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Funding acknowledgements in scientific publications: A literature review

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Abstract

The topic of acknowledgements has produced abundant research since the 1970s, though, as previous studies point out, the value of acknowledgements has not yet been demonstrated and further research is limited by lack of conceptualization. This study focuses on funding acknowledgements (FAs), considering that funding represents an important input in the scientific process. In this context, 183 scientific publications retrieved from Scopus from the 1970s until June 2020 were analyzed, with the aim of systematizing conceptually this body of research and contributing to a theory of acknowledgements. Results are summarized into the following main themes: the meaning of FAs; data sources for acknowledgements; the process of funding; association of funding with productivity, impact, and collaboration; and other aspects affected by funding. The literature reviewed shows that a theory of acknowledgements based on the reward triangle, as in previous studies, is unable to capture the extreme complexity of the scientific activity affecting and being affected by FAs. Funding bodies appear as clear and influential actors in the scientific communication system, making important decisions on the research that is supported, and influencing the type of knowledge produced. Funding agencies hold a responsibility regarding the data that they may collect on their programs, as well as the normalization policies they need to develop so that funded authors can reference with less ambiguity the financial source of their projects. Finally, the need to assess the impact of research funding beyond the scientific community that is, the societal impact, is also addressed.

Key words: funding acknowledgments; scientific performance; research funding; scientific policies; research evaluation

1. Introduction

The topic of acknowledgements has produced abundant research since the 1970s and in several disciplines, as reported in a recent meta-synthesis and bibliometric analysis (Desrochers, Paul-Hus and Pecoskie 2017). Acknowledgements in scientific publications are a voluntary act of gratitude towards different types of support received during the research process. Usually before the bibliographic references of the paper or, alternatively, in footnotes or on the first page, authors may mention diverse entities, such as funding bodies or other colleagues, that in some way have contributed to the research, providing either technical, intellectual, financial support, or a mixture of these (Costas and van Leeuwen 2012). According to Desrochers, Paul-Hus and Pecoskie (2017), acknowledgements can be seen as an expression of scientific debt towards colleagues and institutions, and, Giles and Councill (2004) add, may be useful to a better understanding of scientific collaboration and the division of labour in research. In addition, acknowledgements allow writers to display their scholarly network and to put into practice the academic values of modesty and gratitude, promoting in this way their academic identity (Hyland 2004). Acknowledgments to individuals behave like other bibliometric phenomena following a power law pattern such as citations, with a few individuals being mentioned often and the majority just infrequently, at least in Library and Information Science (Cronin, McKenzie and Stiffler 1992) and in History, Philosophy, Psychology and Sociology journals (Cronin, McKenzie and Rubio 1993a,b).

Despite the important volume of research on the topic, Desrochers, Paul-Hus and Pecoskie's (2017) meta-synthesis concludes, the value of acknowledgements in scholarly communication

has not been demonstrated, and acknowledgements are not yet included as a fully developed topic in major monographic publications in informetrics and bibliometrics, such as De Bellis (2009), Cronin and Sugimoto (2014), or Moed (2017). Desrochers, Paul-Hus and Larivière's (2020) recent chapter on conceptual and theoretical contributions on acknowledgements hinges on the reward triangle theory (Cronin and Weaver, 1995) and builds on it to conclude that most bibliometric research has focused on the intersection of authorship and citations, while acknowledgements have produced a large but dispersed body of literature. In spite of their great diversity, they conclude, acknowledgments relate clearly to a dimension of scholarly activity that is, its socio-cognitive connections and the strong collaborative nature of scientific inquiry.

Although the present contribution focuses on a specific type of acknowledgements, Funding Acknowledgements (FAs) that is, those referring to the financial support received in order to carry out the research, in what follows a first brief introduction to the act of acknowledging in scientific research publications is provided, emphasizing its collaborative and highly variable nature.

1.1 Acknowledgements and sub-authorship

The complex relationship between acknowledgement and collaboration has called the attention of researchers since the beginning. In Mackintosh' analysis of the acknowledging behavior of 23 American sociologists from the fifties to the late sixties (Mackintosh 1972), the more highly collaborative were less inclined to acknowledge support from others than the less collaborative. According to Paul-Hus et al. (2017b) looking at people mentioned in acknowledgments can cast a new light on collaboration, and in their comparative study among different disciplines, including the social sciences, they find that traditional differences in terms of team size are reduced considerably when adding to authors individuals credited in the acknowledgements. Indeed, acknowledgements provide a new insight on scientific collaboration, nowadays an almost universal practice in science, bringing up new questions about sub-authorship and the requirements needed to qualify as a proper author. In some research areas, authors who do not meet the minimum criteria might be listed in the acknowledgements section, as in Nursing and Midwifery (McCann and Polacsek 2018). Cultural influences can also have their effect on scientific practices, and Salager-Meyer, Ariza, and Berbesí's (2009, 2010) work with medical journals stresses variations in the acknowledging practices of Venezuelan, Spanish, and French journals as opposed to US journals. They contend that in Venezuelan, Spanish, and French journals, researchers might be included as proper authors, without having contributed meaningfully to the research, resulting in less frequent acknowledgements. In this sense, acknowledgements could make visible participants in the research process who do not qualify as proper authors, and by making *visible* different actors or hidden processes in the research process, acknowledgements could be seen as sources of new and alternative metrics.

1.2 Variations in acknowledgements

Not all acknowledgements are the same and previous studies have proposed different classification schemes in order to reflect the many faces of acknowledging. The numerous typologies detected in the literature can be classified, according to Desrochers, Paul-Hus and Larivière (2020), depending on these questions: 'who gets thanked for what?', 'who gets thanked instead of being an author?', or 'what are the roles, functions, or statuses of the people and organizations being thanked?' Mackintosh (1972) distinguishes acknowledgements depending on the references they make, as they can mention facilities, access to data or help of individuals. More specifically, Cronin (1991) includes six different categories, focusing on the intentions behind acknowledgements: *paymaster* (grants or fellowships), *moral support* (access to facilities or data sets, use of plant or equipment, familial support), *dogsbody* (secretarial and editorial support), *technical* (programming advice and statistical assistance), *prime mover* (mentorship, project director, and adviser), and *trusted assessor* (feedback, critical analysis, and provision of insight). Still emphasizing the intention behind acknowledgements, Cronin, Shaw and La Barre (2003, 2004) qualify acknowledgements as either *moral, financial, editorial, instrumental/technical*, or *conceptual/cognitive*, adding that when their nature is conceptual or cognitive they afford what is known as 'peer interactive communication' (PIC). PICs, mentioning other academics, attest to conceptual and cognitive contributions that are not substantial enough to grant a recognition of authorship, but still important to the development of the paper. This kind of support is considered the most important for identifying intellectual debt and, according to some; it could be even comparable to citations (Giles and Councill 2004). Looking at people allow to see acknowledgements as a different form of authorship, 'sub-authorship', covering all individuals who make a contribution towards the research outcome and somehow influence the course of the research. In this sense, Mackintosh (1972), studying the acknowledgement behavior of a sample of 23 American sociologists as reflected in their publications, distinguishes the role of *people* being acknowledged, depending on their contribution, into methodologists, theorists, or psi's. Costas and van Leeuwen (2012) qualify acknowledgements addressing individuals who provided technical assistance to the research as "clerical". According to Heffner (1981), who analyses a multidisciplinary set of domains, contributions from other individuals might consists of 'technical aid', covering processes such as the collection or processing of data, operating with laboratory machinery, or doing statistical analysis, or 'theoretical aid', which includes reading, commenting or editing drafts of the manuscripts. The type of contribution may be related to other aspects of the research and, in Heffner's (1981) work, technical sub-authorship was significantly related to funding, whereas theoretical sub-authorship was not.

Disciplinary variations have also been stressed. Paul-Hus et al. (2017a), in a corpus of more than 1 million scientific articles and reviews published in 2015, found that whilst technical support and funding are more frequently mentioned in natural sciences and biomedical research, respectively, conflict of interest is more likely to appear in clinical medicine, and PIC and intellectual debt are more often acknowledged in social sciences than in other fields. In Díaz-Faes and Bordons (2014), PICs predominate in more theoretical- and social-oriented disciplines, such as statistics and probability, and economics, while technical assistance is more frequently acknowledged in experimental research (evolutionary biology) and, the recognition of potential conflict of interest was more common in clinically oriented research (cardiac and cardiovascular systems).

1.3 Funding acknowledgements

Contributions mentioned in acknowledgments appear to have changed in the last decades, progressively emphasizing the role of funding bodies. Longitudinal studies about changing practices of

acknowledgment point both to a growing professionalism and a closer focus on acknowledgements mentioning funding support. Alcaraz and Ariza (2015) encounter, in a sample of 300 papers published in American and European astrophysics journals in 1998, 2004, and 2012, a growing scientific professionalism, as financial, instrumental, and conceptual assistance, as well as mentions to unnamed individuals and anonymous referees increased over time, whilst moral and editorial supports, references to named individuals and identified referees, and emotionally charged words declined. A topic modeling analysis of 595,336 articles containing an acknowledgment section in PubMed in the period 1992–2016 highlights the progressive importance of acknowledgements to funding agencies (An et al. 2017). Although acknowledgements to national support and anonymous reviewers present a low weight for the whole period, those mentioning advice, experimental assistance, feedback, or scholars become less important especially since 2008, and since 2010 it is possible to appreciate an increase in references to financial and organizational support, that as a whole accounted for 45% of all topics extracted.

Despite the increasing use of the acknowledgement section to mention financial support and funding bodies and the growing availability of data to study acknowledgements and in particular the effect of funding on the production of new scientific research, research is seriously limited by the lack of conceptualization and it is still unclear what 'FAs' actually are, Van Honk, Calero-Medina and Costas (2016) argue. With these premises, the present review pretends to contribute to a theory of acknowledgements by focusing on the connections they allow to trace with non-academic actors, specifically with funding entities, looking at research published on the topic from a conceptual point of view and complementing in this way the bibliometric analysis of Desrochers, Paul-Hus and Pecoskie (2017). This study focuses on FAs, assuming that research funding represents an important input in the scientific process. Acknowledgements mentioning funding bodies can be practically classified depending on the origin of the financial support, and Henderson, Howard and Wilkinson, (2003), following the directions of the Research Outputs Database set up by the Wellcome Trust, differentiate intramural funding, extramural funding, personal support or other types of funding, whilst, as for the sources of funding, they identify funding coming from charities and foundations, from governmental agencies and departments, hospital trustees and different sectors of industry. The analysis of FAs is particularly relevant to funding organizations and scientific policy makers as they allow to measure and evaluate the results of their investments. In Zhao's (2010) words, '[. . .] grant based research can play a significant role in expediting and disseminating high-quality research, in setting research directions, and in fostering collaboration' (p. 305) and it thus deserves unclosing the recurring themes of the literature on the topic. Over the past 20 years, FA research has been carried out on the basis of a non-systematic collection of data, within bibliometric studies with different purposes. However, main bibliographic databases have started to index systematically the text of acknowledgements since 2008, allowing the production of an important corpus of research. FAs have been included in bibliometric analysis as an additional indicator to evaluate the scientific performance of disciplines and research topics (Lewison and Devey 1999; Webster 2005; Lewison and Markusova 2010; Lewison and Roe 2012; Mwendera et al. 2017; Klochikhin and Fealing 2018; Meschede 2020) or research groups and institutions (Roa-Atkinson and Velho 2005; Gausia et al. 2015). In some cases, FAs have been used in order to identify major funders (Reyes, Kauffmann and Goic 1995; Lewison and Devey 1999; Henderson, Howard and Wilkinson 2003; Rangnekar 2005; Zanca et al. 2005; Bakker et al. 2010; Alnemary, Alnemary and Alamri 2017; Mwendera et al. 2017), the type of research with higher funding rates—that is, the percentage of papers including FAs (Lewison and Devey 1999; Lewison and Carding 2003; Walsh and Sanchez 2010; Mwendera et al. 2017), the funding rate of specific agencies (Wilson and Itagaki 2007), or the relationship between funding support and impact (Lewison and Devey 1999; Lewison and Carding 2003). The aim of this review is to systematize conceptually this large body of research.

2. Methodology

This theoretical contribution relies on an extensive literature review, and its main purpose is to point to important conceptual themes on FAs and to set the foundation for future research on the topic. Available reviews on FAs (Desrochers, Paul-Hus, and Pecoskie 2017) show the importance of this research area, but mostly from a quantitative and formal point of view.

Relevant contributions were retrieved from the Scopus database in January 2019 and documents until June 2020 have been recently included according to the following search string:

> TITLE-ABS-KEY ((acknowledgement* OR acknowledgment*) AND (funding OR funds OR "financial support" OR "research investment" OR "research support" OR "research output*")) AND (LIMIT-TO (LANGUAGE, "English") OR LIMIT-TO (LANGUAGE, "Spanish")) AND (EXCLUDE (DOCTYPE, "er"))

As a result, 537 articles were retrieved covering the scientific literature from the late 1960s up to the date of the search. The 537 articles were scanned and filtered, and additional relevant research discovered following citations to and from the retrieved articles, was also integrated into this conceptual contribution. The final corpus includes 184 research items on the topic of FAs and related themes.

Results are summarized into five main sections and respective subsections. First, we introduce the meaning of FAs in the context of the scientific process and the politics of science. Second, the main data sources used in order to analyze FAs and their limitations are described, and some attempts to automatically classify funding agencies are presented. Third, we focus on several types of bias in research funding allocation, such as gender or the research topic. Fourth, we cover all the research focusing on the association of funding with other research characteristics, such as productivity, impact and collaboration; and, finally, other aspects affected by funding are also discussed.

3. Results

3.1 The meaning of FAs: the politics of science

The first bibliometric attempts at developing a theoretical basis considered acknowledgements as the third part of the 'Reward Triangle' of science, along with authorship and citations (Cronin and Weaver 1995). In the earliest studies on acknowledgements, FAs were seen as a recognition of quality, such as citations (Lewison and Dawson 1998), as funded research has been selected for funding in competitive selection processes. However, by looking at

acknowledgements as part of a reward system, the potential meaning of acknowledgements was limited to authors or individuals, when actually they might shed light more generally on interests in research and science such as those of political, social and economic actors. This perspective has been of concern to other disciplines and particularly in sociological literature since the seventies. Crawpord and Biderman (1970), for instance, looked at federal funding of research as a possible threat to the independence and autonomy of academic research in sociology and a potential source of contamination of the discipline by external interests. As a consequence of external funding, they discovered a predominance of more empirical and statistical sociological research, though, they observed, the independence and autonomy of sociology was still exerted through the evaluation process and peer review. With a similar perspective, Galliher and Mc Cartney (1973) summarized postures on funding into three main viewpoints: the *apprehensive* viewpoint, which considered funding as a device diverting social scientists from their main purpose; the *benign* viewpoint, which emphasized the help that government was providing for some research tasks; and the *misuse* viewpoint, that considered that government funding should be devoted to other more important social issues. After analyzing 128 research articles on delinquency published on four sociology journals between 1940 and 1970, they disclosed important methodological trends that settled on a positivist theoretical basis and an assumption that delinquent behavior could be reduced to variables that were, as such, controllable, and consequently more attractive to funding agencies for its pragmatism. However, it is difficult to say whether the influence of funding on research is purely 'political' or reflects more general concerns. Lewison, Grant and Jansen (2001), for instance, concluded that the increased productivity of gastroenterology research published between 1985 and 1998, at least in some countries, was related to the incidence of gastrointestinal disease and reported deaths from gastrointestinal neoplasm, though it was not necessarily supported by a higher funding effort. According to Braun (1998), funding agencies decisions result from complex interactions between norms, structures and scientists' interests, though the selection of research proposals relies heavily on peer review and scientific quality. However, the social structures in which scientific judgments are made, whether through anonymous mail review or groups review, may favor more consolidated cognitive perspectives in detriment of more innovative ones, including interdisciplinary research, as we explain later.

