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# Approaching the ‘Reward Triangle’: general analysis of the presence of funding acknowledgements and ‘peer interactive communication’ in scientific publications

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# **Approaching the ‘Reward Triangle’: general analysis of the presence of funding acknowledgements and ‘peer interactive communication’ in scientific publications**

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## **Abstract**

The role of acknowledgments given by researchers in their publications has been a recurrent challenge in the bibliometric field, but relatively unexplored until now. This study presents a general bibliometric analysis on the new ‘Funding Acknowledgment’ information available in the Web of Science. All publications covered by the database in 2009 have been analyzed. The presence and length of the funding acknowledgment text, as well as the presence of ‘peer interactive communication’ in the acknowledgements are related with impact indicators, distribution of papers by fields, countries of the authors, and collaboration level of the papers. It is observed that publications with funding acknowledgments present a higher impact as compared to publications without them. There are also differences across countries and disciplines in the share of publications with funding acknowledgments and the acknowledgment of peer interactive communication. China is the country with the highest share of publications acknowledging funding, while the presence of funding acknowledgments in the humanities and social sciences is very low as compared to the more basic disciplines. The presence of peer interactive communication in acknowledgments can be linked to countries that have a large scientific tradition and are incorporated in scientific networks. Peer interactive communication is also common in the fields of humanities and social sciences and can be linked to lower levels of co-authorship. Observed patterns are explained and topics of future research are proposed.

## **Introduction**

Acknowledgments in scientific publications are a common element in scientific culture, having a social function and cognitive significance (Tiew & Sen, 2002). According to Hyland (2004) (citing Atkinson, 1999), acknowledgements find their origin in the gratitude expressed to patrons, mentors and powerful benefactors in cover letters accompanying scientific articles. However, this did not become a standard practice until the 60s. Since then, acknowledgments have become an important feature of the scholarly communication process, and over time there is increasing presence in scientific publications (Salager-Meyer et al, 2011). Nowadays, it is very common to find a section in scientific articles where the authors acknowledge diverse entities such as funding bodies, colleagues, referees, etc. that in some way have contributed, funded, supported, discussed or inspired the work. For some authors (Hyland, 2004), acknowledgments

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represent a genre that contributes to an author's efforts to create both a professional and personal identity. Acknowledgments have thus become an important standard feature that appears in over half of all published research articles (Cronin et al. 1992; Cronin & Weaver, 1995).

Some authors have given important initial steps in analyzing this type of information (see the bibliographic reviews by Salager-Meyer et al, 2011, Rigby, 2011 and Hyland, 2004). Blaise Cronin and colleagues are among the most important pioneers in this topic within the Library & Information Science discipline, having analyzed the acknowledgments in different fields and journals (Cronin et al, 1992, 2003, 2004).

However, because acknowledgment data have for many years not been machine-readable and analyzable, in the same way that author and citation data are with Thomson Reuters' citation databases, they have been traditionally ignored in both bibliometric analyses and research assessment exercises (Cronin et al, 2003; Giles & Council, 2004). The study by Giles & Council (2004) is probably one of the most extensive, based on an analysis of acknowledgments from more than 335,000 unique publications from CiteSeer.

The situation described above seems to be changing, as recently Web of Science (WoS) announced that from August 2008 onwards, Thomson Reuters is starting to collect funding information presented in the acknowledgment section of publications (Thomson Reuters, 2011)<sup>2</sup>. This new 'Funding Acknowledgment' (FA) information has already been analyzed by several authors in the field of bibliometrics (Shapira & Wang, 2010; Wang & Shapira, 2011; Levitt, 2011; Costas & van Leeuwen, 2011; Wang et al, 2012). The results from these first studies show interesting patterns and promising results.

### *The 'Reward Triangle': authorships, acknowledgments and citations*

From a more theoretical perspective acknowledgments have important conceptual links with two of the most relevant elements in the scientific communication process: authorship and citations (Rennie et al, 1997; Giles & Council, 2004), composing the so-called 'Reward Triangle' (Cronin & Weaver, 1995). According to these authors, "in assessing scholarly performance, two principal measures are used: productivity and impact. The former is traditionally equated with publication counts; the latter with citation counts". However, the problem arises when an "individual is fulsomely acknowledged for his contributions by an author" but "the reward register remains silent" as this type of recognition is never counted. In this sense, "if authorship and citedness are to be

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<sup>2</sup> The funding acknowledgment information is split in three different field tags: 'Funding Agency' (FO), 'Grant number' (FG) and 'Funding text' (FT). The last one is the full text of the acknowledgment given in the paper. In this paper we refer mainly to this particular field.

counted, so should acknowledgements”, and “by admitting acknowledgments the “Reward Triangle” is closed” (Cronin & Weaver, 1995, p. 173).

Bearing in mind this triangle, we observe that acknowledgments often recognize the contribution and role that persons and organizations have had for the development of the research and the writing of the paper. This can be considered as a kind of ‘sub-authorship’ collaboration (Cronin et al, 2003) and according to Laudel (2002, p. 10) “about 37% of the collaborators who are visible in publications were rewarded with acknowledgments”. In this scenario, authors choose to use acknowledgments to identify those who made special intellectual or technical contributions to a study, but that were not sufficient to qualify them for authorship (Kassirer & Angell, 1991; Claxton, 2005). The same idea is also recommended by the guidelines of organizations like the International Committee of Medical Journal Editors (ICMJE, 2011), who suggests “all contributors who do not meet the criteria for authorship should be listed in an acknowledgments section. Examples of those who might be acknowledged include a person who provided purely technical help, writing assistance, or a department chairperson who provided only general support. Financial and material support should also be acknowledged”.

When considering the role of acknowledgments as a kind of subauthorship, it can be claimed that they “provide a revealing window onto trends in collaboration beyond co-authorship” (Cronin & Weaver, 1995, p. 172), thus opening a new perspective on the relationships among researchers, teams and organizations that can not be captured through regular co-authorship studies.

However, Kassirer & Angell (1991) also warn about the growing length and detail of the acknowledgments. They point to the case of reports of multicenter clinical trials, where acknowledgments are often made to everyone who had anything to do with the study, including those who were merely carrying out their jobs, such as technicians. Sometimes, principal investigators from each participating institution are acknowledged, even though they are also identified as authors. This could suggest that acknowledgments can also suffer from the same problems and limitations related to authorship. For example, we could talk about ‘gift acknowledgements’, ‘ghost acknowledgments’, ‘hyper-acknowledgments’, or ‘acknowledgment inflation’ in a similar way we discuss authorship (Claxton, 2005).

Acknowledgments and citations also share some important characteristics. In this sense, acknowledgments have been frequently regarded as ‘super-citations’ (Cronin et al, 1993a) and acknowledgments and citations exhibit a high degree of cultural consensus. Both describe webs of interactions and influence, and in general both declare a relationship (Cronin & Weaver, 1995). Giles & Council (2004) argued that citations alone could fall short of describing the full network of influence underlying primary scientific communication. Whereas citations are formal expressions of debt, acknowledgments are more personal, singular or

private expressions of appreciation and contribution (Giles & Council, 2004), as well as basic manifestations of thanks and gratitude (Gesuato, 2004). Cronin et al (1992) and Giles & Council (2004) show empirically that citations and acknowledgements are correlated, thus reinforcing the idea of the conceptual relationship between these two scientific elements.

Taking all the previous into account, we argue that acknowledgments lay between citations and authorships in this 'Reward Triangle'. Acknowledgments provide information on the collaborative networks of researchers, and on other different types of intellectual influences. Thus, it is clear that the information contained in the acknowledgements can contribute to a better understanding of the context of scientific research and its communication process, and as such it will be useful in the network analysis of scholarly communication.

