Increasing our Understanding of Altmetrics: Identifying Factors That Are Driving Both Citation and Altmetric Counts

Fereshteh Didegah[1], Timothy D. Bowman[1], & Kim Holmberg[1]
[1] Research Unit for the Sociology of Education, University of Turku, Finland

Abstract:
This study examines a range of factors associating with eventual citation and altmetric counts to a paper. The factors include research collaboration, institution impact, journal impact, journal open accessibility, and field type that will be modelled in association with citation counts, Twitter posts, Facebook posts and Mendeley readers. The results show that the factors driving increased citations are different from those driving increased altmetric events. The altmetric events differ from each other in terms of a few factors. The findings from this study can contribute to the continued development of theoretical models and methodological developments associated with capturing, interpreting, and understanding altmetric events. This work can also aid research policy makers with identifying important factors driving altmetric events.
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Contact: Fereshteh.didegah@utu.fi

1 Introduction

Traditionally citations have been used as the main indicators for measuring research impact (Bornmann & Daniel, 2008; Wilson, 1999; Baird & Oppenheim, 1994; Cole & Cole, 1971). As motivations to create citations can vary, a large number of studies have investigated the reasons and motivations to create citations in order to help scholars and institutions better understand what attracts citations to their papers. Some have used context or content analyses, while others have employed survey methods to map reasons to create citations (Moravcsik & Murugesan, 1975; Brooks, 1985). According to the social constructivist view of citations, some research properties other than research quality can also contribute to citation impact (White, 2004; Baldi, 1998; Gilbert, 1977). The so-called citation factors—including various characteristics of research products, such as number of authors or institutions collaborating in the paper, title or abstract features, or the journal where the paper is published—may partly explain why some papers get cited frequently, while others do not.

Although citations are popular when assessing the scientific impact of research, they have been criticized for not being able to reflect a wider societal impact of research (Holmberg, Didegah, & Bowman, 2015), such as educational, cultural, environmental and economic impact. For this purpose some novel indicators, commonly referred to as altmetrics, are being investigated for their potential to reflect the wider impact of scientific research. While they do offer promise, altmetric indicators differ from citations (Haustein, et al., 2014) in what they measure, how they measure impact, and by the persons creating them. Altmetric indicators are varied and each indicator has its own features. There are many questions left unanswered as to the circumstances surrounding the altmetric events and to the value of altmetrics for measuring impact. For instance, "Who is creating altmetric events?" While citations typically indicate that a scholar has referenced a research product, either scholars or the general public can create events captured by altmetrics. Another question is, "When altmetric events occur, how are research products being used?" Currently there is no clear indication of how a research product has been used when examining altmetric events. There are more questions arising from the differences between traditional citations and altmetric indicators to discover. For this work, the question examined will be "Can citation factors also be determinants of altmetric indicators?"

A large number of citation factors have been examined and identified in previous studies (see Didegah (2014) for a comprehensive review of factors examined). Although results of these studies vary across different subject domains, some factors such as journal impact factor or number of authors have been found to be the most important determinants of citation counts across different disciplines (Didegah, 2014; Vanclay, 2013). This study examines some of these factors, including research collaboration, institution impact, journal impact, journal open accessibility, and field type in association with altmetric indicators. This research investigates whether the factors are similarly associated with both citations and altmetrics. The results will lead to a better understanding of altmetrics and contribute to the literature regarding the rationale behind the generation of such indicators and whether they can be considered as alternatives or complements to citations. Moreover, the results can contribute to a theory for altmetrics.

2 Research background

Multi-author research has been widely found to have a citation advantage (Chen, 2012; Gazni & Didegah, 2010; Sooryamoorthy, 2009). Using a Bayesian argument, it has been discovered that while a multi-authored paper has 100% or 77% chance of being cited, a single-authored paper only has an 8% chance of being cited

(Rousseau, 1992). Moreover, the number of authors is a significant factor in all subject fields, although the extent to which it associates with increased citations varies from 1.2% in Space Sciences to 16.3% in Economics and Business (Didegah, 2014). However, a few studies have found no correlation between additional authors and increased citations (Bornmann, Schier, Marx, & Daniel, 2012; Haslam et al., 2008). International collaboration is another important factor contributing to increased citation counts (Sin, 2011; Persson, 2010). While multi-institutional research has been found to receive more citations than single-institutional research (Sooryamoorthy, 2009), modeling this factor simultaneously with the other two above-mentioned patterns of collaboration demonstrated that it is not an important citation factor (Didegah, 2014).

Other citation factors have showed that researchers from high-ranked institutions receive more citations to their papers than those from low-ranked institutions (Leimu & Koricheva, 2005), presumably (at least partly) because they tend to be better researchers. Publishing in a high impact journal is an important signal for increasing attention to a research paper. Most studies confirm that journal impact factor is the most significant determinant of citations (Vanclay, 2013), however one study demonstrates an exception (Stremersch, Verniers & Verhoef, 2007); the similarity between the journals and the small sample size of this study may have affected the results for journal impact factor, as only the five top journals in marketing were taken into account.