More recently, Li and Yan (2019) advocates that more attention should be paid to the non-academic ecosystem in which science and knowledge are produced. They take the term 'academic capitalism' from Slaughter and Leslie (1997) to indicate the entrepreneurial activities undertaken by universities and individual academics to get external financial support for research, and investigate the possible influence of research policies on research topics. Analyzing the topic match between research proposals and the publications derived from the corresponding funded projects, they find that a topic shift occurs from grant to publications based on the same grant, which points to a certain level of freedom for researchers, though they consider that this is something natural in science, as keyword use changes over time regardless of other factors, including funding. From this perspective it makes sense funding people instead of projects, whose topic may change over time anyway. Kaiser (2014) comments on a shift of the National Institutes of Health (NIH) from project to people awards, on the basis of a previous 2012 program that, awarding 70 outstanding researchers, achieved more innovative and higher impact results. This puts a stronger emphasis on individual researchers' assessment than on the research project.

3.2 Data sources for acknowledgements

Different approaches have been proposed to track research funding and scientific outputs, such as using grant proposals reported by the funding agencies themselves, case studies or, even the researchers' CV. However, all of these approaches have several limitations especially to carry out large-scale studies (Wang and Shapira 2011). On the other hand, through FA analysis based on systematically recorded and updated information in bibliographic databases, it is possible to link scientific publications and research funders, allowing macro-level research studies. From citation indexes, such as the Web of Science (WoS) and Scopus, it is possible to obtain both implicit and explicit funding, being the former based on authors' addresses and the latter appearing in the acknowledgement section (Begum and Lewison 2017). In this sense, Morillo, Costas and Bordons (2015) found that, combining information from the authors affiliation with FAs, a wider number of the Spanish cooperative research organizations known as Biomedical Research Networking Centres publications could be identified. This methodological approach may provide a more comprehensive view of the performance of these kind of structures whose scientific production is more susceptible to remain overlooked for its lack of standardization.

3.2.1 Acknowledge window

A technical aspect that has received certain attention is the 'acknowledgment window' or 'acknowledgement lag', in Ihli's (2017) words that is, the time elapsed between the moment a grant is awarded and the publication of the research article acknowledging support. Linking the US National Science Foundation (NSF) research awards, that are publicly available in the NSF databases, with the journal articles indexed in WoS published between 2010 and 2014 through the grant number field, Ihli (2017) established this indicator for the 22 scientific domains classified by the Essential Science Indicators database. The results showed that the majority of publications (63%) acknowledged research support awarded 4 years or earlier with differences among domains, having certain disciplines, such as chemistry or physics, a shorter acknowledgements lag, and others, such as the social sciences, a longer acknowledgements lag, probably due to disciplinary differences in the publication process. Interestingly, she also found a few articles that reported funding from research projects funded by the US NSF more than 30 years before. Campbell et al. (2010) define the time windows of papers published thanks to grant support as those published from one year between the year after the start of a National Cancer Institute of Canada grant and the year after the end, acknowledging that it is an arbitrary time frame that; however, allows to include all those cases in which authors miss to mention funding.

3.2.2 More comprehensive data on FAs since 2008

Bibliographic databases, such as WoS, Scopus, or Pubmed, started to collect FA information included in scientific publications in the last decade. In August 2008, WoS started to collect systematically data on funding text (FX), funding agency (FO), and grant number (GN). Five years later, in July 2013, Scopus also began to index FAs of scientific articles going back to 2008, recording funding information in four fields: FUND-SPONSOR (funding agency), FUND-ACR

(Funding agency acronym), FUND-NO (grant number), and FUND-ALL (information from the previous fields in a single field). However, currently Scopus does not index the full text of the acknowledgements, reducing the possibility of thorough analysis of a non-standardized part of the research article (Paul-Hus, Desrochers and Costas 2016).

3.2.3 Lack of data normalization

Despite being collected systematically by main citation indexes and bibliographic databases, funding data still lack normalization (Grassano et al. 2017) and are collected in non-structured sections with heterogeneous content, where financial support, technical or intellectual assistance, and conflicts of interest, among others, are mixed up. Normalization of funding credits is not enforced by funding agencies, at least according to (Begum and Lewison 2017). Desrochers, Paul-Hus and Pecoskie (2015) underline inconsistencies in the practice of acknowledgements concerning their place within the text or the way of addressing the 'thanked' person or entity. This great disparity hampers their use as indicators. Rigby (2011) identified two types of limitations that should be taken into account when using FAs for bibliometric purposes. On the one hand, there are simple errors and confusions, such as misspelling of funders and grants, funding organizations name changes, especially government departments, and the fact that researchers might not report exactly the funder or the grant number which support their research (e.g. if they have received funding from multiple agencies). On the other hand, cultural and political issues that may lead the authors to exaggerate the productivity of some grants with great reputation or, on the contrary, to not acknowledge their sources of funding. Misspelling and mistakes in the translations of the names of programs and organizations as well as different variations for the same agency are also common (Morillo and Álvarez-Bornstein 2018). Costas and Yegros-Yegros (2013) identified 400 variants of the Austrian Science Fund, whereas Sirtes (2013) found more than 6,000 aliases for the German Research Foundation (DFG), including translations, acronyms, or different programs. In order to deal with these problems and allow tracking funding agencies' contributions, Begum and Lewison (2017) propose a three letters coding system to unify names. Van Honk, Calero-Medina and Costas (2016) discover high variation as well as important inconsistencies in entities indexation in the data collected in WoS, deriving, they argue, from the fact that the content of acknowledgements has been not conceptualized thoroughly enough for operationalization purposes. They suggest, as an alternative, the use of thesauri with standardized lists of funding organizations and formal recommendations from funding bodies to their grantees about funding statements, the funder name and the type of support received.

3.2.4 Limitations of databases reporting FAs

In addition to the lack of normalization of data, coverage of FAs may also present differences across databases. Kokol and Vošner (2018), for the articles published by three prestigious families of biomedical journals in 2015, find significative differences in the number of FAs identified by three databases, being WoS, with 29% of the articles with funding information, the resource with the better coverage, followed by Pubmed (14.6) and Scopus (7.7). However, Powell (2019), looking for the list of publications reporting support from a single NIH grant found that Pubmed returned more publications than WoS and the NIH Research Portfolio Online Reporting Tool for Expenditures and Results (NIH RePORTER), although no one database reported the complete list of publications sponsored by such grant. More recently, Liu (2020) found some kind of error and missing information in 68% of the papers analyzed in a case study based on Scopus funding data. This type of analysis may help researchers in selecting the most appropriate database when performing scientific studies on research funding. However, despite being probably the source with better coverage, WoS also presents limitations that should be taken into account when using its data. First, until 2015 only FAs in the Science Citation Index Expanded (SCIE) were systematically recorded, implying a certain bias against the social sciences and the humanities (Paul-Hus, Desrochers and Costas 2016; Álvarez-Bornstein, Morillo and Bordons 2017; Ihli 2017; Tang, Hu and Liu 2017; Liu, Tang and Hu 2020). Second, FA information is only available for papers written in English and in Chinese, though only when the acknowledgement is written in English (Paul-Hus, Desrochers and Costas 2016; Tang, Hu and Liu 2017; Liu, Tang and Hu 2020), which reinforces its bias against social sciences (before 2015) and humanities research usually published in local languages. Finally, there are also inconsistencies in the type of documents recorded, since in the SCIE only FAs of articles and reviews are collected, while for the social sciences WoS indexes all documents types (Paul-Hus, Desrochers and Costas 2016). Xu, Tan and Zhao (2015), who set out to study funding ratios for social science papers published in the 21 most productive countries in WoS, confirm the limitations outlined by other studies and add the fact that WoS covers only a part of the papers published by a certain institution or researcher, bias which might be greater for the social sciences. On the other hand, more and more funding agencies are imposing requirements for acknowledging support in published documents resulting from funded research, and it is to expect that missing data won't be an important limitation in future research into acknowledgements. In fact, according to Grassano et al. (2017) estimations, the omission of funding information affects <3% of the total set of documents they analyzed, whilst Liu, Tang and Hu (2020), in a recent analysis of FAs, conclude that WoS provides more complete funding information over the years. In 2016, WoS started supplementing grant information with funding agencies and grant numbers from MEDLINE and Researchfish and, interestingly, it is now retrospectively collecting funding data before 2008, although the share is still too small −5% of the papers from 2000 to 2007 (Liu, Tang and Hu 2020).

An additional problem is the potential confounding effect produced by conflict of interest statements, especially in biomedical research (Lewison and Sullivan 2015; Álvarez-Bornstein and Bordons 2019). Examining the FA full text of more than 2 million WoS biomedical papers, Lewison and Sullivan (2015) realized that the list of funders included companies that were mentioned due to potential conflict of interest, even if they had not supported the research. Álvarez-Bornstein and Bordons (2019) reached the same conclusion in an analysis of Spanish cardiovascular research. This would be one more reason, the authors argue, for cautiously using the list of funders provided by WoS.

3.2.5 Automatic classification of funding agencies

Some studies have focused on the accuracy of the funding data for automatic collection. Grassano et al. (2017) encountered a high level of recall and precision (93 and 94%, respectively) for a set of 7,510 documents retrieved from WoS. Only 7% of the documents that

included funding information were not identified as such by WoS (false negative), whereas 6% of the papers with no acknowledgements to funders were identified as having funding data resulting in false positives. However, for the 32% of the documents, the total set of funding agencies included in the acknowledgement section were not correctly listed. Álvarez-Bornstein, Morillo and Bordons (2017) reach similar results with a random sample of 1,045 articles published in 2014 and find that WoS lost some funding information in 12% of all the papers. These inconsistencies were due, in many cases, to the authors reporting incomplete information about, for instance, the grant number, the funder, or even omitting the funding agency in favor of the name of the project or the grant number.

Attempts have been made to develop different methodologies to process automatically the funding information included in scientific publications. Among the other methods developed for the extraction and analysis of acknowledgements in scientific publications, the following can be mentioned (Giles and Councill 2004; Sirtes 2013; Sirtes and Riechert 2014; Gök, Rigby and Shapira 2016; Morillo and Álvarez-Bornstein 2018). Sirtes (2013) proposed a semi-automatic cleaning method based on the funding data from the DFG that, once applied to a set of funding data, reached values of precision and recall of 96% and 94%, respectively. Morillo and Álvarez-Bornstein (2018) developed a methodology that identifies major sponsors and their funded research selecting funders variants as keywords from the WoS funding agency field. Councill et al. (2005) report on a method for automatically extracting acknowledgment information and identifying collected names of acknowledged entities from papers stored in CiteSeer Digital Library, whose first implementation pointed to the viability of the algorithm for providing acknowledgement metadata content in research libraries.

3.2.6 The role of authors and funding agencies

It is often authors who do not always acknowledge funding correctly, which impairs the analysis of funding. Butler (2001), who looks at the research output funded by the Australian National Health and Medical Research Council, observes that usually authors do not detail concrete programs or projects, limiting the possibilities of evaluation at the aggregated level of funding agencies. Possible reasons for omitting acknowledgements include involuntary neglects or the fact that authors receive internal funding by their own institution, which is known as intramural funding as opposed to extramural funding (Lewison, Lipworth and de Francisco 2002; Grassano et al. 2017). According to Henderson, Howard and Wilkinson (2003), who conduct a survey with 83 corresponding authors of the *British Journal of Psychiatry*, 14% of researchers did not acknowledge their source of funding, either because agencies and journals did not provide guidelines or because they understood that it was not necessary.

Funding originates from different funding agencies and each of them might have different policies regarding researchers obligations, and even if all of them keep track of their funding activity, they do not usually abide by the same rules (Lepori et al. 2007). The evaluation of science funding programs is challenging because they can have different goals and expect different types of results, making it difficult to measure their effects. Moreover, linking the outputs associated with a specific grant or agency is also difficult to undertake because of the lack of institutional instruments of explicit input–output data, and, even when they exist, huge efforts to clean and normalize such data are needed (Boyack and Jordan 2011). In addition, according to Boyack and Börner (2003), funding agencies should keep their own databases of grants and resulting publications in order to allow bibliometric analysis and improve the quality of existing data. Indeed, the future of research into FAs depends strongly on the implementation of at least clear guidelines that might improve reliability of data (Álvarez-Bornstein, Morillo, and Bordons 2017). Funding agencies should also be aware of the importance of developing policies and guidelines about how to be mentioned, including references to the country or region (Morillo 2016; Álvarez-Bornstein, Morillo, and Bordons 2017). Some funding and research organizations have provided guidelines to authors in order to standardize FAs or other types of financial support. For example, the National Optical Astronomy Observatory has developed a program for tracking publications that use data from their observatories, telescopes, instruments or even datasets and, also, has set policies to guide authors in acknowledging their support (Hunt and Norman 2018). Journals as well may have their share of responsibility and Koushan et al. (2014) complain of the great laxity of Iranian journals' criteria in this aspect. Even in the cases in which there has not been an external source of funding, Tennen (2015) suggests that an explicit statement should be included, as it is being done with conflicts of interest.

By the means of acknowledgements, funders gain visibility and it becomes clear that research responds to needs and objectives of different societal stakeholders, either public bodies or the private sector. Besides making visible researchers, acknowledgement could make visible other dynamics within science communication, such as support from the private sector. In health research, Pollock and Ewer (2010) claim that authorship of medical publications should be 'integer', with reference to the frequent support of research by private funding, and advocate for a policy of transparency in referring about the actors involved in research and the role that external funding sources might have had in it. In fact, in a study of the correspondence between Coca-Cola and the researchers they financed, Steele et al. (2019) found out that the company did influence the research and cut off funding if the results were unfavourable, regardless of what it claimed on its website about not interfering in the research.

According to some studies, in approximately half of privately funded publications sponsors might remain unacknowledged. For orthopedic research, Chimonas, Frosch, and Rothman's (2011) results compare data about companies' payments for 1 million or over to individual researchers with their respective publications, concluding that:

> [. . .] current journal disclosure policies do not yield complete or consistent information regarding industry payments. More than half of the articles in our sample failed to acknowledge an author's relationship to a company. In no article could readers know how substantial the company payment to an author was (p. 84).

