# To be or not to be on Twitter, and its relationship with the tweeting and citation of research papers

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**Abstract**: The objective of this paper is to understand the relationship between the diffusion and mention of research papers in Twitter according to whether their authors are members or not of that micro-blogging service. To that end, 4,166 articles from 76 Twitter users and 124 from non-Twitter users were analysed. Data on Twitter mentions were extracted from PlumX Analytics, information on each Twitter user was taken from the own platform and citations were collected from Scopus public API. Results show that papers from Twitter users are 33% more tweeted than documents of non-Twitter users. From Twitter users, the increase of followers produces 30% more tweets. No differences were found between the citation impact (i.e. number of citations) of papers authored by Twitter users and non-Twitter users. However, the number of followers indirectly influences the citation impact. The main conclusion is that the participation on Twitter affects the dissemination of research papers, and in consequence, it indirectly favours the likelihood that academic outputs being cited.

**Keywords**: Twitter, Altmetrics, PlumX Analytics, Citation Impact, Research dissemination

## Introduction

Nowadays, Twitter has become one of the most powerful instruments for the spreading of news, comments and opinions around the world. This revolutionary micro-blogging service allows the broadcasting of short messages addressed to an audience of followers, who in turn forward or retweet to a larger public sphere, going through the web space in a viral way. This hybrid between a social network and an information exchange service (Kwak et al., 2010) has reached every facet of life, transforming the current forms of political, economic and social communication (Murthy, 2013).

These changes also occurred in scholarly communication where Twitter became one of the most important tools to disseminate research outputs and to popularise scientific advances (Ebner, 2013). From an altmetrics point of view, the tweeting of research papers could be considered as an early proxy of article-level research impact (Eysenbach, 2011; Priem et al., 2012; Shuai et al., 2012). Because one supposes that the more a document is tweeted and retweeted, the more important or interesting is for the

academic community. To some extent, the strength with which a document is spreading through the network, it could be as well a symptom of future research impact. In this way, concepts such as dissemination and impact are put in relation suggesting that the way a paper has been broadcasted influences the next citation impact (Lawrence, 2001).

In the pre-web era, dissemination was almost an exclusive activity of journal publishers, where authors hardly participated in that task. In this situation, subscriptions and the indexing in bibliographic databases were the only dissemination way that could affect citation impact (Callaham et al., 2002). The open access of articles through repositories and electronic journals evidenced that the broadening of the audience could produce more citation impact (Harnad and Brody, 2004; Moed, 2007). With the coming of the Science 2.0, that is, the use of collaborative web platforms for academic purposes, and the academic social networking sites, authors acquire an active role in the spreading of their own results. Now, researchers post pre-prints on repositories or document sharing sites, write blog entries and/or mention their new outputs in social networks. This intense participation could gain importance in the research evaluation of researchers and affect their academic impact. In this new environment, the research impact of an author could be not only caused by the quality of their works, but by the ability to self-promote in social web spaces. The importance of this new situation means that the research impact is not now external to the authors, but that they can directly influence the way a paper is cited (Dietrich, 2008; Ebrahim et al., 2014).

Considering Twitter as a paradigmatic service for promoting research documents, this study attempts to explore in which way the activity of authors in Twitter influence the spreading of their papers and if this behaviour could have any benefit in the citation impact.

## Related Research

The first studies on Twitter came up shortly after starting the service and they were focused on describing the service and its impact on the social web communication (Java et al., 2007; Huberman et al., 2008). Soon after, many studies highlighted the opportunity that this microblogging service offered to the scientific communication, mainly with regard to the following up of conferences (Letierce et al., 2010; Chen, 2011; Weller et al., 2011) and the dissemination of research advances (Gruzd, 2012; Kim et al., 2012). However, the emerging of altmetrics caused that many researchers saw a parallelism between tweets and citations and explored the possibilities of this network for the research evaluation. Eysenbach (2011) mined 1,573 tweets that mentioned Journal of Medical Internet Research's articles, finding that tweets can predict highly cited articles within the first 3 days of publication. Shuai et al. (2012) analysed the number of tweets to 4,606 pre-prints in Arxiv.org and they observed statistical correlations between tweets and an early citation impact in favour of highly mentioned articles. Thelwall et al. (2013) surprisingly detected a negative correlation between tweets and citations, provoked by the fast increase of paper mentions in Twitter in front of the usual time delay of citations. In one of the most comprehensive studies,

Haustein et al. (2014) analysed the Twitter mentions to 1.4 million of research papers from Pubmed. The correlation between tweets and citations was low and varied according to disciplines and publications. Another study randomly explored 20,000 publications from Web of Science and it found that tweets constituted a different component with regard to citation metrics (Zahedi et al., 2014). More recently, De Winter (2015) studied the citation impact of PLOS One papers and notified that tweets were better predictors of other altmetrics than citations. In general, the weak relationship between both impact measures confirms that tweets and citations are result of different phenomena.