### *Types of acknowledgments*

Acknowledgments can be made for several reasons (Davis & Cronin, 1993). Cronin et al, (1992) have suggested six main types of acknowledgments in scientific publications: moral support; access (to facilities, data, specimens, samples, documents, materials, etc.); clerical support; technical support (computer programming, statistics, etc.); financial support and peer interactive communication (PIC).

The last two types are, from the bibliometric point of view, probably the most important. The PIC type is highly important because it is an acknowledgment type that can imply an intellectual debt comparable to a citation (McCain, 1991; Davis & Cronin, 1993), and to some degree a kind of subauthorship.

Acknowledgements with financial support are also very relevant as they indicate the source of funding or economic support with which the research and publication was made possible. This type of information is highly relevant as it helps to explain why some bibliographic databases (e.g. WoS) started to collect this type of information, and also why several funding agencies are beginning to require explicit and standardized mentioning of the funding of published research (NSF, 2009; NIH, 2011; CHONE, 2011; Building Rural Communities Fund, 2011). However, the proper standardization of the names of funding bodies (Rigby, 2011) and the identification of the different types of support are still a problem in this type of analysis.

Research institutions, funding agencies, etc. increasingly consider bibliometrics (Abramo et al, 2009), and particularly this source of funding information (Butler et al, 1998; Butler et al, 2005). There are already examples of research organizations and funding agencies that have been interested in studying the impact of their funded projects through bibliometric indicators (Butler, et al 1998; Edler & Rigby, 2004). However, this is still a type of bibliometric research in development, as it is difficult to track on a large scale the linkages between R&D

funding and outputs. This is due to the difficulties in tracking the research activities and outputs of each funded project (Wang & Shapira, 2011). This limitation can partly find a solution in the FA analysis as funding awards and acknowledgments correlate relatively well at higher levels (Butler, 2001).

In this study, a general quantitative analysis on the presence of FA and PIC acknowledgments in scientific publications is carried out. This includes different countries and disciplines. We also apply a new perspective compared to previous studies based on acknowledgments, in the sense that the focus is less on studying the actors that are mentioned in the acknowledgments and more on the characteristics and patterns of the publications that contain (or do not contain) them. In particular, we focus on how acknowledgments are distributed across fields, countries, document types and levels of collaboration. Thus, this paper presents a first general perspective on the distribution and patterns of this type of information across scientific publications, with the goal of providing a general framework to support future studies on this topic.

## **Objectives**

The main objective of this paper is to perform a first general exploratory analysis on the presence of FA and PIC acknowledgments existing in the WoS records. The approach focuses on the study of the relationships and patterns of publications that include acknowledgments with other bibliometric characteristics such as citations, disciplines, countries and co-authors. It is also an important aim of this paper to detect and highlight the problems this new source of information (the FA in WoS) could present for future developments.

Several concrete research questions with scientific and political relevance are proposed for further research:

- What is the global distribution of the presence of FA across publications?
- What is the distribution of FA among document types?
- Do publications with FA have higher impact than publications without FA?
- Is the length of FA text related to the impact of publications?
- Is there any relationship between FA and collaboration in publications?
- What is the distribution of funding acknowledgement among disciplines?
- What is the distribution of funding acknowledgement among countries?
- Can details about PIC acknowledgments (such as colleagues reviewing, commenting, discussing, etc. the paper) be systematically identified in the FA texts? Are there identifiable relationships between the presence of PIC and the impact of the publications? Are there different patterns in the presence of PIC acknowledgments across disciplines and countries?

The answer to these questions will provide key information for the understanding of author acknowledgment patterns in scientific publications and will provide a

first general view on the presence and distribution of this type of information in scientific papers across different fields. Along these lines, development of our research questions will very likely provoke new questions, challenging the bibliometric and scientific community-at-large by aiming at a more in-depth understanding of scientific communication and the role of acknowledgments.

## **Methodology**

This study is based on the information available in the FA field tags (FO, FG and FT) in WoS records. As this option is available from August 2008, we have focused only on publications in 2009 (considering citations up to 2010). However, in the development of this research several important limitations have been found, and which need to be taken into account when working with this new source of information:

- A manual analysis of some publications of the authors of this paper, which have acknowledgments but not FA, has been performed. Thomson Reuters did not collect the acknowledgment texts of these papers. This suggests that acknowledgments are only collected when they include funding information. Therefore it cannot be assumed that all types of acknowledgments from all the papers are actually considered.
- As a consequence of the previous, the potential use of the FA information is very much dependent on the algorithm developed by Thomson Reuters, which has not been yet explained in detail. Therefore, it is not completely clear how and from where Thomson Reuters takes this information, and if this is done systematically in all journals, for all publications, for all disciplines, etc.
- Another problem related with the algorithm used by Thomson Reuters is that it is not clear how potential differences of acknowledging across fields and journals are tackled. For example, if in some journals FA and PIC acknowledgments appear in different paragraphs or sections, it is not known how this would be treated and consigned in the database. The assumption in this study is that FA and PIC (as well as other types of acknowledgments) appear together in the same section or paragraph of papers and are collected from the FA field tags of WoS.
- Finally, an important conceptual limitation is that acknowledgements are a volunteer activity. Hence, authors can also decide not to acknowledge funding, colleagues, etc. (or forget to do it). This means that publications without acknowledgments do not necessarily imply that they don't have acknowledgment 'debts'. In a sense, this is the same limitation as the 'citation amnesia' in citation analysis (Garfield, 1982), resulting here in a kind of 'acknowledgment amnesia'. In addition, a kind of 'acknowledgment blindness' could be suggested, because the reviewers of a journal can suggest missing

citations if necessary, but with acknowledgments it is not possible to know if something that should be acknowledged is in fact missing.

Despite these limitations, we argue that a large scale analysis, such as the one presented in this study, can provide meaningful results.

Several CWTS (Center for Science and Technology Studies) standard<sup>3</sup> indicators have also been considered:

- *P*: total number of publications.
- *C*: total number of citations (excluding self-citations).
- *CPP*: citations per publication (excluding self-citations).
- *MNCS*: Mean normalized citation score (excluding self-citations). This is the average impact of the publications as compared to the mean of citations in their subfields (here subfields are considered as the categories of the Journal Citation Reports-JCR).
- *MNJS*: Mean normalized journal citation score (excluding self-citations). This indicator measures the field-normalized impact of journals.

A general classification of all the subfields covered by the WoS is used to analyze the distribution and presence of FA across main scientific disciplines. This classification is based on an aggregation of the JCR subject categories into the 16 main disciplines developed by Henk Moed (2005).

Finally, for the PIC acknowledgments we searched (using wildcards) for a number of word strings that are suspected of indicating review and communication processes by referees of the journals or by colleagues of the authors. These keywords are the following: 'review', 'referee', 'comment', 'suggestion', 'discussion', 'reading', 'advice', 'insight', 'inspiration', 'inspiring', 'correspondence', 'feedback', 'intellectual debt', 'intellectual influence', 'conversations' and 'remarks'.

## **Results**

First, some descriptive figures are presented on the data finally used in the analysis. A total of 1,648,130 publications from 2009 were gathered from the CWTS WoS database. From these publications only citable items were considered (article, reviews and letters –excluding editorials, corrections, etc.) thus amounting to 1,253,909 publications finally included in the analysis.

### *Main figures on the presence of FA and PIC in WoS publications*

All the publications with an acknowledgment text in the WoS database in 2009 were detected and counted. The main indicators of the presence (or not) of acknowledgments in the WoS records are presented in Table 1.

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<sup>3</sup> For a description and discussion of these indicators see Waltman et al (2011).

Table 1. General indicators of the FA distribution. Publications from 2009.