These patterns of collaboration might remain invisible if not referenced in the acknowledgement section. Viergever and Hendriks (2016) claim more transparency about funders of health research, both public and philanthropic, especially regarding what they fund and how they distribute their funds. Differences in funding schemes might have implications even for correlation studies, especially on citation impact (Yan, Wu and Song 2018).

3.2.7 Internal data of funding agencies and private companies

The availability of data from funding bodies, either public or private bodies, could support research into FAs by providing additional information not available in bibliographic databases, such as the identification of all team members or the amount of the grant. The Wellcome Trust in the UK is a private foundation that funds research in the health sciences and has developed a system to keep data about funded projects (Begum and Lewison 2017). According to Henderson, Howard and Wilkinson (2003), the Wellcome trust in 2003 was the major source of data to monitor the output of funded research in the UK. Viergever and Hendriks (2016) mention the initiative www.healthresearchfunders.org in which they collect data (basically research expenditures) about major health research funders in the world.

In a few cases, this information has been studied and taken advantage of Ma, Mondragón and Latora (2015) use the UK Engineering and Physical Sciences Research Council (EPSRC) Grants on the Web system to access a dataset that allows them to study collaboration in terms of partnerships to obtain funding. Boyack and Jordan (2011) too exploit the NIH database for their research. They analyzed research funded by the US Public Health Service (PHS), including the NIH, linking the articles to the grant acknowledged using the NIH Scientific Publication Information Retrieval and Evaluation System, a database developed to retrieve articles funded by the NIH. Seif and Trope (2010), analyzed the impact of the research funded by the Glaucoma Research Society of Canada (GRSC) and find that two thirds parts of the projects granted ended in at least one scientific reviewed publication. However, considering the difficulties to locate the outputs funded by the GRSC, the authors conclude highlighting the importance of accurate internal databases to collect and link grants and results, whether journal articles, conference papers, patents, or press releases. Hottenrott and Lawson's (2017) address the interactions between public and private funding by drawing on a sample and diversified set of data that includes, apart from data extracted from WoS, data obtained from 40 UK universities and their website and the European Patent Office.

A question that remains unanswered is how much of privately and publicly funded research is acknowledged in research publications. Some funding bodies such as universities and the private sector might be explicitly mentioned to a minor degree than governmental bodies (Reyes, Kauffmann and Goic 1995). Moreover, it is possible that some particular organizations, such as commercial companies, might be reluctant to be acknowledged in order to avoid attracting attention to their business plans and to keep them confidential (Rigby 2011; Wang and Shapira 2011). Different estimates have been put forward regarding the percentage of official funding being explicitly acknowledged. Lewison (1994) found that 80% of articles sponsored by the European Commission Biotechnology Action Program acknowledged funding when the level of support provided by the program accounted for 20% or more of the total support received. Lewison (1998) encountered that gastroenterology papers published between 1988 and 1994 mentioned the source of funding in more than half of cases, being the share of governmental funding comparable to that of private nonprofit sources. The problem remains of the inconsistent character of these references within the formally published literature. It depends often on the authors to mention funding bodies and there is no normalized way to do so. Sometimes the grant number might be specified, at other times it might not. There might be cases when the existing source of financial support is not named, though Mussurakis (1994), writing from the health sciences, considers that these are only sporadic cases, which occur especially when the research has been funded by private companies, such as the pharmaceutical industry.

3.3 Process of funding

3.3.1 Funding bias

By responding to specific research policies and heavily depending on the economic capacity of a country, funding is not neutral, and research is conditioned by 'historical trajectories' and 'entrenched in intellectual traditions that differ among nations and world regions' (Leydesdorff and Wagner 2009: 360). From the area of applied linguistics, Salager-Meyer, Ariza and Berbesí (2009, 2010), mentioned earlier, compare nine medical journals published in the USA, Venezuela, Spain, and France, and conclude underlining important differences in the sample in terms of language and geographical context. From the point of view of the economic power, Kokol et al. (2019) argue that a country economic growth also has an influence in nursing scientific production, being the countries with higher levels of gross domestic product the most productive in terms of both total number of publications and funded publications (22% of papers with FA in all countries vs. 28 in G8 countries). In An et al.'s (2017) study of collaboration among countries based on PubMed data, more productive countries appear to be more often referenced in the acknowledgement text, large countries, such as the USA and UK, tend to work as 'hubs' and reference to each other, whereas others, such as China, do not frequently collaborate internationally. Apart from economic affordances, there might be differences among countries in funding practices. Wang et al. (2012) compare funding in 10 countries as reported in 500,807 SCI papers published in 2009, highlighting than in some such as Spain, Germany, and China funding proceeds mostly by one single agency, whereas in others such as the UK, France, and Italy the sources of financial support are diversified.

3.3.1.1 Bias in research allocation. Research has evidenced the existence of important biases in research allocation. According to Laudel's (2005; 2006) research with German and Australian physicists results, funding allocation depends on variables often not related to the quality of the proposal, such as the country's general investment in research, the research field in which applicants are working, the availability of resources to prepare the project proposal, or the continuity of the research trail, that might cut off those who are starting their career or those who have interrupted it. Grimpe (2012), aggregating patents and publications data with data resulting from a survey with over 800 German scientists, conclude that funding is little influenced by merits, and that FP6 grants awarded by the European Union appear more political than other types of grants, addressing scientists who rarely make use of other funding instruments and responding to institutional and disciplinary characteristics of the proposals.

Regarding funding rates detected in the scientific literature about FAs, Díaz-Faes and Bordons (2014) found that 64% of Spanish articles published in 2010 included FAs, though with significant disciplinary differences. For example, the areas of physics, chemistry, biomedicine, agriculture, biology, and environment had percentages of FAs above 80%, whereas the social sciences and the humanities presented FAs in <30% of the papers. Similarly,

Costas and Yegros-Yegros (2013) in a study on Austrian funded publications in 2009–10, found that 53% of documents, including all types, reported FAs with differences among disciplines, being the social and economic sciences the fields with the lowest rates of funding. Sirtes (2013) also found higher values of FAs in chemistry, physics or biological sciences (above 75%) than in medicine, social sciences or humanities (below 40%) in both, German and worldwide scientific production published during 2009–11. Huang and Huang (2018) found a growing funding rate in 6 million documents published by G9 countries in 2009–14 and collected from WoS. Half of all documents mentioned FAs in all countries. Additionally, natural sciences tended to receive most funding and life sciences had the highest funded paper ratio.

3.3.1.2 Topic bias and the 'paradox of interdisciplinarity'. The selection process through which only a few applications are finally funded might also introduce additional bias. In public funding bodies, this process is usually a peer review task, not always exempt from bias. Interdisciplinary research has been found to be underfunded reflecting its limitations among which the low inter-rater reliability (Mutz, Bornmann and Daniel 2016). Kwon et al. (2017), for instance, after proposing a new method to identify interdisciplinary research in the fields of cognitive sciences and educational research, found that articles classified as knowledge-flow mediators that is, interdisciplinary research, were less likely to report FAs than discipline-oriented papers. Bromham, Dinnage and Hua (2016) reached the same conclusion after analyzing the research proposals submitted to the Australian Research Council's Discovery Program between 2010 and 2014. The authors found that interdisciplinary research proposals were less likely to be recommended for funding, maybe due to the greater difficulty to explain and justify proposals that does not fit in a well-defined discipline to a panel 'ill-equipped to evaluate all parts of the project', and the higher costs required, among other reasons (Bromham, Dinnage and Hua 2016). Peer review carried out by funding agencies appears reluctant to support new unorthodox ideas, fostering rather mainstream research (Zoller, Zimmerling and Boutellier 2014) instead of 'breakthroughs or change makers' in different areas of research including robotics (Mejia and Kajikawa 2018).

With reference to the tendency of policy makers and funding agencies to favor discipline-oriented proposals over interdisciplinary research, Woelert and Millar (2013) speak of the 'paradox of interdisciplinarity', first proposed by Weingart (2000): despite the fact that policy makers emphasize interdisciplinary research, few clear policies have been implemented in order to foster it, being poorly supported by funding schemes. Some US national associations and funding agencies, such as the NSF or the NIH, are encouraging research institutions to create interdisciplinary groups in order to build bridges between different fields of knowledge, combining different skills, and perspectives from a wider range of disciplines (Folkstad and Hayne 2011). However, the bias in favor of more mature and established fields as opposed to innovative research fields remains. The promotion of interdisciplinary research, Lyall et al. (2013) argue, requires a serious commitment on the part of funding bodies, allowing more flexible routes in terms of time and space and investing in liasons roles and less visible processes, such as warm-up activities, seed-corn support, team-building interactions, network- and community-building.

Funding bias exists also to specific disciplines or research topics such as rare diseases. In these cases, the analysis of FAs can be useful to identify the main funders of specific disciplines and to show other researchers where to obtain the resources needed to finance they research, mostly when we consider that it is non-profit organizations (charities, family foundations, and philanthropists) that support research into some rare diseases (Stehr and Forkel 2013). Seif and Trope (2010), highlight the problem of glaucoma research that, despite generating more and more interest among Canadian population, receives little funding from public agencies. Footman et al (2014) contend that the analysis of FAs can shed light on what the key research areas for funding agencies are and those that remain underfunded, despite being topics of public concern, such as some diseases causing high mortality among the population. The authors also stress the problem of having all the key funders supporting similar topics in similar geographic areas (i.e. HIV in Sub-Saharan Africa), since it duplicate the efforts and indicates poor coordination between funders, leaving other important issues with few alternative sources of funding, that may remain relatively under-studied.

3.3.1.3 Gender bias. Another recurring bias regards gender as women are found to receive proportionally less funding than men. Desrochers, Paul-Hus and Pecoskie (2017) argue that funding research on gender is rare and hampered by the quality of author data. Rong, Grant and Ward (1989) looked at factors explaining the rise of women authors in the sociological literature in the 1980s, concluding that funding could not be proved as a determinant factor in the sample of 856 articles published between 1974 and 1983. Larivière et al. (2011), studying the entire population of university professors of the region of Quebec (Canada), find a tendency for women to receive less funding from the age of 38, that is when highly educated women tend to have children. Sandström (2009), who connected individual researcher data on funding from Sweden Universities to incoming grants data, found that, of the 151 researchers analyzed, female researchers obtained less funding and on average from less funding bodies. Åström et al. (2013) study the impact of funding on collaboration networks in a sample of 93 scientists carrying out cancer research at the University of Lund (Sweden). If women, in general tended to have fewer publications than men, neither gender nor the type of research could explain the extent and density of the network which was influenced mostly by funding. Finally, Mauleón and Bautista-Puig (2019) concluded that publications authored only by women reported FAs less often than articles signed by men, although the highest funding rate was found in papers performed by both, women and men.

3.3.1.4 Bias at the publication stage. Funding may also generate bias at a later stage, when research is evaluated for publication in journals. Lewison and van Rooyen's (1999) experiment proved that biomedical papers acknowledging funding's bodies were more likely to pass the reviewing process than others. They sent each of the 309 articles received by the journal *BMJ* in the first semester of 1996 to two reviewers. One of the reviewer carried out the review anonymously, whereas the other had access to information regarding number of authors, number of institutions involved and FAs. They found that the 37 articles acknowledging one or more of eight leading funding bodies tended to have a higher score than the rest, and that FAs and reviewing scores were significantly and positively correlated. Some studies have analyzed the main factors affecting the

peer-review process and the probability of a paper to be accepted for publication. Ofri, Bdolah-Abram and Yair (2017), reviewed the 299 abstracts presented at the meetings of the European College of Veterinary Ophthalmologists between 2008 and 2012. and concluded that the presence of FAs was identified as a positive prognostic factor of being accepted.

3.4 Association of funding with productivity, impact, and collaboration

Measuring the returns of research is becoming increasingly important for funding bodies and scientific policy developers since they need to demonstrate the benefit of their investment. In this context, the analysis of FAs can be relevant to evaluate scientific research performance and to measure the impact of funding agencies and research sponsors (Giles and Councill 2004; Rigby 2011). According to Butler (2001), acknowledgements in scientific publications serve as a tool to evaluate the research performance funded by a funding body globally but not to assess concrete funding schemes because few authors specify which specific program provided the support. Furthermore, Rigby (2011) and Wang and Shapira (2011) highlight that measuring the performance of a specific funder may be difficult and problematic since papers usually acknowledge funding from multiple agencies. However, the analysis of FAs can be useful for research funders to identify gaps and overlaps in their portfolios and to improve the effectiveness and the impact of their support (Begum et al. 2016). This is especially relevant for health and biomedical research that has the potential to improve patient care and to reduce the negative effects of some diseases. Lepori et al. (2007) claim that an agreed upon set of indicators to measure public project funding is needed in order to allow comparisons between countries and across time, despite the difficulties that this task entails.

The availability of more structured data has fostered research on funding and its relationship with different outcomes, such as productivity, impact, or collaboration. Even if we present the results of this bulk of research under different headings, it results often difficult to separate these different dimensions of research, as most contributions address several of them at the same time or find important reciprocal implications among all them. As far as we know, the paper by Costas and van Leeuwen (2012) is one of the first general bibliometric studies which analyze, in an exploratory way, the FA information available in WoS. The authors analyzed the presence of FAs in scientific publications published in 2009, focusing on their distribution patterns across disciplines, countries, document types and types of collaboration, and their relationship with the impact of research. The analysis showed that 43% of all publications had FAs, despite important variations among countries. Regarding impact and collaboration, papers with FAs reached higher scientific impact. However, publications with longer FA texts, which could be related to the number of funders, had only slightly higher impact. In addition, a relationship between the presence of FA and the number of authors emerged, since more collaborative publications tended to acknowledge funding more often and had longer FA texts.

3.4.1 Productivity

Productivity is usually measured in terms of publications of research articles or patents, and funding in general has been found to increase productivity. In Mackintosh's (1972) work, more productive sociologists were more likely to acknowledge funding than less productive ones. The publication tracks of the more than a thousand scientists of Carayol and Matt's (2006) research show that, when it is public contractual funding, funding significantly increases productivity. Other works add some nuances to the general accepted association between funding and productivity. MacLean et al. (1998) measure the 'cost per paper', analyzing funded papers on malaria research published in 1984, 1989, and 1994, and comparing research output with funders' investment as inferred directly from a consultation with main international funding bodies. They found that the average cost per paper varied greatly among funding programs, probably due to the fact that some programs expected different types of research results, such as improvement in clinical settings. Auranen and Nieminen (2010) cast some doubts on the effectiveness of a competitive culture of funding at the country level and its productivity, as in their study countries with a high competitive funding system for university research such as the UK, Finland, or Australia, even though they produce more than the rest, are not able to increase productivity, whereas other less competitive countries such as Denmark, Sweden, or Germany managed to be as productive or even more productive without a competitive culture of funding. Other means apart from money can improve research productivity, such as the research conditions or continuity in funding, according to the authors.