However, the impact of tweeted documents is very dependent on the implantation and adoption of this service by the scholarly community. Due to this, other studies have focused on the presence and use of this platform on the part of scholars. Bar-Ilan et al. (2012) analysed the online presence of 57 bibliometricians and they pointed that only 16% researchers have a Twitter account, being the less used social space. Holmberg and Thelwall (2014) searched the most productive authors in Web of Science and they found that only a few of them were Twitter members. Bowman (2015), who surveyed close to 2,000 professors detecting that 32% of them had a Twitter account, found that many of these scholars used this platform only for personal purposes. Holmberg et al. (2014) suggested that 10% of scientists could be registered on Twitter. This low adoption rate directly determines the proportion of tweeted papers. In this sense, Haustein et al. (2014) and Zahedi et al. (2014) showed that the percentage of tweeted papers is very low and it does not reach 10%. Maleki (2014) found that only 5% of the Iranian papers received a mention on Twitter. Holmberg and Thelwall (2014) distinguished that close to the half of the tweets were clearly not related to scientific topics. However, more recent studies have shown that the number of tweeted articles is growing up (Costas et al., 2015; Barthel et al., 2015).

## Objectives

The aim of this study is to observe to what extent the presence of a researcher in a social network such as Twitter influences the number of mentions or tweets that receive their publications. Several specific questions were formulated to accomplish this objective:

- Are documents from Twitter users more tweeted than documents from non-Twitter users?
- What do activity indicators of Twitter members (i.e. total tweets, followers, followings, etc.) influence the tweeting of their documents?
- Is there any difference between the research impact (number of citations) of papers authored by Twitter and non-Twitter users?
- What do attributes of Twitter users (i.e. total tweets, followers, followings, etc.) influence the citation of their documents?

## Methods

### *Data sources*

**PlumX Analytics**: PlumX Analytics is an aggregator of alternative metrics. This means that this platform extracts metrics from secondary sources (e.g. social networks, repositories, publishing platforms, etc.) that describe the performance of the same document in different online environments. Created in 2012 by Andrea Michalek and Michael Buschman, it presents the advantage that their data can be aggregated to an author profile or organization. This allows to present graphics and statistics on the online impact of researchers, departments and universities. Each researcher's profile presents as well links to the page of the same author in other places, which it makes possible to track the presence of the researchers in academic social sites. This service was selected because it offers an easy way to extract information from author's profiles and documents. The coverage of Twitter data is suitable because it employs, since April 2016, Gnip, the official provider of Twitter data. In addition, it uses several elements to identify a mention to a paper (not only DOI), and it offers a direct link between the performance of academic papers and the online presence of their authors.

**Twitter**: Created in 2006, Twitter is the most extended microblogging service around the world and it could be considered a good online instrument to promoting oneself and to share information and opinions on the web. In Twitter, each user can send short messages to a general audience shaped by other members (followers) interested in the opinions and activities of that user. At the same time, this user also follows other users (followings) that, through their messages, provide him/her relevant information. In this way, Twitter becomes a global channel of information exchange and a formidable way for the diffusion of academic results. Twitter was select because this is the most important web tool for spreading information; the number of tweets that a document receives is being used in all the altmetric aggregators (Altmetric.com, ImpactStory, PlumX Analytics, etc.) as a social impact measure; and the use of tweets for research evaluation is currently a hot topic in scientometric and altmetric studies.

**Scopus**: Created in 2004 by Elsevier, the giant of academic publishing, this bibliographic database contains more than 55 million of scientific references and close to 100 million of citations since 1996. Scopus was chosen because this is one of the largest citation indexes, with 22,000 journal titles, books and conferences proceedings. Another reason to use this service is that it recently offers a public and free API to extract citation counts from its publications.