<b>Publications</b>	<b>P</b>	<b>%</b>	<b>C</b>	<b>CPP</b>	<b>MNCS</b>	<b>MNJS</b>
Without acknowledgement information	712594	56.8	201475	0.28	0.99	0.89
With acknowledgement information	541315	43.2	207070	0.38	1.02	1.15
• With FA information	541260	43.2	207062	0.38	1.02	1.15
- With FA & no PIC acknowledgments	417813	77.2 (*)	143197	0.34	0.96	1.10
- With FA & PIC acknowledgments	123447	22.8 (*)	63864	0.52	1.21	1.30

(\*) % calculated based on the n. of publications with FA information.

The number of publications with any type of acknowledgement amounts to 43% of all publications. This basically corresponds to publications with FA information, thus corroborating the observation that Thomson Reuters is collecting the acknowledgments of papers only when funding information is detected. Therefore, publications with acknowledgments but without funding information are not well represented in this figure. The number of publications with FA must be seen as a conservative measure of the total number of publications with acknowledgments. In other words, we can only assume that 56.8% of the publications do not have any FA information, but we don't know exactly how many of them do not have any acknowledgment at all.

Publications with FA have on average more impact than publications without FA (CPP 0.38 vs. 0.28; MNCS 1.02 vs. 0.99) and they are also published in journals of higher impact (MNJS 1.15 vs. 0.89). Moreover 23% of publications with FA include some indication of PIC, and it can be highlighted how these publications present a higher impact as compared to those without PIC acknowledgments (CPP 0.52 vs. 0.34, MNCS 1.21 vs. 0.96 and MNJS 1.30 vs. 1.10).

Table 1 also shows that papers with FA but without PIC have a higher non-normalized average impact (CPP) and are published in better journals (MNJS) than papers without FA. However, the latter have higher scores in their field normalized impact (MNCS) as compared to the former.

Table 2 presents the distribution of publications with FA considering the main document types.

Table 2. Distribution of FA by document types

<b>Document Type</b>	<b>Total pubs</b>	<b>Pubs. with FA</b>	<b>Pubs. with PIC</b>	<b>%FA</b>	<b>% with PIC (*)</b>
Articles	1141960	514342	114805	45.04	22.3
Reviews	69671	26970	8658	38.71	32.1
Letters	42278	3	1	0.01	33.3

(\*) % calculated based on the n. of publications with FA information.

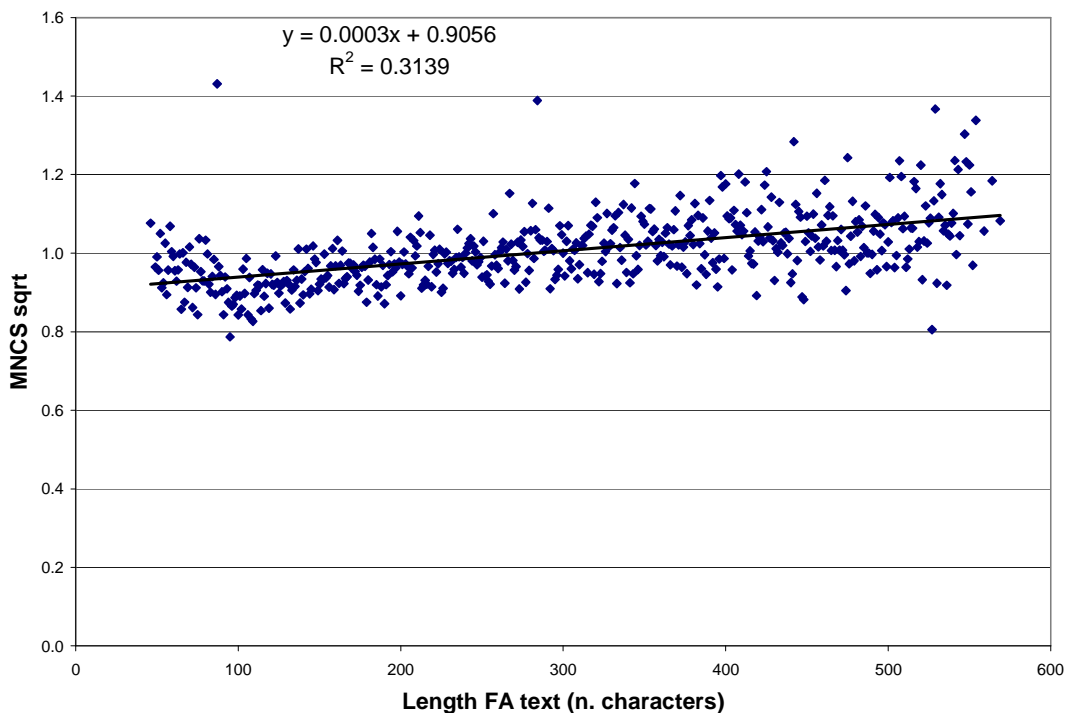
First, letters present only a residual presence of FA, probably due to the short format of this document type. Secondly, comparing articles and reviews, the first type presents a higher share of publications with FA as compared to the second,

indicating that review papers are proportionally less frequently done in the framework of funding programs (or at least less acknowledged by its authors) than regular articles. However, when we look at the presence of PIC among the publications with FA, then review papers tend to present more PIC acknowledgments than articles, suggesting that this is a document type that has more circulation and discussion among colleagues than regular articles.

### Length of the FA text and the impact of publications

In the next analysis, the focus is on the impact of the publications depending on the length of the 'funding text' field tag (FT) of WoS, which is measured by the number of characters of the text. For every grouping of character length we have calculated the MNCS indicator. In the analysis presented in Figure 1 only acknowledgments with a length larger than 30 and shorter than 800 characters were considered. In the figure, only groups of FA text length with at least 300 publications have been included in order to avoid the potential distortions of occasional character-length groupings with fewer publications. Figure 1 presents the correlation between the lengths of the FA text with the MNCS square root.