Jacob and Lefgren (2011a), on the basis of a corpus of 54,741 successful and unsuccessful applications to the NIH, quantify as a 7% increase in productivity the effect of funding, which they qualify as 'modest'. Unsuccessful applicants might find support elsewhere, they conclude. This increase ascends to a 20% more productivity in the case of NIH postdoctoral grants (Jacob and Lefgren 2011b). According to Ebadi and Schiffauerova (2013) the positive association found by several studies between funding and productivity might be due to a selection bias in favor of already more productive researchers, leading to an overestimation of the effect of funding. In Sandström's (2009) study on funding from Sweden Universities, funding did not influence quality in terms of citation-based indicators, nor did the share of basic, strategic, or user-need funding influence productivity.

3.4.2 Impact

A considerable corpus of literature analyses the relationship between funding and citation or other impact indicators assuming that citations allow to quantify the quality, usefulness, and impact of investment or, in general, its success, at least in the earlier studies conducted in this line. Apart from citations, other impact indicators used include the Impact Factor (Díaz-Faes and Bordons 2014) or highly cited papers (Gök, Rigby and Shapira 2016), which are still a citation-based indicator. Another indicator of impact, especially in the biomedical literature, is the nature of research, and Lewison and Devey (1999) consider basic research of higher impact compared with clinical research. In general, it has been found that research with a more basic character tend to received more external support (Lewison and Roe 2012; Costas and van Leeuwen 2012; Díaz-Faes and Bordons 2014; Mwendera et al. 2017; Álvarez-Bornstein, Díaz-Faes and Bordons 2019) and it is more usually funded by public agencies than the clinical one, which receive support from private companies more often (Álvarez-Bornstein, Díaz-Faes and Bordons 2019; Fabiano, Marcellusi and Favato 2018). Obtaining more external support from public agencies appears as an indicator of impact per se.

Evaluating results of funding programs mostly in terms of citation or citation based indicators, it is difficult to assess whether other strategic aims of the funders are achieved or not. Lewison, and Devey (1999) analyze arthritis research carried out internationally in the period 1988–95 on behalf of the UK-based Arthritis Research Campaign (ARC), finding that ARC funded research had greater impact, measured as the Impact factor of the journal in which it was published, but tended to be more clinical than basic, contrary to the world tendency. Results may change depending on the discipline and the sample studied, though in general it seems that the association between citation-based impact indicators and funding is a positive one.

The field of *Library and Information Science* (*LIS*) counts with a few studies from this point of view. Harter and Hooten (1992) collected articles published in the *Journal of the American Society for Information Science* between 1972 and 1990, finding no relationship between funding status and usefulness operationalized as citations. Cronin and Shaw (1999) analyzed FA in 716 articles published in 4 important *LIS* journals between 1989 and 1993, concluding that 25% of the sample studied included a FA, though no relationship between citedness and funding could be confirmed. A positive relationship between frequency of acknowledgment and frequency of citation emerges from Cronin, McKenzie and Stiffler (1992) study of four top-ranked *LIS* journals between 1971 and 1990. Zhao (2010) analyze research funded through specific peer-reviewed grant programs compared with 'normal research' that is, research supported by the researcher's position at their own institutions and that have not received extra financial support, in a set of papers published in 7 core *LIS* journals in 1998. The author finds that funded research achieved substantially higher impact, measured through citation counts, and higher level of collaboration. However, the two most cited *LIS* articles by far were found among the normal research and were more methodologically oriented.

In other social sciences, such as in psychology, this relationship between funding and impact does not appear to be clear-cut. In Haslam et al.'s (2008) analysis of 308 research articles published in the field of social-personality psychology, the impact predictors included first author eminence, senior authors, journal prestige, article length, and number and recency of references, though grant support did not predict impact. In economics a positive association between funding and citation was found by Peritz (1990). In contrast, Cronin, McKenzie and Rubio (1993a,b) do not find a positive correlation between acknowledgement and citation in 10 Sociology journals between 1981 and 1990.

The health sciences present an important corpus of research on funding and citedness or other impact indicators. Studying the international literature published in the area of arthritis research, Lewison and Devey (1999) find that papers with FAs tended to have a significantly higher impact, measured as the impact factor of the journals and as the type of research sponsored. A positive relationship between the presence of FAs and citations was found by Fabiano, Marcellusi and Favato (2018) in a study of 637 publications by leading scientists who appears as founders of 91 UK biotechnology companies, although the origin of the financial support (public/private) did not affect citation counts. The positive association between funding and citedness within the radiology literature published in 1990 in two major journals allows Mussurakis (1994) to claim more financial support for radiology research, since in only 17% of the 736 articles analyzed, formal funding was recognized. Pao (1991) shows that a relationship exists between funding and productivity, on the one hand, and between funding and quality (journal impact factor and citation counts), on the other, in schistosomiasis research funded by four major funding organizations, including the *World Health Organization*, in the period 1970–86. In general, funded research presents an advantage over non funded research in several health specialties, including gastroenterology (Lewison 1998; Lewison and Dawson 1998), malaria research (MacLean et al. 1998); or cardiovascular research (Lyubarova, Itagaki and Itagaki 2009). Lewison and Dawson (1998), after analyzing 185.000 gastroenterology papers published in the period 1988–94, found that funding indeed improves impact; however, other factors turn out to be positively influential such as the number of authors and funding bodies, and the nature of research (basic achieved greater impact than clinical research). Other nuances in the impact of funded research in biomedicine have been detected. Bourke and Butler (1999), for example, aim to discover the influence of the mode of funding (for instance, project funding vs. institution funding) on impact, to find out that, more than the mode of funding, it is the nature of the researcher's appointment to influence the visibility in terms of citations of the resulting research, at least in the biological sciences. Full-time appointed researchers had a higher visibility than researchers busy with other duties apart from research such as teaching or clinical work. Campbell et al. (2010) measure the impact of 685 Principal Investigators supported by the National Cancer Institute of Canada (NCIC) funding. Their publication track records in WoS show a major productivity and a higher average citation impact for all publications supported by the NCIC.

On the other hand, Granda-Orive et al. (2015) do not find a positive effect of funding on citation in a set of 193 WoS research articles on smoking published between 2010 and 2014, though the sample they select only includes the articles with the highest h-index. Abad-García, González-Teruel and Sánchez (2017) compare funding of Spanish pediatric articles published in international journals, on one hand, and on the Spanish journal *Anales de Pediatría*, on the other, in the period 2010–14. The local journal published less funded articles which did not have a greater impact than non-funded articles.

In the natural sciences and engineering, Lewison (1994) compared citations with biotechnology papers funded by the European Commission and published in 1987 and 1988 to citations to a cohort comparison sample of papers published in the same journals, and found that EU funded papers received more citations, though mostly from other European scientists, probably as a consequence of the diffusion activities of the Commission to make results known to all member states. More recently, Morillo (2019) also found greater impact in EU funded research, that shows relative citation rate above the world average, even higher than that with funding from other countries, in a disciplinary analysis of Spanish publications. The positive association between funding and impact, measured in terms of citations, has been confirmed in the STEM disciplines: Astrophysics, Computer Science, Engineering, Environmental Studies, Mathematics, Medicine, and Nanotechnology (Yan, Wu and Song 2018); computer science (Stamou, Tzekou and Zotos 2009); nanotechnology (Wang and Shapira 2015). Díaz-Faes and Bordons (2014), in the categories of cardiac and cardiovascular systems, economics, evolutionary biology, and statistics and probability, found a higher presence of papers with FAs in first quartile journals, which suggest a higher quality of funded research may be due to the strict and rigorous peer-review process that it has to pass through and to the greater access to economic, technical and human

resources. Costas and Yegros-Yegros (2013) reached similar conclusions in an analysis of Austrian research published in 2009–10, where papers with FAs had the highest citation scores and were published in high impact journals. In Ebadi and Schiffauerova (2016) study of Canadian Natural Sciences and Engineering research published in WoS journals in the period 1996–2010, funding had a positive impact both on productivity and quality (number of citations).

3.4.2.1 The effect of multiple funding on impact. The number of countries or funding bodies involved in the research as funders also may contribute to generate more scientific impact, probably for the greater acceptance that this circumstance generates in peer reviewers and suggesting that the funding review process selects 'more promising' projects (Wang and Shapira 2015). According to Rigby (2013), the number of funders might be considered an indicator of impact, because research supported by a high number of agencies is supposed to have passed through several peer review processes. Boyack and Jordan (2011) analyzed research funded by the US PHS, concluding that research supported by the PHS receives twice as much citations and that citation impact even increases when research received funding from different types of agencies apart from the PHS, such as other US governmental agencies or private foundations (10% and 40% higher, respectively). However, the relationship between citation impact and number of funding sources is weak, so the count of funding bodies should not be considered as an indicator of research impact and quality per se, according to Rigby (2011). Yan, Wu, and Song (2018) did not encounter major impact when several funding sources were acknowledged suggesting that research support could be better taken advantage of, if it is distributed among different research teams.

Rigby and Julian (2014) raise the issue of the 'double-dipping' or double funding in research that is, the fact that researchers receive more financial support from more than one institution for the same project, and whether it leads to a waste of resources, in a context of scarcity of funding or, in contrast, research produced under these conditions achieves greater citation impact. By analyzing articles and reviews published between 2008 and 2012 collected from WoS funded by the European Molecular Biology Organization or the Human Frontier Science Program, or from both, they found that jointly funded articles were statistically more likely to receive more citations than those financed separately. However, this finding could be attributed to the involvement of larger research groups rather than double funding.

3.4.2.2 Institutional scientific impact. At the institutional level, funding can be considered as a measure of achievement and research performance (García and Sanz-Menéndez 2005; Belter 2013). In the evaluation of British university departments carried out in 1985–86 and 1989, departments were prized based on their capacity to attract funding, Gillett (1991) explains. However, the case of Psychology departments analyzed in (Gillett 1991) showed a financial advantage for less efficient departments with below average publication records over others. Hornbostel (2001), studying the case of German universities, looks for a relationship between funding and research performance indicators, concluding that both productivity and citations tend to rise with funding, at least in areas where funding is usual, such as physics. A funding indicator could be useful in universities internal processes of decision making and monitoring, pointing to research performance and some degree of investments in infrastructure and technical equipment, Hornbostel (2001) concludes.

Some studies have tried to answer the question of whether private funders have been more successful in selecting important research than governmental agencies. Using the number of citations as a measure of important research, Diamond (2006) tried to demonstrate if importance is related to the type of funding agency. After analyzing the FA information included in 53 Chemistry papers published in 1985 by North American scientist in the Reports section of *Science*, he found that the number of private grants was a positive and statistically significant predictor of whether the article will be highly cited in both the short and the long term, concluding that private funders were more likely to produce important research. Morillo (2016) studied the interaction of the public and private sector through the FAs in order to provide a different perspective and complement the information of other approaches especially focused on co-authorship as an indicator of collaboration. The author argue that research funded by both, the public and the private sector, is performed in greater research groups with several researchers from different organizations and produce higher impact than that funded only by public or private agencies separately.

Another line of research is the analysis and the assessment of the scientific output derived from specific funding schemes. For example, Rodríguez-Padial et al. (2019) analyzed the impact of the scientific production published from 2012 to 2017 that acknowledged funding from The Spanish Society of Cardiology/Spanish Heart Foundation, concluding that, on the basis of the number of citations per article, the bibliometric impact of the funded research was 'acceptable'. Möller, Schmidt and Hornbostel (2016) assess the effects of the German Excellence Initiative by focusing on the papers produced by the Clusters of Excellence, one of its funding lines aimed at strengthening the German research system, enhancing its international competitiveness and the international visibility of German universities. The proportion of papers in the world 10% most cited paper was higher for articles resulting from the funding program than for articles published in the pre-funding period, concluding that the Excellence Initiative has succeeded in fostering excellence research, though its effect in the German research system has generally been moderate, since the worldwide impact of its scientific production has experienced only a slightly increase.

It remains to be determined whether research funders expect results as citations or have different expectations about the impact of the research they support. Te et al. (2018) look at the research output of the project Go4Health, co-funded by the European Commission's Seventh Framework Program and Australia's National Health and Medical Research Council. All documents published within the project were analyzed from a qualitative (content analysis) and quantitative point of view (citation analysis), concluding that the analysis showed the contribution of funded programmatic research to the global health discourse. Gök, Rigby and Shapira (2016) address the relationship between citation impact of funded articles and the source of funding (national public funders, international public funders, EU funders, and nongovernmental and corporate funders) for six small European countries (Belgium, Denmark, Netherlands, Norway, Switzerland, and Sweden). Analyzing publications collected in WoS from January 2009 to December 2011, the study finds that in general funded research is more likely to be highly cited than non-funded research, and that research funded by nongovernmental corporate entities tends to be associated with higher citation impact articles than international or

EU funding. The authors argue that public funders may be pursuing more complex strategic objectives than citations, such as broad participation of EU members in the case of European research programs.

3.4.2.3 Alternative impact measurements. Citations are only one side of a multidimensional concept such as research impact and alternatives have been explored to measure the impact of research funding. Zhao et al. (2018) address the relationship between FAs and usage counts, measuring whether funded papers attract more usage on the basis of the Usage Count indicator provided by WoS. With this purpose, a total of 300,010 articles published in 2013 in six subject categories were analyzed concluding that a positive correlation between funding and usage metrics existed, but with differences among disciplines.

The aggregated results concerning the relationship among funding and impact might change if, instead of citation and citation based indicators such as the impact factor, a different conception of impact is taken. Simply by pointing to a wide range of relationships among people, companies, institutions, and research (Councill et al. 2005), acknowledgements have a high potential to reflect some kind of societal impact. They draw attention to traditionally invisible actors of the scientific production system, such as governmental and corporate sponsors of research. A corpus of research analyzes scientific references in patents in order to describe the connection between basic research and innovation, whilst funding bodies acknowledged in the scientific articles cited are also studied and characterized. Ellwein, Kroll and Narin (1996) analyzed scientific articles cited in eye-care technology patents and found that research funded by the National Eye Institute appeared cited in 31% of all patents retrieved (41% when the NEI was mentioned with another funding body), pointing to a less manifest, though clear link between public funding and innovation. In Anderson et al. (1996), it is a corpus of 1,105 US patents in human molecular and cell technology to be studied by a similar methodology and evidencing the importance of basic research for innovation and intellectual property, on the one hand, and of government agencies and industry as the most important funding bodies.