### *Data extraction*

Data were obtained during April 2016. A first step was to crawl and harvest the most exhaustive list of author's profiles from PlumX Analytics. To do that, public institutional profiles from that aggregator were searched in Google (site: plu.mx). Thus, organization's web page from Georgia Southern University

(plu.mx/georgiasouthern/g/), St. Mary's College of California (plu.mx/stmarysca/g/), University of South California (plu.mx/usc/g/) and University of Pittsburgh (plu.mx/pitt/g/) were found and used to extract author's profiles. Besides, other members from different institutions were gathered from the generic page of PlumX Analytics (plu.mx/plum/g/). These pages contained a total list of 1,097 author's profiles with papers published during 2013 to 2016. That time window was defined to select only publications that might be mentioned on Twitter while it was wide enough to include citations to those papers as well. This crawl yielded 62,874 publications with their corresponding altmetric counts.

PlumX Analytics displays a web page by each one of their authors where they can include information and links on their digital presence in social networks. From the initial list, only 36 profiles included a Twitter account. Due to the number of Twitter users in the sample is very low, all these authors were included in the sub-sample Twitter users. Next, to broaden the sample list and to obtain the control group (i.e. non Twitter users), a random list of alphabetically ranked profiles by PlumX Analytics author's code were checked (e.g. /u/adale) one by one. Each name was verified in Twitter, to confirm if each author was really registered on Twitter, despite he/she did not mention it in its PlumX profile. 40 more authors were found on Twitter and then they were moved to the Twitter user group. This manual checking was performed until to reach the number of 200 individuals in total. The way for identifying authors in Twitter was firstly through searching the name in the social network; then, from the results, profile picture was compared with the same in PlumX; and finally, the location, followers and tweets were analysed to detect any link to the searched author (i.e. she/he lives in the same city, follows the university account, tweets messages on the same research speciality, etc.). Finally, 76 profiles that had a Twitter account were selected along with other 124 profiles that were not registered in that social network. Because this manual exploration is a time consuming process, only a statistical representative sample was selected. In addition, the total list of publications from those profiles (4,166 papers) was considered a wide enough sample for the statistical representativeness of the analyses.

Finally, Scopus public API (api.scopus.com) was used to extract citations from the items obtained from PlumX Analytics. DOI was used to match the publications, so documents without this identifier were not searched.

## *Statistics*

In this study, two statistical analyses were performed to respond to the formulated questions. In addition, all the variables were transformed to logarithmic scale (ln+1) which permits the utilization of parametric statistics, more powerful than the non-parametric ones:

**Student's t-Test for independent samples**: it was used to compare the mean of the sub-samples (i.e. to be or not to be on Twitter). This is the most extended and used

statistical test for small samples where the normal distribution is assumed. This test allows checking the differences between means and establishing confident intervals for them. An advantage of this test is that it allows the comparison between samples of different size.

**Regression analysis**: it was utilised to estimate the influence of Twitter activity metrics (total tweets, followers, followings, etc.) on the distribution of tweets and citations in each researcher. Simple regression analysis was performed because these variables are not independent among them.

## Results

From the final list of 4,166 papers, the number of tweets and retweets that these papers received were analysed. Twitter users published 2,082 articles, being an average of 27.4 papers by author. On the contrary, authors without a Twitter account published 2,084 documents, with 16.8 papers by author. Although the first ones publish, in average, more papers than the second ones, no statistical differences were found between these groups (p-value=.835). Therefore, there are no differences between the scientific production of Twitter and non-Twitter users.