Figure 1. Correlation of MNCS with the length of the FA text

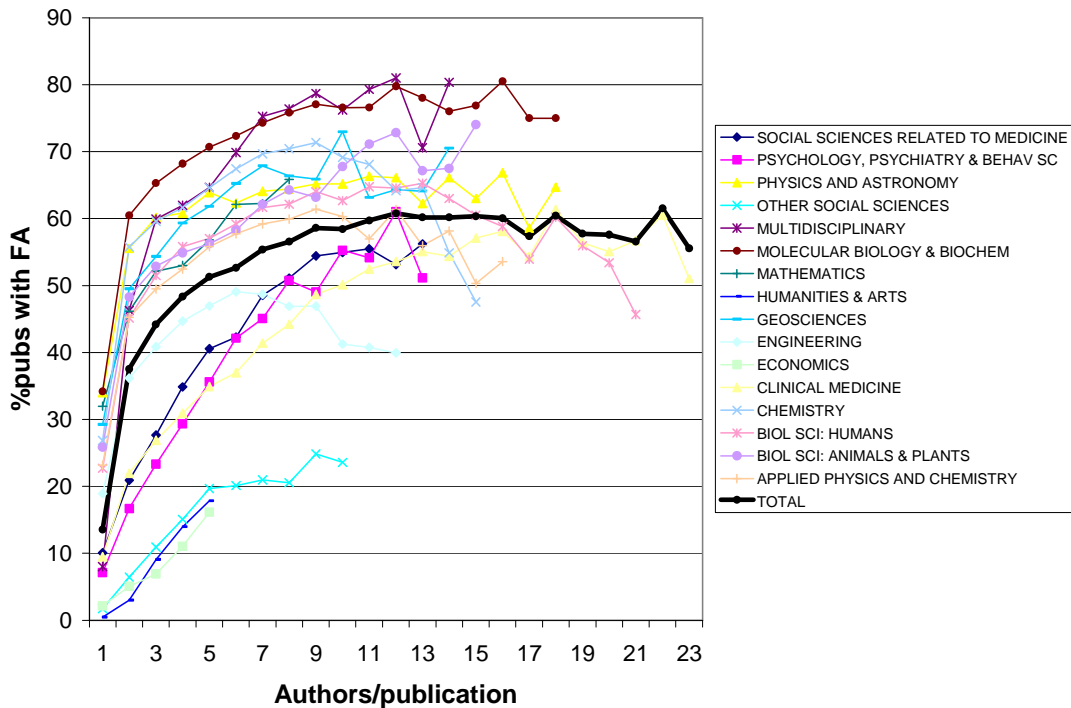
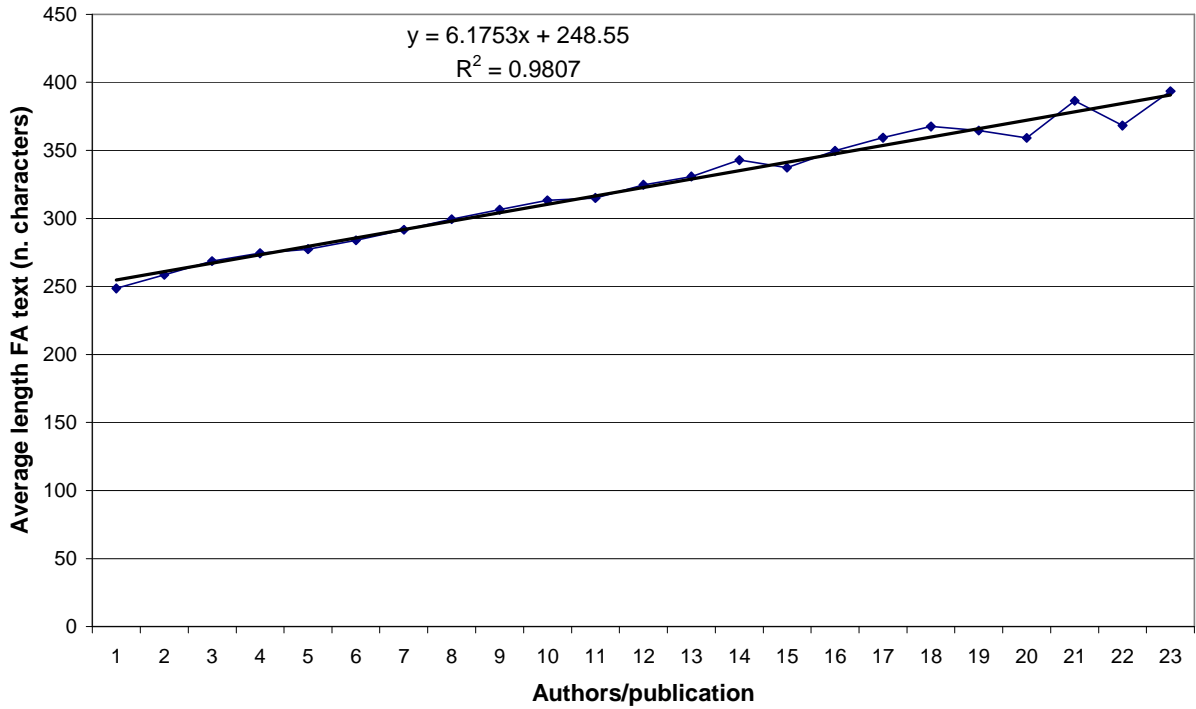


Although the correlation is not very high ( $R^2=0.314$ ), there is a positive relationship between the length of the funding text and the field normalized impact of the publications.

### Length of the FA text and the collaboration of publications

The relationship between the presence and the length of FA text in the publications and the number of co-authors in the papers is shown in Figure 2. Only groups of authors/publication with at least 300 publications have been included (this is the reason for the threshold of 23 authors/publication in the graphs).

Figure 2. Relationships between the length and presence of FA and the number of authors per publication



In Figure 2, on the one hand, the graph on the top shows how the length of FA text has a clear linear relationship with the number of authors per publication,

showing an increase of about 6 characters in length with every extra co-author. On the other hand, the graph on the bottom shows something relatively different. According to the graph, the share of publications with FA information has a positive relationship with collaboration. In general, publications with lower levels of collaboration (i.e. fewer authors) tend to less frequently bear FA, while with higher levels of collaboration there is an increase in the share of publications with FA. However, in contrast with the graph on top, this relationship is not linear but curvilinear, and this curvilinear pattern is consistent not only for the total of the publication (thick black line) but also for the different disciplines considered in the analysis (colored lines in the graph)<sup>4</sup>. This suggests that there are some kind of 'maximum points' in the relationship of authors/publication and the share of FA presence. In the case of considering all WoS publications this maximum point is reached from the group of 11 authors per publication onwards, when the percentage of publications with FA reaches the level of 60% but does not seem to move further from here (differences by disciplines can be observed, but the pattern is quite consistent across them).

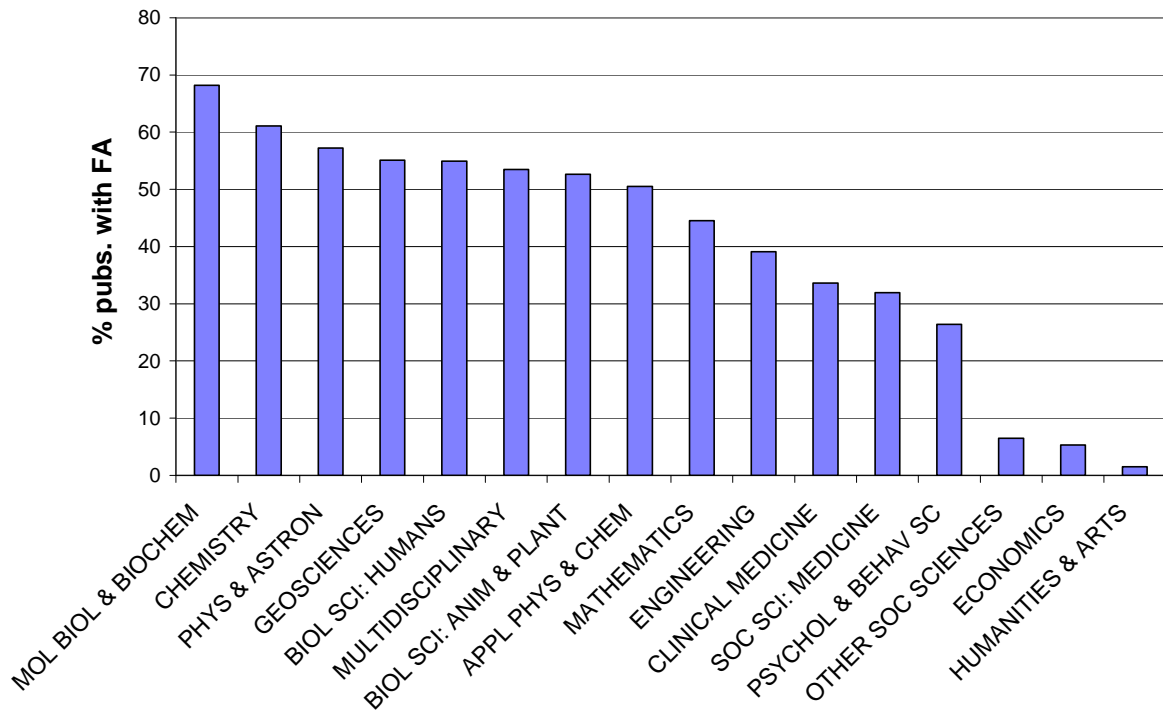
### FA presence by disciplines

In the following analysis, the distribution of publications with FA information among scientific disciplines is presented (Figure 3).

Figure 3. Distribution of the share of publications with FA by main disciplines

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<sup>4</sup> Most of the disciplines have their maximum points around the values of 60-70% of publications with FA. However, there are exceptions such as 'Molecular Biology & Biochemistry' or the 'Multidisciplinary journals' that clearly exceed this threshold (above 70% in both cases), as well as other disciplines that hardly reach the value of 60% (basically the humanities and social sciences).