The traditional rationale for public funding of basic research assumes that basic research simply provides codified information to society, according to Salter and Martin's (2001). However, the way basic research promotes economic development is much more complex and not always straightforward. Salter and Martin (2001) mention at least six different important ways in which basic research supports economic development: 1, it is a source of new and useful knowledge; 2, it provides new instrumentation and methodologies; 3, it allows obtaining tacit knowledge and skills to those involved in basic research, especially graduate students; 4, it grants access to national and international networks of experts; 5, it fosters the ability to solve complex problems; and finally, 6, basic research might support the creation of spin-off companies, transferring skills, tacit knowledge, problem-solving abilities directly into a commercial environment. If governments are under increasing pressure to justify public expenditure on basic research, Salter and Martin (2001) argue, a new rationale for basic research should be developed, getting over the simple provision of codified information, and accepting new accomplishments as research results, such as new interactions, networks and technological options and diversity. This means that measuring results in terms of impact citation-based indicators is too restrictive. In this sense, and considering that funding gives visibility to non-academic actors in knowledge production, it is surprising that little research has dealt with the societal impact of funded research.

The literature on fundings often mentions the difference among basic and clinical research, in some cases considering basic research per se as an indicator of research quality. However, clinical research allow to apply knowledge into practice in a more agile way, as Liebow et al. (2009) point out, by observing that an important share of asthma research funded by the National Institute of Environmental Health Sciences (NIEHS) between 1975 and 2005 was published in clinical oriented journals. However, a more thorough understanding of health and societal impact of the NIEHS funding, including 'changes in health legislation, reductions in asthma mortality, emergency department utilization, hospitalization rates, rescue medicine use, and improvements in quality of life' (1,152) was hindered by the lack of reliable data sources in these dimensions.

Exclusive reliance on bibliometric indicators does not allow to evaluate the ability of research funding to address societal problems such as those undertaken by transdisciplinary research. Koier and Horlings (2015) set out to evaluate two research programs on climate adaptation in The Netherlands and point out important limitations of WoS as a source of data: it does not reflect accurately enough information to reconstruct a program's output and is unable to reflect the contribution of non-academic actors, disregarding locally and practically oriented research.

The growing reliance on purely bibliometric indicators to assess the impact of funding schemes responds to increasing demands for accountability, transparency, efficiency, and responsiveness of public sector activities under the paradigm of the New Public Management which supports the managerial governance of private organizations for public bodies (Sá, Kretz and Sigurdson 2013). However, among the negative effects of this new culture, Sá, Kretz and Sigurdson (2013) mention a reward in favor of conformity rather than risk-taking and unorthodox research, threatening diversity to deal with research problems and making invisible all research that cannot be measured by established indicators. Interviews with international research councils and the analysis of the pertinent legislation allows them to conclude that the actual capacity of agency staff is still underdeveloped, especially with regard to longer-term impact and outcomes.

3.4.3 Collaboration

Funding has also been studied from the point of view of collaboration. Although several studies conclude that FAs are related to increased collaboration, others highlight the role FAs in revealing patterns of sub-authorship and giving preference to more collaborative teams. Heffner (1981) observes a parallel increase in collaboration and funding, and looks at a relationship between these two variables, expanding the concept of collaboration to sub-authorship. He finds that for the 395 articles published between 1974 and 1975 in political sciences, chemistry, biological sciences, and psychology, there was a significant relationship between funding and the number of authors, on the one hand, and between funding and technical sub-authorship, on the other, whilst the relationship was not significant for funding and theoretical sub-authorship. Morillo (2016) also concludes that funded research tends to have the highest number of authors and organizations and the greatest proportion of national

collaboration in a sample of WoS Spanish articles from eight different thematic areas. A higher number of authors in papers with FAs, as compared with those without FAs, is also found by Díaz-Faes and Bordons (2014) in a set of Spanish articles. Yegros-Yegros and Costas (2013), addressing the factors influencing the acknowledgement of funding in a set of documents published by Canada, Germany, The Netherlands and Spain during 2009–11, find that both national and international collaborations were more likely to report FAs and, specifically, the collaboration with countries such as USA and China contributed more substantially to the presence of FAs. In addition, Möller (2019), also found higher international collaboration rates for research funded by foreign agencies in a study of the research performance in four European countries. Finally, in a study on Russian cancer research, Lewison and Markusova (2010) find that papers in international collaboration reported funding from more agencies than those in only domestic collaboration.

If funding fosters collaboration, collaboration in turn can also achieve greater funding support because of its potential influence on citation and impact. According to Levitt (2011), the comparatively higher citation rates of research funded under some NSF scheme might depend on the NSF funding larger teams than the pharmaceutical industry. The fact that funded research is carried out by larger research groups can be explained by the enhancement of scientific collaboration by funding agencies (Wang and Shapira 2011). Funding affords greater economical and technical resources promoting collaboration, and funding agencies tend to finance more complex research which is usually performed in greater research groups and requires more infrastructure (Zhao 2010; Díaz-Faes and Bordons 2014).

When funding bodies are looked at as research partners, collaboration with different funding bodies might result in different outcomes. In terms of scientific production, Beaudry and Allaoui (2012) show that, in the field of Canadian nanotechnology, public funding clearly increases scientific productivity, whereas private funds lead to more patenting at the expense of scientific production. Hottenrott and Lawson (2017) look at the interactions between public and private funding when different sources of funding are mentioned in the same article. When public and private funding occur simultaneously, the patentability of research outcomes increases, pointing to the complementarity of public- and private-sector research funding. However, basic science publications, citations or average impact factor increase only when funding comes exclusively from public bodies, whereas industry funding and public funding occurring in the same acknowledgement reduce publication rate and research quality. On the other hand, according to Azoulay et al.'s (2018) study, public funding from the NHI leads to an increase of private-sector patenting.

The way funding bodies support research may influence not only the kind of knowledge that is produced but also impact. Shapira and Wang (2010), relying on the analysis of nanotechnology research published between 2008 and 2009 in journals covered by WoS, find that sponsors who concentrate funds in fewer institutions have lower research impact. They suggest opening funding competitions to international researchers and fostering mobility and international collaborations of domestic researchers.

Funding fosters collaboration and allows setting larger and long-lasting collaboration teams. Ubfal and Maffioli (2011), compare funded and non-funded research projects in Argentina, a developing country, and conclude that funding clearly affects collaboration by fostering larger teams of researchers that kept working even after the completion of the project. In Defazio, Lockett and Wright's (2009) study too collaboration increases in the post-funding period as a capitalization of funding opportunities. Funding more than gender or the type of research (basic versus clinical) resulted in greater and denser research collaboration networks for the 93 Swedish scientists involved in cancer research whose publications were analyzed in (Åström et al. 2013). The impact of funding on collaboration is confirmed by Ebadi's (2014) study of researchers funded by the Natural Sciences and Engineering Research Council of Canada (NSERC) in the period 1996–2010 with data extracted from Scopus and Scimago Journal Rankings. Although differences in the quantity and quality of research existed among Canadian provinces, funding had a positive impact on collaboration in all provinces, and academic researchers were found to work in smaller teams than non-academic researchers. According to Ebadi (2014), a Matthew Effect exists in the sense that funding, scientific team size and past productivity influence the rate and quality of publication, increasing in this way the chances of getting funded again and of further collaboration. This might also cast some doubts on the positive relationship between funding and productivity, as the way funding influences productivity is far more complex and may be due also to collaboration patterns (Ebadi and Schiffauerova 2013). Clark and Llorens's (2012) study, relying on data of a previous survey by the Research Valuing Mapping Project of 2,086 academically based research scientists and engineers, confirms the association between government funding and increased collaboration, as well as its impact on productivity and consequently on the probabilities of obtaining future financial support. However, they add some nuances to the extensive literature they review on the positive associations between funding and collaboration, as it seems that funding resources support collaboration only up to a certain extent, and that, in order to encourage further collaboration, other strategies should be promoted, such as conferences, colloquia, symposia, trainings, or networking activities.

Collaboration is related to the internationalization of funding agencies programs, whose indicators are assessed in a participatory fashion in (Reale et al. 2012). Internationalization, Reale et al. (2012) argue, allows enlarging the set of collaborators and expertise, strengthening research excellence and innovation performance, and responding to global challenges. International funding, which is an implicit form of international collaboration, can sometimes allow to achieve improved results, as in the case of Russia described by Markusova, Libkind and Aversa (2012). Analyzing all the articles corresponding to Russian authors in WoS for 2009, they found out that publications supported by foreign agencies had more visibility and were published in higher impact journals than average Russian publications. In (Tan, Zhao and Ye 2012), the collaboration network of 1,871,699 funded research articles in the SCI Expanded and Social Sciences Citation Index of WoS during 2009–11 shows a clear dominance of the USA and few European countries, leading the authors to conclude that policy makers should foster collaboration with a wider range of countries. The effect of funding on collaboration seems independent of other factors, such as the amount of funding. Ebadi (2014) differentiates Canadian provinces into two classes, 'high funding' provinces and 'low funding' provinces. The effect of funding resulted in more quality research for the high funding provinces, whereas low funding provinces gained in productivity increasing the quantity of publications. However, the effect on collaboration was the same for the two groups. Zhou and Tian (2014) look at funding and collaboration in Chinese mathematics research and find again a difference among Chinese provinces in terms of

capacity to obtain funding and to establish collaboration networks. The provinces that were better at establishing cross-institutional and international collaboration also performed better in raising productivity and achieving research funds as well.

3.4.4 From collaboration to diversity

The interconnections between funding, productivity, impact, and collaboration and their reciprocal influence may generate a situation of concentration of resources, responding to the Matthew Effect that Ebadi detected in his analysis of Canadian provinces (2014). With a longitudinal perspective on the 43,000 grants awarded by the UK EPSRC between 1985 and 2013, Ma, Mondragón and Latora (2015) observe that whilst total funding increased steadily over time, the number of grants declined after 2001, with a trend to fewer grants of larger value. The network analysis of partnership of successful projects showed that leading universities had become the knowledge brokers of the network coordinating partnership and increasing their ability to produce varied and high impact research. These elite institutions besides tended to collaborate with each other. Commenting on Ma, Mondragón and Latora's (2015) results, Szell and Sinatra (2015) observe that it is not clear whether this progressive concentration of funding should be a matter of concern, considering that elite universities are producing high impact research. However, the risk of failure exists and funding bodies must be aware of the fact that investing highly on few institutions could also have a high cost. Considering the polarization of funding in certain institutions, countries or even regions, Fortin and Currie (2013) suggest that diversity instead of excellence should guide scientific policies and allocation of research funds. They find out that the amount of funding had only a weak influence on impact, at least on the sample of researchers who had been awarded a grant by the Natural Sciences and Engineering Research Council of Canada (NSERC) in 2002. Larger grants had proportionally a weaker impact per dollar and impact resulted as a decelerating function of funding. Mutz, Bornmann and Daniel (2016) draw on De Los Reyes and Wang (2012) theoretical contribution in favor of a continuous model of financial support in which funding is allocated based on reviewers' ratings, covering in this way more proposals than in a dichotomous 'winner takes all' model.

3.5 Other aspects affected by funding

Other aspects may be affected by funding, such as education and training. Oleksiyenko and Sá (2010) describe global health as an emerging academic field in a few Canada and US universities, pointing to the influence of funding and research also on training and education. Their study highlights a cumulative advantage of US institutions in terms of domestic sources of support and previous academic structures.

Thomas and Nedeva (2012) develop a 'researcher characterization framework' that takes into account researchers themselves rather than their output in order to study the impact of research funding agency schemes and promotion and possibilities to get tenure. A survey with 184 successful and unsuccessful but above quality thresholds applicants to the European Research Council (ERC) early career Starting Grants (StG) allows them to find a variety of grantee types, mostly not yet independent researchers whose 'standing' could be impacted by the funding scheme.

An important aspect that funding can influence is the nature of knowledge that is produced. Among the external factors influencing research that can be tracked through FAs, the influence of the private sector in research is of special concern in health research. Campbell, Louis and Blumenthal (1998) collected results from a survey with 2,167 Life Sciences scientists working at 50 US universities about research-related *gifts* from private companies which were not related to grants or contracts. Forty-three percent of respondents reported having received *gifts*, and of these 66% declared that these *gifts* were important to their research. However, only in some cases were such gifts acknowledged in the corresponding publications. Making private funding visibles is of pivotal importance considering that commercial funded research tends to be biased towards positive results (Begum and Lewison 2017). Receiving funding from the private sector, especially from multinational companies, can lead to possible conflicts of interest, meaning that the relationships of scientists with private companies can have an influence on the research carried out, potentially detrimental to the public good. Among the papers that have studied the role of companies acknowledged in scientific publications as funders, Stuckler, Ruskin and McKee (2018) investigated the email correspondence between the majors of an important soft drink company and the scientist researching on a project about childhood obesity funded by this company. Although in more than a half of the papers resulting from the project the authors clearly expressed that the funder had no role or influence on the research, Stuckler, Ruskin and McKee (2018) found evidence of company attempts of what they called 'soft power' that is, the authors tried to please and satisfy the funders by following their guidance in the study design and in the presentation of the findings.

4. Conclusions

The extensive interdisciplinary literature covered in this review shows the great interest in studying research funding through acknowledgements for several different purposes. Some studies look at the funding landscape of certain disciplines or research areas, whereas others search impact indicators for evaluating funding programs, interventions or grants. An important bulk of research addresses acknowledgements and FAs in the context of scientific communication, highlighting the information they can offer on authorship, sub-authorship and collaboration, and the connections between funding, productivity, and impact. From this point of view, the literature reviewed, even if it was focused on FAs and acknowledgements may cover more than simply funding, shows that a theory of acknowledgements based on the triangle metaphor (Cronin and Weaver 1995; Desrocher, Paul-Hus, and Larivière 2020) is unable to capture the extreme complexity of the scientific activity affecting and being affected by FAs. Considering the way collaboration, productivity, impact and funding interact in the scientific production system, the reward triangle connecting authors, acknowledgements and citation appears as a simple clique of a much more complex network in which each node connects with others, influences others and is being affected by others. Productivity, impact and collaboration influence the probability of obtaining research funds and funding in turn has an impact on productivity, citation and collaboration, in such a way that it is impossible to untangle individual contributions. The nature of knowledge itself conditions the possibilities of funding, by penalizing, for instance, interdisciplinary research (Bromham, Dinnage and Hua 2016), whereas external actors show clearly their influence in the knowledge produced by deciding how and to whom afford financial support.

Such a complexity requires drawing on a more complex set of data than citation indexes may afford, in order to provide a better conceptualization of FAs in scientific communication and knowledge production, and exploit all their potential. Even if citation indexes data allow a large perspective and their quality has been improving over time, they gather information in a non-normalized fashion and cannot provide all funding bodies internal data, such as all the research partners that do not qualify as authors of a particular article, for instance, and it is therefore important that other data sources are exploited, such as data coming from funding bodies or research and academic institutions. This might place a certain responsibility on funding agencies regarding the data that they may collect on their programs, as well as the normalization policies they need to develop so that funded authors can reference with less ambiguity the financial source of their projects. Available data are still scattered or incomplete and their availability depends greatly on authors, journals and funding agencies. As a matter of fact, initiatives are being taken such as FundRef, a registry of funding organizations sponsored by CrossRef, now implemented in many publishers' submission systems, allowing authors to select among a preloaded set of normalized funders, which may increase the accuracy of funding data. It is up to funding agencies and journals to enforce authors to mention funding, if there was any, or the absence of financial support in those cases in which the research was carried out without a specific grant. On the other hand, if funding bodies have a responsibility in collecting and making data about funded programs available, the research community should systematically collect information about the availability of data from funding bodies and other sources, as advances of research into FAs depend also on relying on more precise, robust, and diversified datasets than those available in citation indexes. Diverse datasets imply also diversifying methodologies and several studies mentioned in this review use less common techniques to complement traditional citation-based analysis, such as content-analysis (Slaughter and Leslie 1997; An et al. 2017; Te et al. 2018) or network analysis and other forms of visualization (Boyack and Börner 2003). From this point of view, the investigative potential of FAs is still high and full of creative opportunities for research.