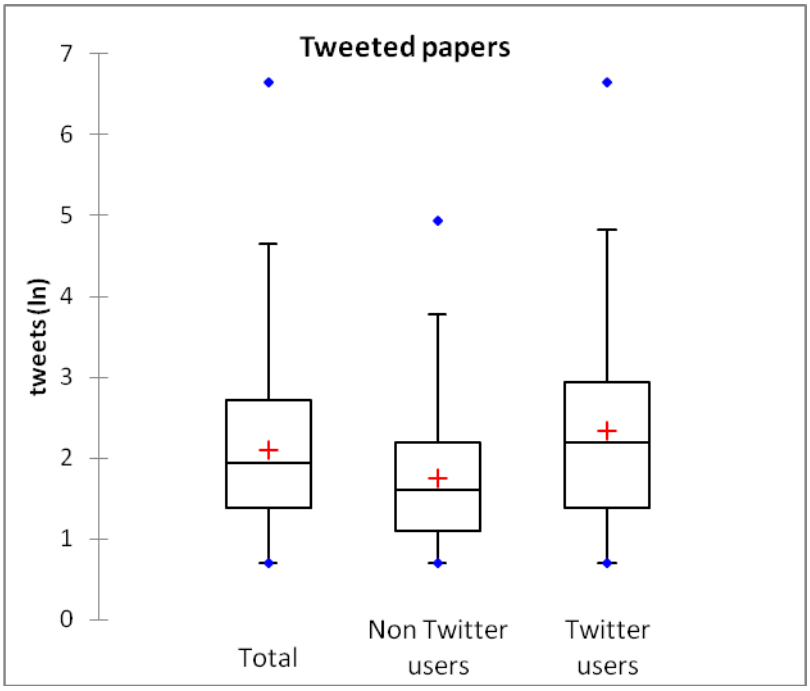


Figure 1. Box plot (log scale) of the distribution of tweeted papers according to whether authors are registered on Twitter or not

However, many of these articles were not tweeted. From the 4,166 articles in the study, only 342 were mentioned in this network (8.2%). This proportion is rather low and it evidences the poor use of Twitter to disseminate research articles. According to Twitter and non-Twitter users, 121 (5.8%) documents authored by non-Twitter users were tweeted, while the network mentioned 221 (10.6%) articles from Twitter users. In average, documents from twitterers receive 33% more tweets than papers from non-

Twitter users (Twitter users mean= (±.15) 2.33; Non Twitter users mean= (±.16) 1.75), which it demonstrates the high importance that authors have for the spreading and impact of their own documents on Twitter. These differences are confirmed by the Student's t-test, detecting statistical differences (p-value < .0001) between these groups (Figure 1).

## *Authors on Twitter*

A second question is whether the networking activity of the authors on Twitter influences the times that their publications are mentioned on the network. Thus, articles from the 76 scholars registered in Twitter were selected, concretely 2,068 papers. Then it was observed the number of tweets that received those papers. To quantify the activity of each user, number of total tweets, followers and followings were manually extracted from each profile. All these variables were normalized by the time period that each user was registered on Twitter. Because the more time passes since a user is registered in that online social network, the more tweets, followers, and followings they could have. Thus, each variable is expressed as a ratio of the number of months since the authors were joined to the network to April 2016, date of the study.

| Source | Value | Standard error | t | Pr > \|t\| | Lower bound (95%) | Upper bound (95%) |
|---|---|---|---|---|---|---|
| total tweets (ln) | 0.154 | 0.045 | 3.448 | 0.001 | 0.065 | 0.243 |
| followers (ln) | 0.306 | 0.050 | 6.102 | < 0.0001 | 0.206 | 0.406 |

Table 1. Coefficients of the simple regression model for number of tweets per month

Table 1 shows the result of the regression models of the number of tweets per month to papers authored by Twitter users. Simple regression model was used because both variables, total tweets, and followers, are related between them and they could produce collinearity problems. In this sense, the number of followers depends on the number of tweets posted, because it is hard to follow to someone that does not post anything. The models present that the total number of tweets posted by the authors and the number of followers that they have, positively influence the times that papers are tweeted. Followers is the most influential variable because it explains 34% ($R^2$=.341) of the tweets received by the publications of Twitter users while total tweets only predict 14% ($R^2$=.142). Although these fits are rather low, results state that the number of followers and total tweets significantly influence the mention of documents in Twitter. The interpretation of the coefficients allows us to state that 1% growth of the number of tweets per month produces an increase of .15% of tweets while 1% increase of followers per month generates .31% of new tweets.

## *Citations vs. Tweets*

A third question is the extent to which the number of tweets that a paper receives is related to the number of citations, distinguishing between documents authored by

Twitter and non-Twitter users. From the initial 4,166 papers, 1,543 (37%) articles were identified in Scopus. The remaining ones would be documents that are not indexed in Scopus or do not have a DOI. Correlation between both metrics is rather low (Spearman r=.179) and it demonstrates that both measures express a very different impact phenomena.

