact of an adoption of biological materials may bring benefits in clinical trials that show immediately in patient's condition change, while that of metadata best practice guidelines may not be so obvious nor direct because the change in metadata quality and search performance cannot be known until metadata quality is inspected and search results are analyzed against the queries.

2.3 Benefits

If E and A are relatively straightforward to quantify, benefits B is not. This aspect of research impact has always been a challenge. Macro-level measures such as proportion of Gross Domestic Product (GDP) increase due to Research & Development (R&D) spending signals the contribution of R&D activities to a country's economic growth, but how can we quantify the benefits that resulted from information science research at both macro- and meso-levels? In other words, how does information science research contribute to the improvement of productivity and quality of life?

Measuring benefits of information science research needs to consider two important factors: scope and type. The scope factor includes societal, organizational, and individual levels. A research output may benefit individuals in one way but this benefit may be translated into other types for an organization or community. A good example would be the development of institutional repositories (IRs). While theoretical and application research on this subject help build effective information systems in the form of IRs, the benefits for researchers in the institutional community may be measured by the time saved in managing their research artifacts (including data among other research products) from avoiding technical hassles. Although the data of benefits may be difficult to collect, it is not impossible to capture and the chain benefit change at individual, institutional, and societal levels would make such data collection worthwhile. Research on the B segment in Equation 1 would be the most challenging yet perhaps most revealing way to assess the impact of information science research.

3. How Is Impact Measured Currently?

A large number of measures have been used to assess research impact. Bollen et al. [3] analyzed 39 existing and proposed measures of scholarly impact and concluded that no single indicator can be used alone to measure scholarly impact. Table 1 summarizes the measures listed in Bollen et al. from a methodological perspective.

Citation measures have functions of ranking, measuring citedness and relatedness of formal publications, and supplying data for mathematical models of research achievements. The popular use of citation data did not make it more effective or accurate in evaluating impact. Bollen et al.'s research reveals that usage measures show a greater reliability than citation measures in general and "Usage Closeness centrality is positioned closest to all other measures" [3]. One point worth making here is that, although Bollen et al. call all the measures in Table 1 as "scientific impact measures," they are all citation-based measures and have the inherent limitations for getting the whole picture of impact.

Table 1. Existing measures for scholarly impact (compiled according to Bollen et al., [3])

Function of measures	Type	
	Citation	Usage
Ranking	Scimago Journal Rank, PageRank, Y-factor	PageRank,
Citedness	Cites per doc, Journal Impact Factor, Scimago Total Cites, Journal Cite Probability	Journal Use Probability, Usage Impact Factor
Relation	Closeness centrality, out-degree centrality, degree centrality, in-degree centrality, betweenness centrality	Closeness centrality, degree centrality, in-degree centrality, betweenness centrality, out-degree centrality
Index	Immediacy index, H-index, citation half-life	

4. Conclusion

Needless to say, assessing the impact of research requires more than citation data. Although bibliometric studies have developed numerous measures for research impact, or "scientific impact," they are all citation-based measures and thus unavoidably limited by the inherent problems due to these constraints. This paper analyzed the misconception about what research impact is and what exactly citation data measures or cannot measure for impact. The framework of impact assessment in this paper, though still in its preliminary form, offers a more holistic view on the composite of research impact.

The three components of research impact, Extent of (intellectual) impact, Adoption of technology and practices, and Benefits to society, emphasize the diffusion of knowledge processes and outcomes. How to operationalize the measures in the impact model will need further research.

While current assessment of research impact relies largely on empirical data and measures, there is a lack of theory and formal (rational) models for evaluating the impact for the information science discipline. The framework offered in this paper is an attempt to fill this blank. The next step will be to further refine the detail of the framework and gather more empirical evidence to rationalize it into a model and theory.

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