Some scientific literature has explored acknowledgements searching for new indicators (Desrochers, Paul-Hus and Pecoskie (2015). However, the complexity and diversity of FAs does not allow to obtain ready for use indicators to apply in evaluation processes, not only for the lack of data normalization and the bias that it introduces, but also because we still do not know if citation-based indicators really suit the aims and objectives of the multiple actors converging in the dynamics of knowledge production. Indeed, this review points at funding bodies as clear and influential actors in the scientific communication system, making important decisions on the research and researchers that are supported, and influencing the type of knowledge that is produced and is made visible in major databases. For instance, if public funding appears to result in more scientific publications, private funding increases the chances of patenting research results and publishing positive results. These actors have responsibilities not only in the collection, normalization, and availability of data, as mentioned earlier, but also in determining their policies regarding expected results and responding to the claims of transparency and diversity in funds allocation strategies that a certain sector of the scientific community has made. This review has shown that funding increases productivity and, more often than not, impact of funded research. However, funding has also been found to be biased, responding to several different factors either related to the researcher (from position to gender), the nature of the research (interdisciplinary, unorthodox. . .), or the type of collaboration. The phenomenon of polarization of research funding has also been observed with certain concern both in terms of research topics and areas (Díaz-Faes and Bordons 2014; Footman et al. 2014; Zoller, Zimmerling, and Boutellier 2014) and institutional or regional capacity for attracting funding (Ebadi 2014; Fortin and Currie 2013), whilst the process itself of funding allocation seems to respond to a San Matthew effect (Ebadi and Schiffauerova 2013; Ebadi 2014), rewarding already highly productive authors. Research evaluation has traditionally been carried out according to the needs and values of the scientific community with the addition of an increasing bureaucratization required by public funding institutions. If we are to exploit acknowledgements to look at whether research satisfies funders aims and, through these, societal needs, new values should be integrated in the research evaluation process, such as diversity and transparency, for example. If diversity can address the problem of progressive polarization of research funding, transparency is especially important in making visible, among the other, the participation of the private sector in the research process (Pollock and Ewer 2010). It is imperative that the scientific community and funding bodies agree on expected results and make these explicit and transparent, addressing clearly their connection to specific societal interests and possible evaluation criteria and supporting datasets. Citation indexes data may be easy to use but do not allow to fully evaluate the output and collaboration networks of certain research projects addressing problems such as climate change and adaptation (Koier and Horlings 2015). Indeed, it emerges from the review that scientific research can provide more than codified information and that dimensions such as new interactions, networks and technological options and diversity should be integrated into the research evaluation process (Salter and Martin 2001; Sá, Kretz and Sigurdson 2013). A new model of funding allocation has also been claimed (De Los Reyes and Wang 2012; Kaiser 2014; Mutz, Bornmann and Daniel 2016), whilst the actual capacity of agency staff has been considered 'underdeveloped' with regard to longer-term impact and outcomes (Sá, Kretz and Sigurdson 2013). Probably a thorough reflection on research policies and expected outcomes would also be able to solve problems such as the 'paradox of interdisciplinarity' (Woelert and Millar 2013). In sum, the future of FA research depends on the collaborative effort of the research community and funding bodies. The research community should make an effort to discover and analyze new datasets, not just data from citation indexes, such as institutional or funding bodies data, and draw on new and thus more informative research methods. On their part, funding bodies should systematically collect data, and identify more clearly the objectives and results they expect from the research they fund. If funding bodies, as it appears from this review, can be considered as actual research partners, research should be evaluated not only on the basis of the scientific community values but also of the values of the society and the social actors that funding bodies represent. In other words, research into FA could help understand and shape a new scientific communication system.

To conclude this review retaking the objective stated at the beginning, the need to summarize research into FAs from a conceptual perspective, our opinion is that advances of research into FAs might be achieved in the framework of what is known as 'societal impact of research', a research area that does not count yet on a fully developed theory (Tahamtan and Bornmann 2020). However, research

into the societal impact of science addresses concepts that have emerged from this review such as interactions (De Jong et al. 2014), networks (Joly et al. 2015), and contributions (Temple et al. 2018), while taking into account the economical dimension of research which is implicit in the concept itself of FAs (Miettinen, Tuunainen and Esko 2015). FAs research could profit from this already extensive body of research.

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References

Abad-García, M. F., González-Teruel, A., and Sánchez, G. S. (2017) 'Investigación Pediátrica Española Financiada: Contribución de Anales de Pediatría a su Difusión', *Anales de Pediatría*, 86: 306–13.

Alcaraz, D. I. M., and Ariza, M. A. A. (2015) 'Exploring Acknowledgement Practices in English-Medium Astrophysics Research Papers: Implications on Authorship', *LFE: Revista de Lenguas Para Fines Específicos*, 21: 132–59.

Alnemary, F. M., Alnemary, F. M., and Alamri, Y. A. (2017) 'Autism Research: Where Does the Arab World Stand?', *Review Journal of Autism and Developmental Disorders*, 4: 157–64.

Álvarez-Bornstein, B., and Bordons, M. (2019). 'Industry involvement in biomedical research: Authorship, research funding and conflicts of interest', in *17th International Conference on Scientometrics and Informetrics, ISSI 2019*, pp. 1746–51.

Álvarez-Bornstein, B., Díaz-Faes, A. A., and Bordons, M. (2019) 'What Characterises Funded Biomedical Research? Evidence from a Basic and a Clinical Domain', *Scientometrics*, 119: 805–25.

Álvarez-Bornstein, B., Morillo, F., and Bordons, M. (2017) 'Funding Acknowledgments in the Web of Science: Completeness and Accuracy of Collected Data', *Scientometrics*, 112: 1793–812.

An, J., Jeon, S., Jones, T., and Song, M. (2017) 'Data-Driven Pattern Analysis of Acknowledgments in the Biomedical Domain', *Data and Information Management*, 1: 35–48.

Anderson, J., Williams, K., Seemungal, D., Narin, F., and Olivastro, D. (1996) 'Human Genetic Technology: Exploring the Links between Science and Innovation', *Technology Analysis & Strategic Management*, 8: 135–56.

Åström, F., Hedenfalk, I., Graffner, M., and Nilbert, M. (2013). 'Effects of research funding, gender and type of position on research collaboration networks: a micro-level study of Cancer Research at Lund University', in Gorraiz J., Schiebel E., Gumpenberger C., Hörlesberger M., and Moed H. (eds), *Proceedings of ISSI 2013 Vienna: 14th International Society of Scientometrics and Informetrics Conference*, pp. 677–89. Austrian Institute of Technology GmbH Vienna.

Auranen, O., and Nieminen, M. (2010) 'University Research Funding and Publication Performance—an International Comparison', *Research Policy*, 39: 822–34.

Azoulay, P., Graff Zivin, J. S., Li, D., and Sampat, B. N. (2018) 'Public R&D Investments and Private-Sector Patenting: Evidence from NIH Funding Rules', *The Review of Economic Studies*, 86: 117–52.

Bakker, V. J., Baum, J. K., Brodie, J. F., Salomon, A. K., Dickson, B. G., Gibbs, H. K., Jensen, P., and McIntyre, P. B. (2010). 'The Changing Landscape of Conservation Science Funding in the United States', *Conservation Letters*, 3: 435–44.

Beaudry, C., and Allaoui, S. (2012) 'Impact of Public and Private Research Funding on Scientific Production: The Case of Nanotechnology', *Research Policy*, 41: 1589–606.

Begum, M., and Lewison, G. (2017) 'Web of Science Research Funding Information: Methodology for Its Use in Analysis and Evaluation', *Journal of Scientific Research*, 6: 65–73.

Begum, M., Lewison, G., Wright, J. S., Pallari, E., and Sullivan, R. (2016) 'European Non-Communicable Respiratory Disease Research, 2002-13: Bibliometric Study of Outputs and Funding', *PLoS One*, 11: e0154197.

Belter, C. W. (2013) 'A Bibliometric Analysis of NOAA's Office of Ocean Exploration and Research', *Scientometrics*, 95: 629–44.

Bourke, P., and Butler, L. (1999) 'The Efficacy of Different Modes of Funding Research: Perspectives from Australian Data on the Biological Sciences', *Research Policy*, 28: 489–99.

Boyack, K. W., and Börner, K. (2003) 'Indicator-Assisted Evaluation and Funding of Research: Visualizing the Influence of Grants on the Number and Citation Counts of Research Papers', *Journal of the American Society for Information Science and Technology*, 54: 447–61.

Boyack, K. W., and Jordan, P. (2011) 'Metrics Associated with NIH Funding: A High-Level View', *Journal of the American Medical Informatics Association*, 18: 423–31.

Braun, D. (1998) 'The Role of Funding Agencies in the Cognitive Development of Science', *Research Policy*, 27: 807–21.

Bromham, L., Dinnage, R., and Hua, X. (2016) 'Interdisciplinary Research Has Consistently Lower Funding Success', *Nature*, 534: 684.

Butler, L. (2001) 'Revisiting Bibliometric Issues Using New Empirical Data', *Research Evaluation*, 10: 59–65.

Campbell, E. G., Louis, K. S., and Blumenthal, D. (1998) 'Looking a Gift Horse in the Mouth: Corporate Gifts Supporting Life Sciences Research', *JAMA*, 279: 995–9.

Campbell, D., Picard-Aitken, M., Côté, G., Caruso, J., Valentim, R., Edmonds, S., Williams, G. T., Macaluso, B., Robitaille, J. P., Bastien, N., and Laframboise, M. C. (2010) 'Bibliometrics as a Performance Measurement Tool for Research Evaluation: The Case of Research Funded by the National Cancer Institute of Canada', *American Journal of Evaluation*, 31: 66–83.

Carayol, N., and Matt, M. (2006) 'Individual and Collective Determinants of Academic Scientists' Productivity', *Information Economics and Policy*, 18: 55–72.

Chimonas, S., Frosch, Z., and Rothman, D. J. (2011) 'From Disclosure to Transparency: The Use of Company Payment Data', *Archives of Internal Medicine*, 171: 81–6.

Clark, B. Y., and Llorens, J. J. (2012) 'Investments in Scientific Research: Examining the Funding Threshold Effects on Scientific Collaboration and Variation by Academic Discipline', *Policy Studies Journal*, 40: 698–729.

Costas, R., and van Leeuwen, T. N. (2012) 'Approaching the "Reward Triangle": General Analysis of the Presence of Funding Acknowledgments and "Peer Interactive Communication" in Scientific Publications', *Journal of the American Society for Information Science and Technology*, 63: 1647–61.

Costas, R., and Yegros-Yegros, A. (2013). 'Possibilities of funding acknowledgement analysis for the bibliometric study of research funding organizations: case study of the Austrian Science Fund (Fwf)', in *14th International Society of Scientometrics and Informetrics Conference*, pp. 1401–8. AIT Austrian Institute of Technology, Viena, 15–19 July.

Councill, I. G., Giles, C. L., Han, H., and Manavoglu, E. (2005). 'Automatic acknowledgement indexing: expanding the semantics of contribution in the CiteSeer digital library', in *Proceedings of the 3rd International Conference on Knowledge Capture*, pp. 19–26. ACM.

Crawford, E. T., and Biderman, A. D. (1970) 'Paper Money: Trends of Research Sponsorship in American Sociology Journals', *Social Science Information*, 9: 50–77.

Cronin, B. (1991) 'Let the Credits Roll: A Preliminary Examination of the Role Played by Mentors and Trusted Assessors in Disciplinary Formation', *Journal of Documentation*, 47: 227–39.

Cronin, B., and Shaw, D. (1999) 'Citation, Funding Acknowledgement and Author Nationality Relationships in Four Information Science Journals', *Journal of Documentation*, 55: 402–8.

Cronin, B., and Sugimoto, C. (2014). *Beyond Bibliometrics. Harnessing Multidimensional Indicators of Scholarly Impact*. Cambridge, Massachusetts: The MIT Press

Cronin, B., and Weaver, S. (1995) 'The Praxis of Acknowledgement: From Bibliometrics to Influmetrics', *Revista Española de Documentación Científica*, 18: 172–7.

Cronin, B., McKenzie, G., and Rubio, L. (1993a) 'Accounting for Influence: Acknowledgments in Contemporary Sociology', *Journal of the American Society for Information Science*, 44: 406–12.

Cronin, B., McKenzie, G., and Rubio, L. (1993b) 'The Norms of Acknowledgement in Four Humanities and Social Sciences Disciplines', *Journal of Documentation*, 49: 29–43.

Cronin, B., McKenzie, G., and Stiffler, M. (1992) 'Patterns of Acknowledgement', *Journal of Documentation*, 48: 107–22.

Cronin, B., Shaw, D., and La Barre, K. (2003) 'A Cast of Thousands: Coauthorship and Subauthorship Collaboration in the 20th Century as Manifested in the Scholarly Journal Literature of Psychology and Philosophy', *Journal of the American Society for Information Science and Technology*, 54: 855–71.

Cronin, B., Shaw, D., and La Barre, K. (2004) 'Visible, Less Visible, and Invisible Work: Patterns of Collaboration in 20th Century Chemistry', *Journal of the American Society for Information Science and Technology*, 55: 160–8.

De Bellis, N. (2009). *Bibliometrics and Citation Analysis: From the Science Citation Index to Cybermetrics*. Lanham, Maryland: Scarecrow press.

De Jong, S., Barker, K., Cox, D., Sveinsdottir, T., and Van den Besselaar, P. (2014) 'Understanding Societal Impact through Productive Interactions: ICT Research as a Case', *Research Evaluation*, 23: 89–102.

De Los Reyes, A., and Wang, M. (2012) 'Applying Psychometric Theory and Research to Developing a Continuously Distributed Approach to Making Research Funding Decisions', *Review of General Psychology*, 16: 298–304.

Defazio, D., Lockett, A., and Wright, M. (2009) 'Funding Incentives, Collaborative Dynamics and Scientific Productivity: Evidence from the EU Framework Program', *Research Policy*, 38: 293–305.

Desrochers, N., Paul-Hus, A., and Larivière, V. (2020). 'The Angle Sum Theory: Exploring the Literature on Acknowledgments in Scholarly Communication', in *Sugimoto, C. Theories of Informetrics and Scholarly Communication*, pp. 225–47. Berlin/Boston: De Gruyter Saur.