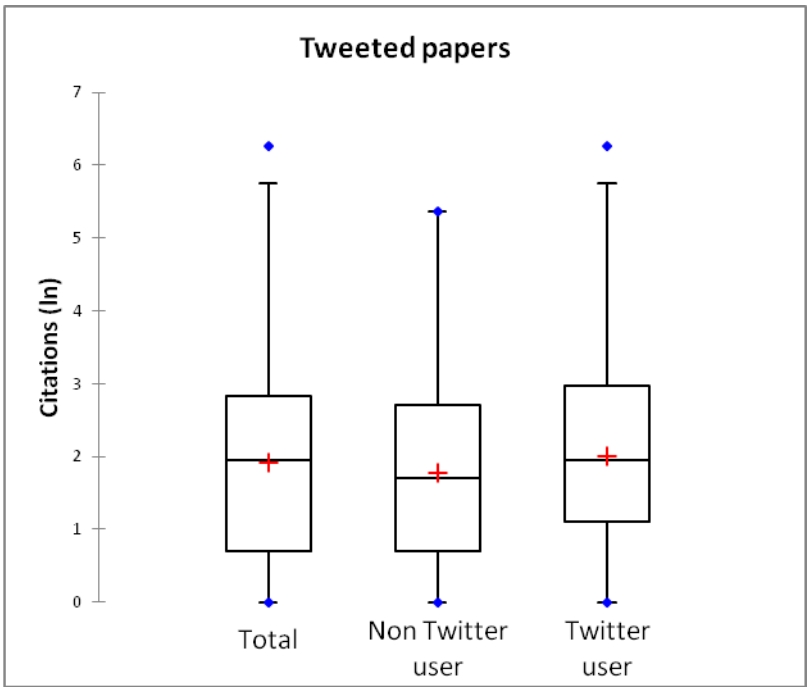


Figure 2. Box plot (log scale) of the distribution of cited papers according to whether authors are registered on Twitter or not.

From the 1,543 cited papers, 289 (18.7%) were previously mentioned on Twitter. This percentage shows that impacted articles are hardly mentioned in this social network and it evidences that there are many high-quality articles that are unnoticed in this environment. Now, the sample is shaped by two groups: 179 (62%) articles belonging to Twitter users and 110 (38%) to non-Twitter users. Figure 2 shows the number of received citations to each tweeted paper according to whether the author is Twitter or non-Twitter user. Although papers from non-Twitter users are slightly less cited than Twitter users (Non Twitter users mean= (±.24) 1.77; Twitter users mean= (±.21) 2.00), the Student's t-test does not find statistically significant differences (p-value=.144) between these two sets. This demonstrates that the number of citations of a paper is independent of the number of times that it is mentioned on Twitter, therefore the number of tweets does not affect the number of citations of that paper.