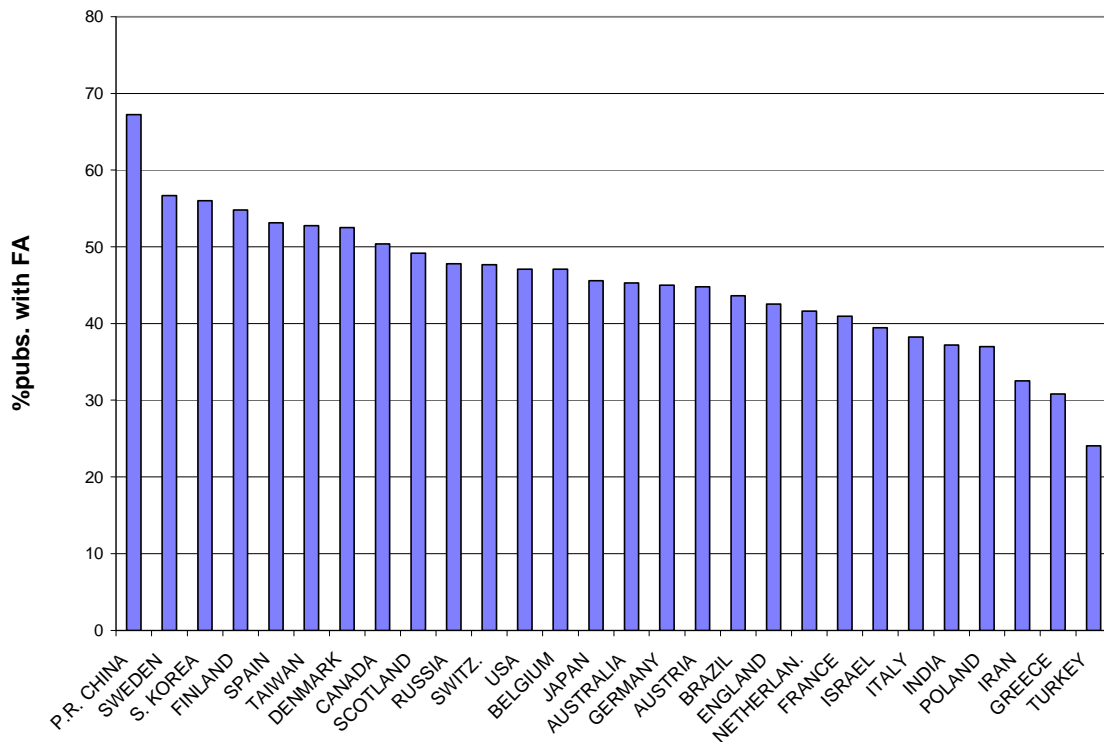


Publications from the natural science disciplines (including Molecular Biology & Biochemistry, Chemistry, Physics & Astronomy, Geosciences, Biological Sciences, Multidisciplinary journals, etc.) have the highest share of FA. Combined, the share of FA in the natural science disciplines is higher than 50%. There is a second group of disciplines with shares lower than 50% but higher than 20% of publications with FA information. Included in this group are applied/clinical sciences (Engineering, Clinical Medicine), Mathematics, Social Sciences applied to medicine, Psychology and Psychiatry & Behavioral Sciences. There is also a third group with disciplines that have shares of FA lower than 10%. This group includes Economics, Social Sciences and Humanities & Arts, thus suggesting that these fields are less funded than the other basic and applied/clinical fields.

### FA presence by countries

The next analysis focuses on the distribution of FA mentions within the papers of the most important countries (Figure 4). For this analysis we have focused only on countries with more than 10,000 publications in 2009.

Figure 4. Distribution of the share of publications with FA by countries



The most striking result in Figure 4 is the dominant position of China, where more than 65% of the publications in this country have an FA mention. Other countries that also have high levels of FA (more than 50% of their publications) are some Asian countries (South Korea and Taiwan), some Scandinavian countries (Sweden, Finland and Denmark), and Spain and Canada. In the other side of the spectrum, with the lowest levels of funding mentions (less than 40%) are Turkey, Greece, Iran, Poland, India, Italy and Israel. It is remarkable that at the end of this list we also find some European countries such as the Netherlands, England and France, that have slightly less than 43% of their publications with the presence of FA.

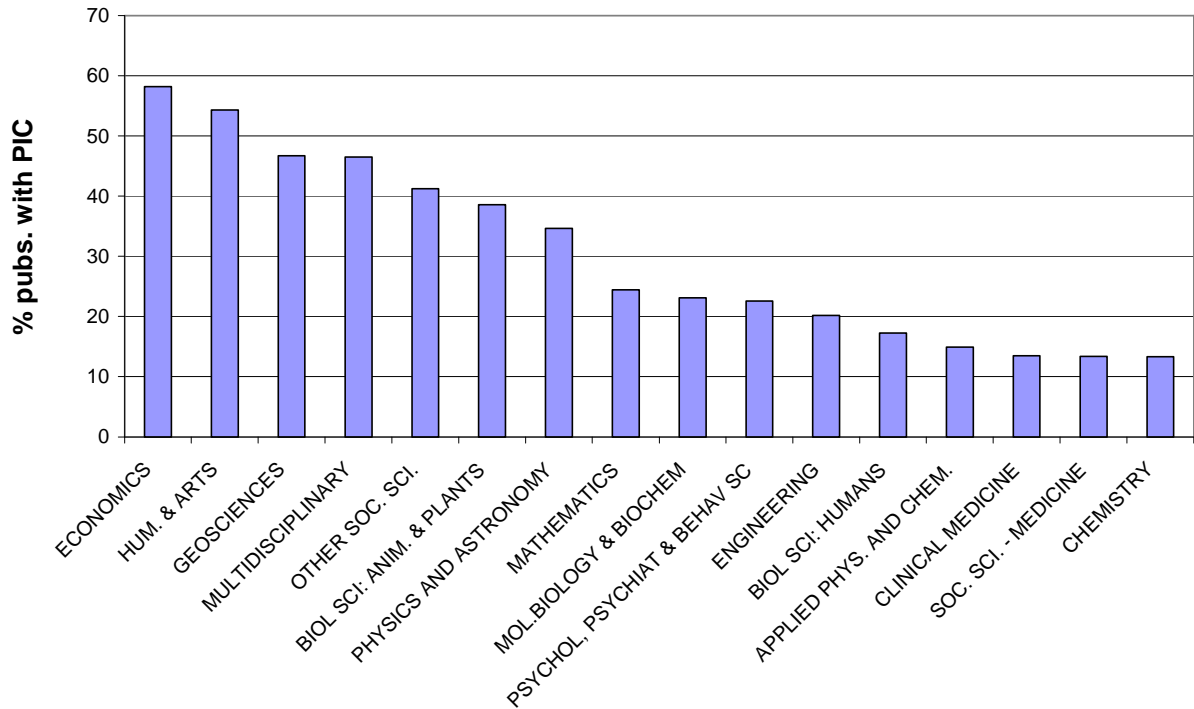
#### Presence of PIC acknowledgments in publications

In the following the focus moves towards the analysis of the presence of PIC acknowledgments within the text of the FA of scientific publications. Unfortunately we cannot examine all the potential PIC activities of all the papers due to the above-mentioned limitation of Thomson Reuters, whereby collection of acknowledgments occurs only when funding information is detected. This is the reason the percentages of PIC acknowledgements are calculated based on the total number of papers with FA and not on all the papers (this holds for all the analyses based on PIC).

## Disciplines

The distribution of PIC acknowledgments among the different main scientific fields is presented in Figure 5.