Desrochers, N., Paul-Hus, A., and Pecoskie, J. (2015). 'Founding concepts and foundational work: establishing the framework for the use of acknowledgments as indicators', in A.A. Salah, Y. Tonta, A.A. Akdag Salah, C. Sugimoto, and U. Al (eds) Proceedings of ISSI 2015 Istanbul: 15th International Society of Scientometrics and Informetrics Conference, Istanbul, Turkey: Bogaziçi University Printhouse, 29 June to 3 July, 2015.

Desrochers, N., Paul-Hus, A., and Pecoskie, J. (2017) 'Five Decades of Gratitude: A Meta-Synthesis of Acknowledgments Research', *Journal of the Association for Information Science and Technology*, 68: 2821–33.

Diamond, A. M. (2006) 'The Relative Success of Private Funders and Government Funders in Funding Important Science', *European Journal of Law and Economics*, 21: 149–61.

Díaz-Faes, A. A., and Bordons, M. (2014) 'Acknowledgments in Scientific Publications: Presence in Spanish Science and Text Patterns across Disciplines', *Journal of the Association for Information Science and Technology*, 65: 1834–49.

Ebadi, A. (2014). 'Impact of Funding on Scientific Output and Collaboration', Doctoral dissertation, Concordia University. <https://spectrum.library.concordia.ca/979002/4/Ebadi_PhD_F2014.pdf> accessed Jan 2020.

Ebadi, A., and Schiffauerova, A. (2013) 'Impact of Funding on Scientific Output and Collaboration: A Survey of Literature', *Journal of Information & Knowledge Management*, 12: 1350037.

Ebadi, A., and Schiffauerova, A. (2016) 'How to Boost Scientific Production? A Statistical Analysis of Research Funding and Other Influencing Factors', *Scientometrics*, 106: 1093–116.

Ellwein, L. B., Kroll, P., and Narin, F. (1996) 'Linkage between Research Sponsorship and Patented Eye-Care Technology', *Investigative Ophthalmology & Visual Science*, 37: 2495–503.

Fabiano, G., Marcellusi, A., and Favato, G. (2018) 'Public–Private Contribution to Biopharmaceutical Discoveries: A Bibliometric Analysis of Biomedical Research in UK', *Scientometrics*, 124: 1–16.

Folkstad, J., and Hayne, S. C. (2011). 'Visualization and analysis of social networks of research funding', in *2011 44th Hawaii International Conference on System Sciences*, pp. 1–10). IEEE.

Footman, K., Chersich, M., Blaauw, D., Campbell, O. M., Dhana, A., Kavanagh, J., Dumbaugh M., Thwala S., Bijlmakers, L. A., Vargas, E.,, Kern E.,, Becerra F.,, and Penn-Kekana, L. (2014) 'A Systematic Mapping of Funders of Maternal Health Intervention Research 2000-2012', *Globalization and Health*, 10: 72.

Fortin, J. M., and Currie, D. J. (2013) 'Big Science vs. little Science: How Scientific Impact Scales with Funding', *PloS One*, 8: e65263.

Galliher, J. F., and Mc Cartney, J. L. (1973) 'The Influence of Funding Agencies on Juvenile Delinquency Research', *Social Problems*, 21: 77–90.

García, C. E., and Sanz-Menéndez, L. (2005) 'Competition for Funding as an Indicator of Research Competitiveness', *Scientometrics*, 64: 271–300.

Gausia, K., Thompson, S. C., Lindeman, M. A., Brown, L. J., and Perkins, D. (2015) 'Contribution of University Departments of Rural Health to Rural Health Research: An Analysis of Outputs', *Australian Journal of Rural Health*, 23: 101–6.

Giles, C. L., and Councill, I. G. (2004) 'Who Gets Acknowledged: Measuring Scientific Contributions through Automatic Acknowledgment Indexing', *Proceedings of the National Academy of Sciences of the United State of America*, 101: 17599–604.

Gillett, R. (1991) 'Pitfalls in Assessing Research Performance by Grant Income', *Scientometrics*, 22: 253–63.

Gök, A., Rigby, J., and Shapira, P. (2016) 'The Impact of Research Funding on Scientific Outputs: Evidence from Six Smaller European Countries', *Journal of the Association for Information Science and Technology*, 67: 715–30.

Granda-Orive, J. I. D., Alonso-Arroyo, A., García-Río, F., López-Padilla, D. E., Solano-Reina, S., Jiménez-Ruiz, C. A., and Aleixandre-Benavent, R. (2015) 'Anatomía de la Financiación Mundial de Artículos de Excelencia en Tabaquismo, 2010-2014', *Revista Panamericana de Salud Pública*, 38: 410–7.

Grassano, N., Rotolo, D., Hutton, J., Lang, F., and Hopkins, M. M. (2017) 'Funding Data from Publication Acknowledgments: Coverage, Uses, and Limitations', *Journal of the Association for Information Science and Technology*, 68: 999–1017.

Grimpe, C. (2012) 'Extramural Research Grants and Scientists' Funding Strategies: Beggars Cannot Be Choosers?', *Research Policy*, 41: 1448–60.

Harter, S. P., and Hooten, P. A. (1992) 'Information Science and Scientists: JASIS, 1972–1990', *Journal of the American Society for Information Science*, 43: 583–93.

Haslam, N., Ban, L., Kaufmann, L., Loughnan, S., Peters, K., Whelan, J., and Wilson, S. (2008) 'What Makes an Article Influential? Predicting Impact in Social and Personality Psychology', *Scientometrics*, 76: 169–85.

Heffner, A. (1981) 'Funded Research, Multiple Authorship, and Subauthorship Collaboration in Four Disciplines', *Scientometrics*, 3: 5–12.

Henderson, C., Howard, L., and Wilkinson, G. (2003) 'Acknowledgement of Psychiatric Research Funding', *The British Journal of Psychiatry*, 183: 273–5.

Hornbostel, S. (2001) 'Third Party Funding of German Universities. An Indicator of Research Activity?', *Scientometrics*, 50: 523–37.

Hottenrott, H., and Lawson, C. (2017) 'Fishing for Complementarities: Research Grants and Research Productivity', *International Journal of Industrial Organization*, 51: 1–38.

Huang, M. H., and Huang, M. J. (2018) 'An Analysis of Global Research Funding from Subject Field and Funding Agencies Perspectives in the G9 Countries', *Scientometrics*, 115: 833–47.

Hunt, S., and Norman, D. J. (2018) 'The NOAO Publications Tracking Program: Developing Policies & Procedures for Usage, Acknowledgment, and Citation of Data', *In EPJ Web of Conferences*, 186: 12007.

Hyland, K. (2004) 'Graduates' Gratitude: The Generic Structure of Dissertation Acknowledgements', *English for Specific Purposes*, 23: 303–24.

Ihli, M. (2017). 'Methods for synthesis of funding agency & publisher data', in *Proceedings of the 6th International Workshop on Mining Scientific Publications*, pp. 57–63.

Jacob, B. A., and Lefgren, L. (2011a) 'The Impact of Research Grant Funding on Scientific Productivity', *Journal of Public Economics*, 95: 1168–77.

Jacob, B. A., and Lefgren, L. (2011b) 'The Impact of NIH Postdoctoral Training Grants on Scientific Productivity', *Research Policy*, 40: 864–74.

Joly, P. B., Gaunand, A., Colinet, L., Larédo, P., Lemarié, S., and Matt, M. (2015) 'ASIRPA: A Comprehensive Theory-Based Approach to Assessing the Societal Impacts of a Research Organization', *Research Evaluation*, 24: 440–53.

Kaiser, J. (2014) 'NIH Institute Considers Broad Shift to "People" Awards', *Science*, 345: 366367.

Klochikhin, E., and Fealing, K. H., (2018). 'Describing Scientific Outcomes', in Fealing K. H.. et al. (eds) *Measuring the Economic Value of Research: The Case of Food Safety*, pp. 157–74. Cambridge: Cambridge University Press.

Koier, E., and Horlings, E. (2015) 'How Accurately Does Output Reflect the Nature and Design of Transdisciplinary Research Programmes?', *Research Evaluation*, 24: 37–50.

Kokol, P., and Vošner, H. B. (2018) 'Discrepancies among Scopus, Web of Science, and PubMed Coverage of Funding Information in Medical Journal Articles', *Journal of the Medical Library Association*, 106: 81.

Kokol, P., Železnik, D., Završnik, J., and Blažun Vošner, H. (2019) 'Nursing Research Literature Production in Terms of the Scope of Country and Health Determinants: A Bibliometric Study', *Journal of Nursing Scholarship*, 51: 590–8.

Koushan, M., Pejhan, A., Shomoossi, N., and Shomoossi, A. (2014) 'Ethical Considerations in Publishing Medical Articles in Iranian Journals', *Acta Facultatis Medicae Naissensis*, 31: 105–11.

Kwon, S., Solomon, G. E., Youtie, J., and Porter, A. L. (2017) 'A Measure of Knowledge Flow between Specific Fields: Implications of Interdisciplinarity for Impact and Funding', *PLoS One*, 12: e0185583.

Larivière, V., Vignola-Gagné, E., Villeneuve, C., Gélinas, P., and Gingras, Y. (2011) 'Sex Differences in Research Funding, Productivity and Impact: An Analysis of Québec University Professors', *Scientometrics*, 87: 483–98.

Laudel, G. (2005) 'Is External Research Funding a Valid Indicator for Research Performance?', *Research Evaluation*, 14: 27–34.

Laudel, G. (2006) 'The 'Quality Myth': Promoting and Hindering Conditions for Acquiring Research Funds', *Higher Education*, 52: 375–403.

Lepori, B., Van den Besselaar, P., Dinges, M., Van der Meulen, B., Potì, B., Reale, E., Slipersaeter, S. and Theves, J. (2007) 'Indicators for Comparative Analysis of Public Project Funding: Concepts, Implementation and Evaluation', *Research Evaluation*, 16: 243–55.

Levitt, J. M. (2011) 'Are Funded Articles More Highly Cited than Unfunded Articles? A Preliminary Investigation', *ISSI Proceedings*, 2: 68.

Lewison, G. (1994) 'Publications from the European Community's Biotechnology Action Programme (BAP): Multinationality, Acknowledgement of Support, and Citations', *Scientometrics*, 31: 125–42.

Lewison, G. (1998) 'Gastroenterology Research in the United Kingdom: Funding Sources and Impact', *Gut*, 43: 288–93.

Lewison, G., and Carding, P. (2003) 'Evaluating UK Research in Speech and Language Therapy', *International Journal of Language & Communication Disorders*, 38: 65–84.

Lewison, G., and Dawson, G. (1998) 'The Effect of Funding on the Outputs of Biomedical Research', *Scientometrics*, 41: 17–27.

Lewison, G., and Devey, M. E. (1999) 'Bibliometric Methods for the Evaluation of Arthritis Research', *Rheumatology, (Oxford, England)*, 38: 13–20.

Lewison, G., Grant, J., and Jansen, P. (2001) 'International Gastroenterology Research: Subject Areas, Impact, and Funding', *Gut*, 49: 295–302.

Lewison, G., Lipworth, S., and de Francisco, A. (2002) 'Input Indicators from Output Measures: A Bibliometric Approach to the Estimation of Malaria Research Funding', *Research Evaluation*, 11: 155–63.

Lewison, G., and Markusova, V. (2010) 'The Evaluation of Russian Cancer Research', *Research Evaluation*, 19: 129–44.

Lewison, G., and Roe, P. (2012) 'The Evaluation of Indian Cancer Research, 1990–2010', *Scientometrics*, 93: 167–81.

Lewison, G., and Sullivan, R. (2015) 'Conflicts of Interest Statements on Biomedical Papers', *Scientometrics*, 102: 2151–9.

Lewison, G., and van Rooyen, S. (1999) 'Reviewers' and Editors' Perceptions of Submitted Manuscripts with Different Numbers of Authors, Addresses and Funding Sources', *Journal of Information Science*, 25: 509–11.

Leydesdorff, L., and Wagner, C. (2009) 'Macro-Level Indicators of the Relations between Research Funding and Research Output', *Journal of Informetrics*, 3: 353–62.

Li, K., and Yan, E. (2019) 'Are NIH-Funded Publications Fulfilling the Proposed Research? An Examination of Concept-Matchedness between NIH Research Grants and Their Supported Publications', *Journal of Informetrics*, 13: 226–37.

Liebow, E., Phelps, J., Van Houten, B., Rose, S., Orians, C., Cohen, J., Monroe, P. and Drew, C. H. (2009) 'Toward the Assessment of Scientific and Public Health Impacts of the National Institute of Environmental Health Sciences Extramural Asthma Research Program Using Available Data', *Environmental Health Perspectives*, 117: 1147–54.

Liu, W. (2020) 'Accuracy of Funding Information in Scopus: A Comparative Case Study', *Scientometrics*, 124: 803–11.

Liu, W., Tang, L., and Hu, G. (2020) 'Funding Information in Web of Science: An Updated Overview', *Scientometrics*, 122: 1509–24.

Lyall, C., Bruce, A., Marsden, W., and Meagher, L. (2013) 'The Role of Funding Agencies in Creating Interdisciplinary Knowledge', *Science and Public Policy*, 40: 62–71.

Lyubarova, R., Itagaki, B. K., and Itagaki, M. W. (2009) 'The Impact of National Institutes of Health Funding on US Cardiovascular Disease Research', *PLoS One*, 4: e6425.

Ma, A., Mondragón, R. J., and Latora, V. (2015) 'Anatomy of Funded Research in Science', *Proceedings of the National Academy of Sciences of the United States of America*, 112: 14760–5.

Mackintosh, K.H. (1972). 'Acknowledgements Patterns in Sociology', PhD thesis, University of Oregon.

MacLean, M., Davies, C., Lewison, G., and Anderson, J. (1998) 'Evaluating the Research Activity and Impact of Funding Agencies', *Research Evaluation*, 7: 7–16.

Markusova, V. A., Libkind, A. N., and Aversa, E. (2012) 'Impact of Competitive Funding on Research Output in Russia', *Collnet Journal of Scientometrics and Information Management*, 6: 61–9.

Mauleón, E., and Bautista-Puig, N. (2019). 'A new approach to funding acknowledgment field in the Spanish case: Can be used to identify gender gap in research funding?', *17th International Conference on Scientometrics and Informetrics, ISSI 2019*, pp. 2758–9.

McCann, T. V., and Polacsek, M. (2018) 'Addressing the Vexed Issue of Authorship and Author Order: A Discussion Paper', *Journal of Advanced Nursing*, 74: 2064–74.

Mejia, C., and Kajikawa, Y. (2018) 'Using Acknowledgement Data to Characterize Funding Organizations by the Types of Research Sponsored: The Case of Robotics Research', *Scientometrics*, 114: 883–904.

Meschede, C. (2020) 'The Sustainable Development Goals in Scientific Literature: A Bibliometric Overview at the Meta-Level', *Sustainability*, 12: 4461.