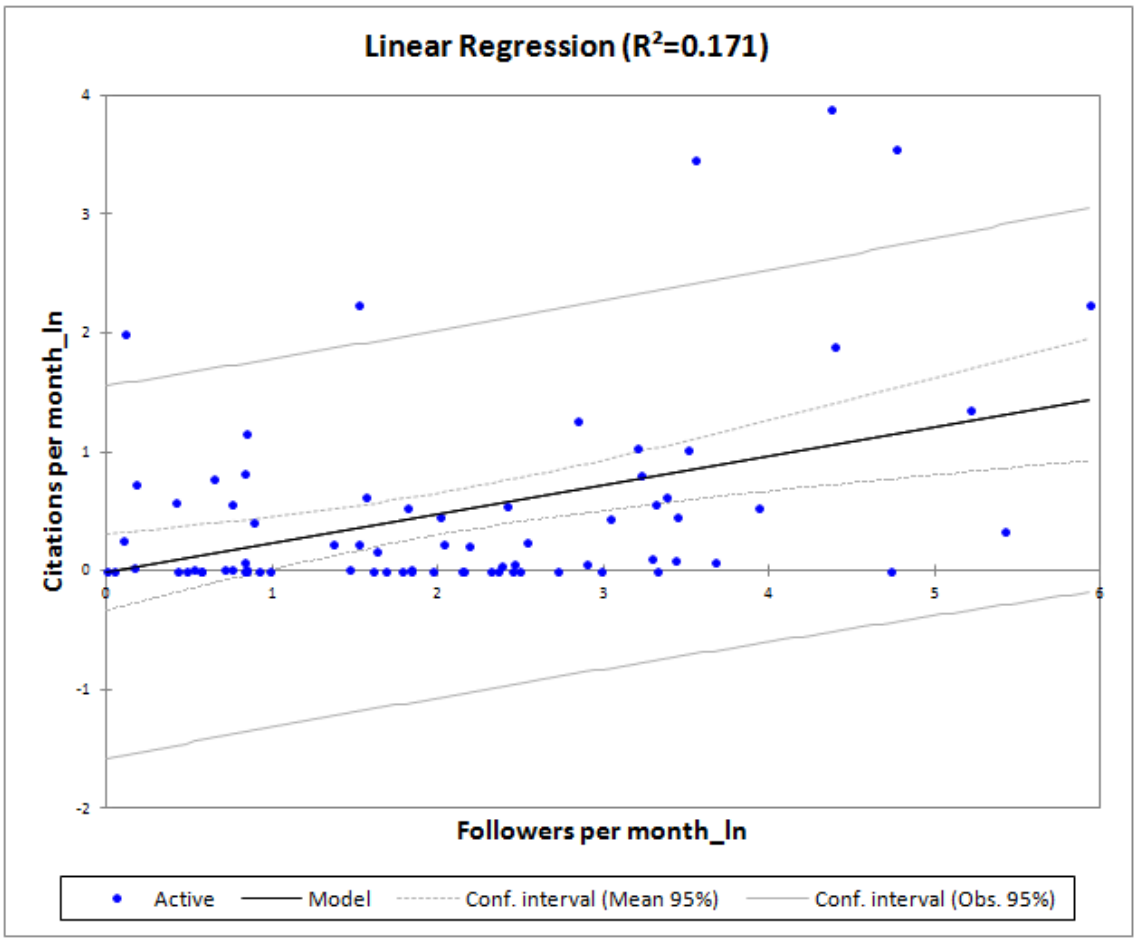


Figure 3. Scatter plot of the linear regression analysis between Citations per month and Followers per month

| Source | Value | Standard error | t | Pr > \|t\| | Lower bound (95%) | Upper bound (95%) |
|---|---|---|---|---|---|---|
| Followers (ln) | 0.245 | 0.063 | 3.884 | 0.000 | 0.119 | 0.370 |

Table 2. Coefficient of the simple regression models for the number of citations per month

Finally, the relationship between the citation impact and the activity in Twitter was studied. The objective is to discover whether the diffusion of papers on Twitter influences the research impact of those publications. To that end, a regression analysis was done to explain which Twitter activity metrics (i.e. total tweets, followers, and followings) influence the citations impact of papers authored by the 76 researchers with a Twitter account (Figure 3 and Table 2). These variables were also normalized by date of signing up for Twitter, included citations. Results show that followers per month is the only variable that influences citation counts (p-value=.0001). However, the effect of this variable is insignificant, because an increase of 10% of followers just causes an increase of 2.4% of citations. Even more, the observed fit is rather weak and it means that this influence is only statistically true for 17% of authors. These results make clear

that the needed effort to disseminate papers on Twitter is very high in relation to the number of citations that these papers could receive.

## Discussion

This analysis on the influence of being a Twitter member in the impact and spreading of academic outputs has reported several interesting results that allow us to discuss the role of this network in the academic communication system. First to all, the percentage of tweeted papers is quite low. From the initial sample, only 8.2% articles were mentioned on Twitter. This percentage is similar to that found by Haustein et al. (2014) (9.4%) and even lower than the results of Zahedi et al. (2014) (1.6%) and Meleki (2014) (5%). These results verify that only a small fraction of papers is mentioned on Twitter and it questions that this social network can be a representative tool for the monitoring of the social impact of scholarly results. In this way, doubts arise not only with regard to the suitability of Twitter messages as proxies for research assessment but as indicators for the study of the social impact of science.

However, there are significant differences between the diffusion and impact of documents in the Twitter environment, demonstrating that the papers from Twitter users could reach 33% more mentions than papers from non-users. This means that the social impact of a document on this broadcasting network is greatly influenced by the active performance of its authors. This influence is demonstrated by the regression analysis, where followers ($\beta$=.30) and, in less extent, tweets ($\beta$=.15) are factors that improve the impact of a document on Twitter. These results suggest that many of the tweets that cite a paper could be caused by the promotion activities of their authors, announcing the publication of that article. In addition, the followers' network is a powerful way to multiply the audience and the retweeting of messages. This fact questions that the mention of articles on Twitter may be due to the scientific quality or importance of the papers, and it suggests that these mentions could be more linked to the ability of the authors to promote their outputs (Darling et al., 2013). In my opinion, the tweeting of documents has to be considered more as a measure of active promotion and spreading of new results, rather than as a metric for the social assessment of research papers (Allen et al., 2013). Thus, the popularity of weird (i.e. Ig Nobel Prizes) and controversial papers (irreproducible, fraudulent, etc.) on Twitter would be just examples of how far is the dissemination of papers in that network from the academic impact measured in citations.