Figure 5. Share of publications with PIC acknowledgments by fields



This figure shows a relatively inverse pattern as compared to the previous figure with distribution of papers with FA by main disciplines (Figure 3). Economics, Humanities, Social Sciences, Geosciences and also Multidisciplinary fields are the ones that proportionally include more PIC acknowledgments (more than 40%). On the other side, some of the natural and biomedical sciences (Chemistry, Social Sciences applied to Medicine, Applied Physics & Chemistry, Clinical Medicine or Biological Sciences for humans) present the lowest levels of PIC acknowledgments (less than 20%).

## Countries

The presence of publications with PIC acknowledgments by countries is displayed in Figure 6.

Figure 6. Share of publications with PIC acknowledgments by countries

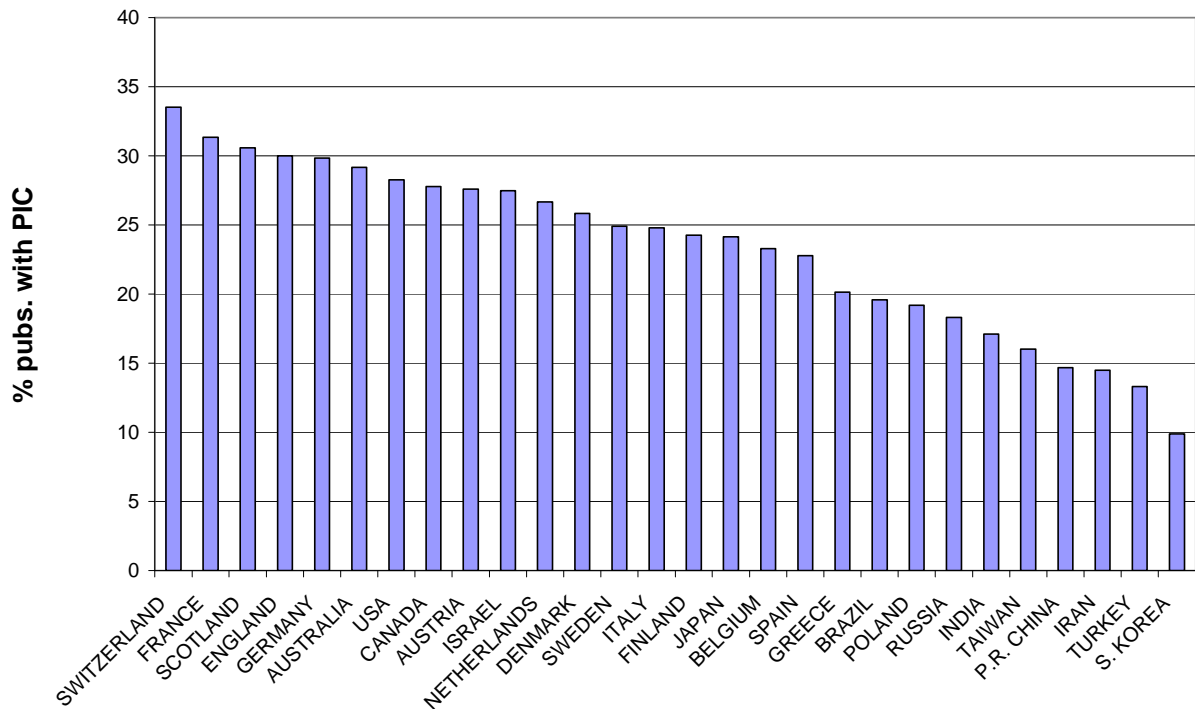


Figure 6 shows that among the countries with higher percentages of PIC (more than 25% of the FA publications with PIC) we find some of the strongest English-speaking countries (Australia, Canada, England and Scotland from the UK, and the USA), as well as some other strong European countries including Switzerland, France, Germany, Austria, the Netherlands and Denmark. In a second block we find other non-English speaking European countries (e.g. Sweden, Italy, Finland, Belgium, Spain and Greece) and Japan, all of them with shares between 25% and 20% of their publications with FA that includes PIC acknowledgments. Finally, there is a third block of countries with less than 20% of publications that include PIC mentions. This group is composed of the BRIC countries (Brazil, Russia, India and China) as well as other Asian and emerging countries (Taiwan, Iran, Turkey and South Korea) and also Poland.

#### *Collaboration of authors*

Finally, the relationship of PIC presence and the number of collaborators in a paper is presented (Figure 7).

Figure 7. Share of publications with PIC acknowledgments by collaboration

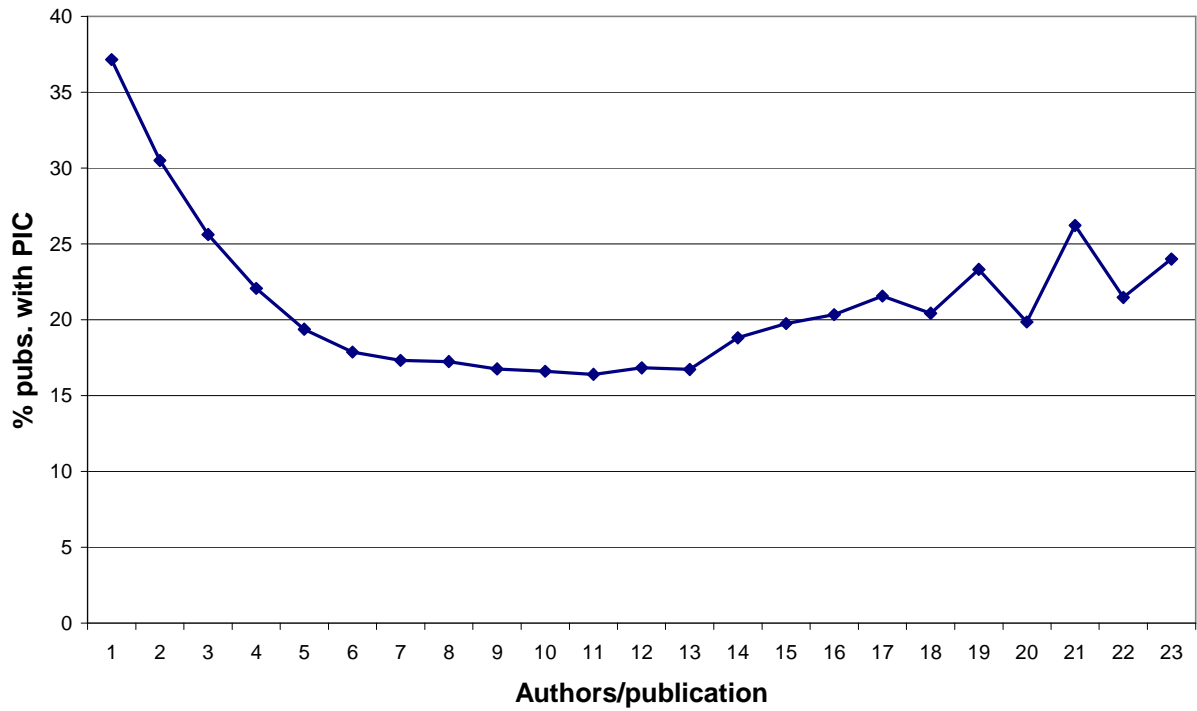


Figure 7 shows that publications with fewer authors tend to present more PIC acknowledgments than publications with more collaboration. However, interestingly enough, there seems to be a turning point in the papers with 13 authors onwards. In this group the percentage of papers with PIC acknowledgments tends to increase again.