Miettinen, R., Tuunainen, J., and Esko, T. (2015) 'Epistemological, Artefactual and Interactional–Institutional Foundations of Social Impact of Academic Research', *Minerva*, 53: 257–77.

Moed, H. (2017). *Applied Evaluative Informetrics*. Cham: Springer.

Möller, T. (2019) 'The impact of research funding agencies on the research performance of five european countries-a funding acknowledgements analysis', in ISSI, pp. 2279–87.

Möller, T., Schmidt, M., and Hornbostel, S. (2016) 'Assessing the Effects of the German Excellence Initiative with Bibliometric Methods', *Scientometrics*, 109: 2217–39.

Morillo, F. (2016) 'Public–Private Interactions Reflected through the Funding Acknowledgements', *Scientometrics*, 108: 1193–204.

Morillo, F. (2019) 'Collaboration and Impact of Research in Different Disciplines with International Funding (from the EU and Other Foreign Sources)', *Scientometrics*, 120: 807–23.

Morillo, F., and Álvarez-Bornstein, B. (2018) 'How to Automatically Identify Major Research Sponsors Selecting Keywords from the WoS Funding Agency Field', *Scientometrics*, 117: 1755–70.

Morillo, F., Costas, R., and Bordons, M. (2015) 'How is Credit Given to Networking Centres in Their Publications? A Case Study of the Spanish CIBER Research Structures', *Scientometrics*, 103: 923–38.

Mussurakis, S. (1994) 'Financial Support for Research in Radiology: A Survey of Original Investigations Published in the AJR and Radiology', *American Journal of Roentgenology*, 163: 973–9.

Mutz, R., Bornmann, L., and Daniel, H. D. (2016) 'Funding Decision-Making Systems: An Empirical Comparison of Continuous and Dichotomous Approaches Based on Psychometric Theory', *Research Evaluation*, 25: 416–26.

Mwendera, C. A., De Jager, C., Longwe, H., Hongoro, C., Mutero, C. M., and Phiri, K. S. (2017) 'Malaria Research in Malawi from 1984 to 2016: A Literature Review and Bibliometric Analysis', *Malaria Journal*, 16: 246.

Ofri, R., Bdolah-Abram, T., and Yair, N. (2017) 'Factors Affecting Peer-Reviewed Publication of Abstracts Presented at Meetings of the European College of Veterinary Ophthalmologists (2008–2012)', *Veterinary Ophthalmology*, 20: 533–8.

Oleksiyenko, A., and Sá, C. M. (2010) 'Resource Asymmetries and Cumulative Advantages: Canadian and US Research Universities and the Field of Global Health', *Higher Education*, 59: 367–85.

Pao, M. (1991) 'On the Relationship of Funding and Research Publications', *Scientometrics*, 20: 257–81.

Paul-Hus, A., Desrochers, N., and Costas, R. (2016) 'Characterization, Description, and Considerations for the Use of Funding Acknowledgement Data in Web of Science', *Scientometrics*, 108: 167–82.

Paul-Hus, A., Díaz-Faes, A. A., Sainte-Marie, M., Desrochers, N., Costas, R., & Larivière, V. (2017a) 'Beyond Funding: Acknowledgement Patterns in Biomedical, Natural and Social Sciences', *PLoS One*, 12: e0185578.

Paul-Hus, A., Mongeon, P., Sainte-Marie, M., and Larivière, V. (2017b) 'The Sum of It All: Revealing Collaboration Patterns by Combining Authorship and Acknowledgements', *Journal of Informetrics*, 11: 80–7.

Peritz, B. C. (1990) 'The Citation Impact of Funded and Unfunded Research in Economics', *Scientometrics*, 19: 199–206.

Pollock, R. E., and Ewer, M. S. (2010) 'The Integrity of Authorship: Doing the Right Thing', *Cancer*, 116: 3986–7.

Powell, K. (2019) 'Searching by Grant Number: Comparison of Funding Acknowledgments in NIH RePORTER, PubMed, and Web of Science', *Journal of the Medical Library Association*, 107: 172.

Rangnekar, D. (2005) 'Acknowledged: Analysing the Bibliometric Presence of the Multiple Sclerosis Society', *Aslib Proceedings: New Information Perspectives*, 57: 247–60.

Reale, E., Inzelt, A., Lepori, B., and Besselaar, P. V. D. (2012) 'The Social Construction of Indicators for Evaluation: Internationalization of Funding Agencies', *Research Evaluation*, 21: 245–56.

Reyes, H., Kauffmann, R., and Goic, A. (1995) 'Who Finances Medical Research in Chile?', *Revista Médica de Chile*, 123: 1243–51.

Rigby, J. (2011) 'Systematic Grant and Funding Body Acknowledgement Data for Publications: New Dimensions and New Controversies for Research Policy and Evaluation', *Research Evaluation*, 20: 365–75.

Rigby, J. (2013) 'Looking for the Impact of Peer Review: Does Count of Funding Acknowledgements Really Predict Research Impact?', *Scientometrics*, 94: 57–73.

Rigby, J., and Julian, K. (2014) 'On the Horns of a Dilemma: Does More Funding for Research Lead to More Research or a Waste of Resources That Calls for Optimization of Researcher Portfolios? An Analysis Using Funding Acknowledgement Data', *Scientometrics*, 101: 1067–75.

Roa-Atkinson, A., and Velho, L. (2005) 'Interactions in Knowledge Production: A Comparative Case Study of Immunology Research Groups in Colombia and Brazil', *Aslib Proceedings*, 57: 200–16.

Rodríguez-Padial, L., Lozano, I. F., Urbano, R. H., Melchor, L. S., Massip, A. E., Sánchez, M. A., and Romo, A. Í. (2019) 'Evolución e Impacto Bibliométrico de Las Becas de la Sociedad Española de Cardiología/Fundación Española Del Corazón en el Periodo 2007-2012', *Revista Española de Cardiología*, 72: 1012–9.

Rong, X. L., Grant, L., and Ward, K. B. (1989) 'Productivity of Women Scholars and Gender Researchers: Is Funding a Factor?', *The American Sociologist*, 20: 95–100.

Sá, C. M., Kretz, A., and Sigurdson, K. (2013) 'Accountability, Performance Assessment, and Evaluation: Policy Pressures and Responses from Research Councils', *Research Evaluation*, 22: 105–17.

Salager-Meyer, F., Ariza, M. Á. A., and Berbesí, M. P. (2009) 'Backstage Solidarity" in Spanish and English Written Medical Research Papers: Publication Context and the Acknowledgment Paratext', *Journal of the American Society for Information Science and Technology*, 60: 307–17.

Salager-Meyer, F., Ariza, M. Á. A., and Berbesí, M. P. (2010). 'Hidden Influencers and the Scholarly Enterprise: A Cross-Cultural/Linguistic Study of Acknowledgments in Medical Research Articles', in Ruiz-Garrido M. F., Palmer-Silveira J. C., and Fortanet-Gómez I. (eds) *English for Professional and Academic Purposes*, pp. 43–58. Brill, Amsterdam: Rodopi.

Salter, A. J., and Martin, B. R. (2001) 'The Economic Benefits of Publicly Funded Basic Research: A Critical Review', *Research Policy*, 30: 509–32.

Sandström, U. (2009) 'Research Quality and Diversity of Funding: A Model for Relating Research Money to Output of Research', *Scientometrics*, 79: 341–9.

Seif, G., and Trope, G. (2010) 'Impact of 10 Years of Glaucoma Research Funding: The Glaucoma Research Society of Canada', *Canadian Journal of Ophthalmology*, 45: 132–4.

Shapira, P., and Wang, J. (2010) 'Follow the Money. What Was the Impact of the Nanotechnology Funding Boom of the past Ten Years?', *Nature*, 468: 627–8.

Sirtes, D. (2013). 'Funding acknowledgements for the German Research Foundation (DFG). The dirty data of the web of science database and how to clean it up', in *14th International Society of Scientometrics and Informetrics Conference*, pp. 784–95. Vienna. 15–19 July.

Sirtes, D., and Riechert, M. (2014). 'A fully automated method for the unification of funding organizations in the web of knowledge', in *Proceedings of the 19th International Conference on Science and Technology Indicators*, pp. 594–7.

Slaughter, S., and Leslie, L. L. (1997). *Academic Capitalism: Politics, Policies, and the Entrepreneurial University. North Charles Street*, Baltimore: The Johns Hopkins University Press.

Stamou, S., Tzekou, P., and Zotos, N. (2009, November). 'Quantifying the impact of funded research works', in *2009 Fourth International Conference on Digital Information Management*, pp. 1–6. IEEE.

Steele, S., Ruskin, G., McKee, M., and Stuckler, D. (2019) 'Always Read the Small Print": A Case Study of Commercial Research Funding, Disclosure and Agreements with Coca-Cola', *Journal of Public Health Policy*, 40: 273–85.

Stehr, F., and Forkel, M. (2013) 'Funding Resources for Rare Disease Research', *Biochimica et Biophysica Acta (BBA)-Molecular Basis of Disease*, 1832: 1910–2.

Stuckler, D., Ruskin, G., and McKee, M. (2018) 'Complexity and Conflicts of Interest Statements: A Case-Study of Emails Exchanged between Coca-Cola and the Principal Investigators of the International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE)', *Journal of Public Health Policy*, 39: 49–56.

Szell, M., and Sinatra, R. (2015) 'Research Funding Goes to Rich Clubs', *Proceedings of the National Academy of Sciences of the United States of America*, 112: 14749–50.

Tahamtan, I., and Bornmann, L. (2020) 'Altmetrics and Societal Impact Measurements: Match or Mismatch? A Literature Review', *El Profesional de la Información*, 29: e290102.

Tan, A. M., Zhao, S. X., and Ye, F. Y. (2012) 'Characterizing the Funded Scientific Collaboration Network', *Current Science*, 103: 1261.

Tang, L., Hu, G., and Liu, W. (2017) 'Funding Acknowledgment Analysis: Queries and Caveats', *Journal of the Association for Information Science and Technology*, 68: 790–4.

Te, V., Floden, N., Hussain, S., Brolan, C. E., and Hill, P. S. (2018) 'What Did the Go4Health Policy Research Project Contribute to the Policy Discourse on the Sustainable Development Goals? A Reflexive Review', *Globalization and Health*, 14: 51.

Temple, L., Barret, D., Blundo Canto, G., Dabat, M. H., Devaux-Spatarakis, A., Faure, G., Hainzelin, E., Mathé, S., Toillier A. y, Triomphe, B. (2018) 'Assessing Impacts of Agricultural Research for Development: A Systemic Model Focusing on Outcomes', *Research Evaluation*, 27: 157–70.

Tennen, H. (2015) 'Whoever Pays the Piper Calls the Tune: A Case of Documenting Funding Sources', *Ethical Challenges in the Behavioral and Brain Sciences*, 208.

Thomas, D., and Nedeva, M. (2012) 'Characterizing Researchers to Study Research Funding Agency Impacts: The Case of the European Research Council's Starting Grants', *Research Evaluation*, 21: 257–69.

Ubfal, D., and Maffioli, A. (2011) 'The Impact of Funding on Research Collaboration: Evidence from a Developing Country', *Research Policy*, 40: 1269–79.

Van Honk, J., Calero-Medina, C., and Costas, R. (2016). 'Funding acknowledgements in the Web of Science: inconsistencies in data collection and standardization of funding organizations', in I. Rafols, J. Molas-Gallart, E. Castro-Martinez, and R. Woolley (eds) *International Conference on Science and Technology Indicators: Peripheries, Frontiers and Beyond*. Valencia (Spain). 14–16 September 2016.

Viergever, R. F., and Hendriks, T. C. (2016) 'The 10 Largest Public and Philanthropic Funders of Health Research in the World: What They Fund and How They Distribute Their Funds', *Health Research Policy and Systems*, 14: 12.

Walsh, B. A., and Sanchez, C. (2010) 'Reported Research Funding in Four Early Childhood Journals', *Early Childhood Education Journal*, 37: 289.

Wang, J., and Shapira, P. (2011) 'Funding Acknowledgement Analysis: An Enhanced Tool to Investigate Research Sponsorship Impacts: The Case of Nanotechnology', *Scientometrics*, 87: 563–86.

Wang, J., and Shapira, P. (2015) 'Is There a Relationship between Research Sponsorship and Publication Impact? An Analysis of Funding Acknowledgments in Nanotechnology Papers', *PLoS One*, 10: e0117727.

Wang, X., Liu, D., Ding, K., and Wang, X. (2012) 'Science Funding and Research Output: A Study on 10 Countries'. *Scientometrics*, 91: 591–9.

Webster, B. M. (2005) 'International Presence and Impact of the UK Biomedical Research, 1989-2000', *Aslib Proceedings*, 57: 22–47.

Weingart, P. (2000) 'Interdisciplinarity: The Paradoxical Discourse', in Practising Interdisciplinarity, pp. 25–41. Toronto (Canada): University of Toronto Press.

Wilson, M. P., and Itagaki, M. W. (2007) 'Characteristics and Trends of Published Emergency Medicine Research', *Academic Emergency Medicine*, 14: 635–40.

Woelert, P., and Millar, V. (2013) 'The 'Paradox of Interdisciplinarity', *Australian Research Governance. Higher Education*, 66: 755–67.

Xu, X., Tan, A. M., and Zhao, S. X. (2015) 'Funding Ratios in Social Science: The Perspective of Countries/Territories Level and Comparison with Natural Sciences', *Scientometrics*, 104: 673–84.

Yan, E., Wu, C., and Song, M. (2018) 'The Funding Factor: A Cross-Disciplinary Examination of the Association between Research Funding and Citation Impact', *Scientometrics*, 115: 369–84.

Yegros-Yegros, A., and Costas, R. (2013). 'Analysis of the web of science funding acknowledgement information for the design of indicators on "external funding attraction"', in *14th International Society of Scientometrics and Informetrics Conference*, pp. 84–95, Vienna. 15–19 July.

Zanca, J. M., Brienza, D. M., Ammer, M. L., Bennett, R. G., and Lyder, C. H. (2005) 'Acknowledged Funding Sources in Pressure Ulcer Literature: A Systematic Review', *Advances in Skin & Wound Care*, 18: 84–91.

Zhao, D. (2010) 'Characteristics and Impact of Grant-Funded Research: A Case Study of the Library and Information Science Field', *Scientometrics*, 84: 293–306.

Zhao, S. X., Lou, W., Tan, A. M., and Yu, S. (2018) 'Do Funded Papers Attract More Usage?', *Scientometrics*, 115: 153–68.

Zhou, P., and Tian, H. (2014) 'Funded Collaboration Research in Mathematics in China', *Scientometrics*, 99: 695–715.

Zoller, F. A., Zimmerling, E., and Boutellier, R. (2014) 'Assessing the Impact of the Funding Environment on Researchers' Risk Aversion: The Use of Citation Statistics', *Higher Education*, 68: 333–45.