With regard to citation impact, tweeted documents from Twitter users and non-Twitter users are cited in the same proportion, with no statistical differences between both groups. These results are in line with previous studies (Thelwall et al., 2013; Haustein et al., 2014; Zahedi et al., 2014; De Winter, 2015), confirming the weak relationship between tweets and citations. This means that the promotion activity on Twitter does not significantly affect the research impact of these publications, and authors not registered in Twitter can attract as many citations as Twitter users. These results reinforce the hypothesis that Twitter is a formidable medium for promoting publications

but this spreading is not always related to citation impact. However, in the case of authors with a Twitter account, the regression analysis shows that the number of followers ($\beta$=.24) helps to get more citations. Although this relationship is very weak ($R^2$=.17), this result introduces the importance of diffusion in the citation impact because the more audience a paper has, the more likelihood there is of being cited. Therefore, it could be stated that despite the diffusion of academic results on Twitter does not influence directly the attraction of citations, the mention of these results on Twitter enlarge the audience and therefore the probability of being cited. In other words, the number of tweets does not have to be seen as a reflection of research impact, but as a cause, among others, that provokes the citation. In this sense, the active promotion of papers on Twitter could slightly affect the upcoming impact of a publication. Although this study is only limited to Twitter, it is possible that other communication instruments such as document sharing services (i.e. ResearchGate) or bookmarking sites (i.e. Mendeley) could also favour the citation to papers. Therefore, it could be advisable that similar studies about other social networks could explore in more detail the relationship between impact and dissemination.

However, although these results are in tune with previous analyses (Thelwall et al., 2013; Haustein et al., 2014), the obtained data could suffer from several technical limitations. The first one is that the mentions from an aggregator would differ from the real ones in Twitter. This may due to the algorithm used to extract mentions and the reliability of data providers. PlumX Analytics claims that uses several identifiers (DOI, PubMed ID, etc.) and, since April 2016, it counts with the official data provider of Twitter (Gnip). These actions favour the data completeness and reduce the loss of mentions. However, there is not clear information about the merging of identifiers or the extraction of mentions in the case of documents without a clear identifier. Another limitation is that not all the Twitter accounts of scholars are used for posting scientific topics. Bowman (2015) warned that there are many researchers that do not use Twitter for academic purposes, and Holmberg and Thelwall (2014) advised that more than the half of tweets from scholars is not related to scientific issues. Other problem is when you match two different data sets, it is also possible the appearance of false positives and negatives. Precisely, the manual heuristic used in this study was employed to an exact matching. Finally, some studies have evidenced altmetric differences among disciplines (Zahedi et al., 2014; Haustein et al., 2015), which it suggests that a subject bias could alter the obtained results. In our case, data were randomly extracted from authors belonging to generalist universities which it avoids any deviation in the results. In any case, Neither PlumX nor Twitter have not got a subject classification, so it is not possible to determine a probable disciplinary bias in the sample. All these drawbacks could distort the perception about the researchers' activity and alter the results. Due to this, these findings are only an approximation and they have to be considered with some caution. Forthcoming studies would specify these relationships and confirm the role of Twitter in the promotion and impact of academic papers.

## Conclusions

Several conclusions can be extracted from the results. The main one is that the involvement on Twitter affects the mentioning of research papers, and in consequence, it indirectly could influence the research impact because the visibility of academic outputs could benefit the citing of those materials. With regard to the research questions, these results allow to claim:

- Documents from Twitter users are more tweeted than papers from non-Twitter users.
- The number of followers of a researcher is the Twitter metric that most significantly influences the tweeting of documents.
- Papers authored by Twitter users receive as many citations as papers from non-Twitter users. Therefore, the involvement of authors in Twitter does not improve the citation impact of their papers.
- In the limited case of papers in which the participation of their authors in Twitter improves the citation (17%), the variable that most influences the impact is the number of followers.

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