## Discussion and conclusions

The analysis of acknowledgments attached to publications is without doubt a very relevant but relatively untapped aspect in bibliometric studies. For many years this 'third edge' of the 'reward triangle' has not been properly explored, while claims of its potential benefits have been suggested elsewhere (Cronin et al, 1992, 1993b, 2004). Due to recent changes in the WoS, the analysis of the acknowledgments section of publications has become possible. WoS includes since August 2008 (Thomson Reuters, 2011) the acknowledgment text of publications when they mention any funding source. However, the incompleteness of the data provided by WoS partially limits and jeopardizes the potential use of this source for more varied analytical purposes. In addition, the lack of information about the details of how acknowledgments are collected and how the possible different traditions and cultures of acknowledging across fields and journals are treated, raise the question whether some biases can exist in the coverage of this type of information. More research on this problem would help to clarify this point and increase the reliability of this new source. Hopefully, database providers will also realize the important potential of this new source and will extend the data collection to all types of acknowledgments and provide more explanations about their methodologies.

Two particular limitations must be taken into account in the consideration of the results obtained in this study. The first one is that we only considered a two-year citation window, so it must be assumed that the impact patterns observed will be the same in the future as publications get their normal levels of citations. The second is a determination of the PIC indications in the acknowledgment text based on word selection as described in the methodology. For example, this could be insufficient for publications in languages other than English or with other ways of signaling PIC. With these limitations in mind, the results presented must be seen as preliminary and future analysis should verify or discuss them. As such, there are interesting aspects of our initial research questions that warrant discussion.

### *What is the global distribution of FA presence across publications?*

Publications with FA represent approximately 43% of all publications covered in the database. This value is in relative agreement with the results of Giles & Council (2004), who found that approximately 56% of papers contained acknowledgments (includes all acknowledgments, not only FA). It is also in agreement with Cronin et al (2003) who detected 49% of acknowledgments in papers from *Psychological Review*. Also, the values provided by Wang et al (2012) for 10 different countries are fully in agreement with the global figures provided here.

### What are the document types that include more FA?

Review papers tend to present proportionally less FA than regular articles, thereby suggesting they are less frequently a direct result of funded research. This may also imply lower levels of collaboration or scientific infrastructures. Salager-Meyer et al (2011) also found fewer acknowledgments in review papers than in research papers. However, the observation that review papers include proportionally more PIC acknowledgments than regular papers suggests that this document type is subject of more comments from and discussions with colleagues than other document types. A potential conclusion is that regular articles need more collaboration and infrastructure, which requires more funding, while review papers require less infrastructure and funding but they involve more interaction with other colleagues. The inclusion of all acknowledgments from all papers in the database could help to clarify this issue.

### Do publications with FA have higher impact than publications without FA?

Publications with FA present an overall higher impact as compared to publications without FA. Levitt (2011) also found that papers with NSF (US National Science Foundation) acknowledgments were more cited than non-NSF funded publications. The results of Giles & Councill (2004) also support this observation, as they found some correlation between funding organizations and the impact of their papers.

However, a remarkable result of our study is that publications that present only FA (without PIC) are published in high impact journals, but they present a lower field-normalized impact (MNCS) as compared to publications without FA. Leaving aside the potential limitation of the citation window, this could be interpreted as an indication that funding is one driving force in reaching higher impact journals (as Levitt (2011) already pointed out), but not the only factor for finally achieving higher impact.

### Is the length of FA text related to the impact of publications?

Publications with longer FA texts, which could reasonably be seen as publications with more funding sources, have only a slightly higher impact. This is in line with the findings of Rigby (2011, p. 373) that “a positive relationship does exist between the number of funding sources of a paper and citation impact, albeit a relatively weak one”. This claim suggests the relationship between the number of funding sources and the impact of papers is somehow more complex and deserves more research.

### *Is there any relationship between FA and collaboration in publications?*

Publications with fewer authors tend to be less funded than collaborative publications. This reinforces the idea that funded research is more frequent in fields where collaboration and big scientific infrastructures are important characteristics than in fields where collaboration and special infrastructures are less common (e.g. humanities and social sciences). It is remarkable that the relationship between the share of publications done in the framework of funding programs and the level of collaboration (i.e. the number of authors per publication) has a curvilinear relationship, this being the case for most of the disciplines studied in this paper. This may suggest that even in the more collaborative and stronger disciplines some unfunded, curiosity-driven research is still carried out; or simply that in these disciplines still an important part of the scientific activity is nevertheless not directly funded.

What is clear is that the level of collaboration in the publications is related to the length of the FA text, what could be reasonably related with a broader presence of different funding sources in the acknowledgments (i.e. more co-authors acknowledging more different funding sources). A potential explanation for this finding is that the different authors of collaborative publications (especially internationally collaborative publications) bring their own different financial support to a project and they acknowledge them separately. This aspect of the presence of co-funding in collaborative publications has been previously discussed by Wang & Shapira (2011, p. 583) in their study of nanotechnology. They show that “national boundaries still matter” and that “national funding acknowledgments overall remain more important than international ones” (with the exception of the European Union). This supports the idea that in international collaborative publications the authors tend to acknowledge their local funding sources separately.

Finally, it can be argued that higher impact publications with FA and longer FA texts could be related to a higher level of collaboration observed in these publications. Publications created in collaboration and especially in international collaboration tend to present a higher impact and visibility (Narin et al, 1991; Bordons et al, 1993; Katz & Hicks, 1997, van Leeuwen, 2009). As a consequence, the higher impact publications with FA could be intermediated by the higher collaboration level of these publications. In this sense, funding could be seen as a facilitator of collaboration more than a direct influence over the impact of publications. Future research should focus on disentangling the different influences of collaboration and funding on the impact of publications.

### *Which scientific fields are more likely to acknowledge funding?*

The distribution of the papers with FA by scientific disciplines shows a clear bias towards the more basic disciplines. Cronin et al (2004) also found different levels

of intensity of acknowledgements across disciplines, with chemistry articles having the highest share of acknowledgments (75%), followed by psychology (49%) and philosophy (25%). This supports the general pattern observed in our results, that natural sciences tend to include more FA, followed by the social sciences and finally the humanities.

The explanation for this pattern, also suggested by Cronin et al (2004) and Wanner et al (1981), is that research in the natural science fields requires more material and physical collaboration, needing more resources and external support as compared to the humanities and social sciences. Moreover, research in the natural sciences is often carried out by teams requiring substantial funding for equipment and support personnel, while in the humanities, scholars more often work alone, with a lower need of capital investment in buildings and instrumentation.

However, it could be also argued that this low share of FA in the social sciences and humanities could be influenced by cultural factors. Most research in these fields is funded by basic research programs, based on direct funding that does not require mandatory acknowledgment. In contrast, the basic research that belongs to the more densely funded fields has as a consequence a broader tradition in formal, and probably also mandatory, acknowledgement of their funding sources. This is something that has not yet been developed in the social sciences and humanities.

Finally, it is interesting to mention how the most applied fields tend to show a relatively lower level of FA, which suggests that in these fields funding comes from sources that do not necessarily require any explicit acknowledgment (e.g. private companies, industry, contracts, etc.).

#### *In which countries are papers more likely to acknowledge funding?*

The main results by countries show that some countries present a higher share of publications with FA (e.g. China, Sweden, South Korea, Finland or Spain), while other countries have lower levels of publications with FA (e.g. Turkey, Greece, Iran, Poland, etc.). These results are in agreement with the results presented by Wang et al (2012) for a selection of 10 countries. There are several potential explanations for the different patterns across countries:

- The existence of mandatory regulations of explicit mention to the funding received across the different national scientific systems.
- The existence of different types of basic or applied funding sources across countries that do not have similar acknowledgment requirements (e.g. in the Netherlands with the so-called 'third money flow' (Smits, 1985) based on contract research). Countries with lower shares of FA could also be related to systems with more basic direct funding that don't require explicit acknowledgements.

- The different disciplinary orientations across countries, with some countries focusing less on humanities and social sciences and clinical/applied sciences than others. In this sense, cultural differences across countries could also play a role in the acknowledgement of funding.

In general, it can be suggested that differences in the share of FA by countries also represents different traditions of funding scientific research across countries. These differences are worth being studied more deeply in the future.

The case of China presenting a predominant share of FA in its publications is remarkable, something that was also observed by Wang et al (2012). Among the reasons for this strong pattern in China, we suggest: a different orientation in its scientific lines as compared to other countries (with a higher focus on natural sciences and engineering, Science-Metrix, 2010); a strong investment in research in this country during the past years (Royal Society, 2011); cultural differences in authorship and acknowledging in Asian countries (Salager-Meyer et al, 2011; Salita, 2010) with stronger ideas of gratitude; and also the idea that Chinese researchers use more of their funding as a signal of potential research capacity<sup>5</sup>.

Building on this last idea of acknowledgments as a sign of strength, the concept of the 'handicap principle' for citations suggested by Nicolaisen (2007) and Nicolaisen & Frandsen (2007) could be somehow applied to acknowledgments too, in a way that authors acknowledge sources of funding and the PIC of other strong colleagues as a 'cost signaling' element. In words of Ben-Ari (1982, p. 67), the authors of the papers with acknowledgments could be sending a meta-message of "listen to me because I am related to someone important enough not to be ignored"<sup>6</sup>.

*Can PIC acknowledgments be accounted through the FA text? Do PICs have any effect on the impact of publications? Are there different patterns in the PIC activities across disciplines, countries and document types?*

The analysis of the PIC acknowledgments of researchers, paying gratitude towards other colleagues and scientists who have reviewed or discussed their papers, is possible through the new tools provided by WoS. However, the new

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<sup>5</sup> The NSFC and the Ministry of Science and Technology of China have an unwritten rule that acknowledging grant funding makes scientists more likely to receive future funding. Chinese applicants in order to gain access to international collaboration funding must have proven their ability with a 3-year domestic grant; this means that acknowledging 3-year domestic grants allows scientists to signal other partners that they are eligible to apply for international collaboration funding.

<sup>6</sup> In this sense, it can be assumed that everybody can cite any relevant or eminent researcher, but acknowledging such a researcher is more difficult and it would imply a minimum capacity of interaction with that researcher.

tools are limited due to the above-mentioned restrictions in data collection of all the acknowledgments from all publications.

The main conclusion from the analysis of PIC acknowledgments is that they have a positive relationship with the impact of the publications. In addition, the fact that review papers also present proportionally more PIC acknowledgments suggests that reviews, which are also more cited (Peters & van Raan, 1994), discuss and condense more different views and perspectives in a given domain, thus requiring exchange of ideas with other colleagues.

The fact that publications with lower levels of collaboration also include more PIC acknowledgments suggests that when authors publish alone, there is a higher frequency of comments and opinions from other colleagues. In contrast, when authors publish in collaboration, the different views among co-authors are already incorporated in the text, so they include fewer PIC acknowledgments. This finding also supports the conceptual relationship between acknowledgments and authorship. It can be argued that when scientists collaborate less, an acknowledgment may compensate it with comments and opinions provided by other persons. This would in turn validate and corroborate the idea of acknowledgments as containers of a kind of 'subauthorship'.

If PIC acknowledgments also indicate a kind of subauthorship, it can be suggested that the higher impact of publications with FA and PIC could be intermediated by this extra 'subcollaboration' type. In other words, the higher impact of publications with FA and PIC is intermediated by the broader collaborative spectrum of these publications, with more co-authors or sub-co-authors. Complementary to this is Rigby's idea (2011, p. 367) that "the link between funding and impact is that the more often an individual research idea is successfully peer reviewed, which it would be if it were the subject of a grant application that was funded, the more plausible to peers it is and the more likely it is to lead to research of high quality". As such, it could be expanded by arguing that the PIC activities of researchers can also work as a form of extra 'peer review' before publication, thus enhancing the quality of the research.

Examined by disciplines, the social sciences and humanities present proportionally more PIC acknowledgments than in other fields. In line with the previous statements, it can be argued that the higher level of PIC in these fields is a way of compensating the lower levels of collaboration, which occurs more frequently by comparison to other fields from the natural and basic sciences. Another complementary explanation can be the time lag in the production of publications in the social sciences and humanities as compared to the natural sciences. The first group has a slower pace of publication where researchers can spend more time discussing their findings, pre-prints, etc.; while the second group corresponds to fields with a much faster publication process and much faster obsolescence of new findings. As such, this allows less time for authors to ask for and receive feedback about their manuscripts from other colleagues.

Finally the analysis by countries also shows an interesting pattern that shows English-speaking countries displaying among the highest degree of acknowledgments of PIC activities<sup>7</sup>. However, this can be partly explained by better coverage in the WoS of humanities and social sciences output from English speaking countries. This is followed mostly by European non-English speaking countries (which could also suffer from having more papers with acknowledgments in their own language and therefore not recorded by WoS) and finally by some Asian countries, the BRIC countries, and other emerging countries. The main explanation of this position for the last group could be that these countries are quickly growing in production (Rons, 2011) and developing their research systems by investing more resources in research and rapidly increasing their scientific output (Royal Society, 2011). However, they are still lacking part of the scientific culture of other countries as they are not yet fully introduced into the so-called international 'invisible colleges' (Price, 1963; Zuccala, 2006), which are networks of scientists where the communication and discussion of ideas, the exchange of preprints, information and data, etc. are characteristic elements. This idea of the potential isolation of researchers from these countries was already suggested by Arunachalam (2005) and Luo (2006).

### Future research

Although with some methodological and technical limitations, there is no doubt that the analysis of acknowledgments in scientific publications brings new opportunities for studying scientific influence and the relationships among scientists, research organizations, funding agencies, etc. The development of new lines of research on this topic will also provoke new theoretical and empirical research questions (Rigby, 2011). In the same fashion as it happened with citations (Nicolaisen, 2007) a theoretical framework for the analysis of acknowledgements will be necessary. A new theoretical framework would help address questions such as (as already suggested by Cronin & Weaver, 1995): What do acknowledgements mean and measure? Why do authors acknowledge? What do they acknowledge? When do they acknowledge? What is the role of acknowledging in scientific communication? Are theories for citation analysis (e.g. normative and constructivist) also valid for the understanding of acknowledgments? What if we could (as we can) study and measure them in a systematic way? Would this possibility change the behaviour of scientists in their acknowledging practices?

Further research will be necessary in order to study more deeply the role of FA, and acknowledgments in general, in scientific publications. In addition to the enlargement of the citation window, there are other remarkable possibilities such

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<sup>7</sup> According to Salager-Meyer et al (2011, p. 777) "Anglo-American medical researchers... have always been more prone to acknowledge those who might have had an influence upon the final draft of the published article", because acknowledgments have been mandatory in English-medium medical journals since the late 1970s.

as analyzing the persons, organizations, etc. that give and receive acknowledgments, allowing the possibility of studying other aspects like the roles of scientists and organizations in knowledge production, the evolution of these roles over time, the different networks that can be extracted from acknowledgments, etc. In addition, multivariable analysis will be also useful in order to analyze how all the variables (collaboration, length of the acknowledgments, type of funding, PIC indicators, other types of acknowledgements, publication journals, etc.) interact and are correlated among them, and how they may influence the impact and visibility of publications.

Finally, it is important to mention that already back in 1995, Cronin & Weaver suggested the potential development of a sister tool of the Science Citation Index. This is something they termed the 'Acknowledgment Index'. They also provided instructions on how this new tool could be implemented. Perhaps the time has come to employ this sort of tool to facilitate development of the so-called 'influmetrics'. In combination with other new emerging analytical approaches such as altmetrics, bookmarking analysis, blogging analysis or webometrics among others (Priem et al, 2010; Priem & Hemminger, 2010; Gorth & Gurney, 2010; Wouters & Costas, 2012) this could increase the analytical spectrum of different types of influences that scientific activities can have over the scientific community and society-at-large.

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