Field type, in terms of Natural Sciences versus Social Sciences or theoretical sciences versus applied sciences, is also a driver of citations (Kulkarni, Busse, & Shams, 2007; Callaham, Wears. & Weber, 2002; Peters & Van Raan, 1994), with natural and applied sciences having an advantage over the others. This advantage is also demonstrated in the UK Research Assessment Exercise (RAE) from 2001, where the mean citation counts for biomedical articles was about 30, for social science articles 5, and for humanities articles 2 (Mahdi, D'Este, & Neely, 2008). In addition, open access journals are found to receive a higher number of citations than non-open access journals (Vanclay, 2013; Eysenbach, 2006).

As reviewed above, the factors included in the current study have been widely studied in association with citation counts in prior research, while studies into citation factors in the context of altmetrics is almost none-existent. Haustein, Costas, and Larivière (2015) studied the association between discipline and document type, title, and paper length, number of references, and research collaboration with both citation and altmetric counts including blogs, Twitter, Facebook, Google+, mainstream media, and newspaper mentions. They concluded that factors driving citations and altmetric counts mostly differ from each other, although research collaboration and number of listed references in the research articles were found to increase both citation and altmetric counts.

Some other factors including journal impact factor, institution impact, and journal open accessibility will be studied in this research using a more advanced simultaneous statistical model, a negative binomial-logit hurdle model. Previous studies have used mostly simple regression or correlation tests that do not allow a simultaneous assessment of factors. This is a key omission because inappropriate models may generate misleading conclusions and non-simultaneous tests may identify apparent important factors that are not relevant when other factors are also considered.

3 Research questions

While not the first to research altmetric factors, this work examines newer and additional factors contributing to altmetric events using a more reliable statistical model. The goals of this study can be summarized in the following research questions:

- Do the factors driving citations differ from those driving altmetric events?
- Does the influence of the factors differ between each altmetric platform?

4 Methods

Sample: Research publications published by Finnish institutions from 2012 to 2014 were extracted from the Web of Science (WoS) database, Thomson Reuters, accounting for 48,443 documents of all types. These publications were searched and matched using DOIs with altmetric event data as collected by Altmetric.com and only 13,623 had altmetrics data.

Variables and measures: There are two groups of dependent and independent variables in this study. Dependent variables include citation counts, Mendeley readers, Twitter posts, and Facebook posts. Citation counts were extracted from WoS and the altmetric events were collected and provided by Altmetric.com.

Independent variables include individual and international collaborations, institution impact, journal impact factor, journal open accessibility, and field type. It is difficult to analyze collinear variables since their effect on the outcome may result from either true associations or spurious correlations. Hence, as institutional collaboration is highly correlated with individual and international collaborations, institutional collaboration was not included in the model. To identify open access journals the Directory of Open Access Journals (DOAJ) was used. Regarding the field type, each publication in WoS has a subject area that was mapped into one of the

OECD broad fields1. Thus, all publications were categorized into three fields: Medical & Natural Sciences; Engineering & Technology; and Social Sciences & Humanities. Table 1 summarizes how each variable were measured.

Statistical modeling: Given that the dependent variables of this study are count data (citation and altmetric counts), count regression models are the most appropriate models. The basic count models are Poisson and Negative Binomial (NB) models. Since the data in this study is over dispersed, the Poisson model, in which the mean and the variance are assumed to be equal (Cameron & Trivedi, 1998), is not appropriate, whereas the NB model is more appropriate. Furthermore, the data has more zeros than are accounted for in the NB distribution requiring a count model that can deal with excess zeroes. A negative binomial-logit hurdle model is the best fit for the data; after passing a hurdle in order to gain positive counts this model creates a scenario in which the positive counts follow a Poisson or NB distribution. The model has two parts: a negative binomial part that models the positive non-zero observations and a binary (or logit) part that models the zero observations. Hence, the significant factors of both positive counts and zero counts of dependent variables can be determined through the two parts of the model. The hurdle model is also preferred since it simultaneously assesses a number of factors with citation and altmetric counts rather than simpler regression models that separately test factors, which may generate inappropriate models.

Table 1. Factors and measures

Factors	Measure
Individual collaboration	Number of authors listed in the WoS 'AU' field for the publication.
International collaboration	Number of different country names listed in the WoS 'C1' field for the publication.
Institution impact	Maximum Mean Normalized Citation Score (MNCS) of different institution names listed in the WoS 'C1' field for the publication.
Journal impact factor	Journal Impact Factor retrieved from JCR for the publishing journal in the WoS 'SO' field for the publication.
Journal open accessibility	Open access (1); non-open access (0)
Field type	OECD field of paper: Medical & Natural sciences (1); Engineering & Technology (2); Social sciences & Humanities (3)

5 Results

5.1 Citation counts

Hurdle models were run with the six factors for the association between citation counts, Mendeley readers, Twitter posts, and Facebook posts. The results of the hurdle model for citation counts are presented in Table 2. The negative binomial part of the model shows that all factors are significant factors of citations except for field type. Individual and international collaborations associate with increased citation counts and a unit change in each factor contributes to 0.1% and 11.1% increased citations, respectively. The impact of the institution of affiliation also associates with increased citation counts and a unit change in the factor increases the number of citations by 3%. Journal impact also significantly contributes to 9.5% increase in the citation counts, while the open accessibility factor significantly associates with decreased citation counts and a unit change in the factor decreases the number of citations by 3.7%.

The logit part of the model shows that all factors are significant factors of zero citations except for field type. Four significant factors including individual and international collaborations, institution impact, and journal impact factor associate with decreased zero citations, while the open accessibility factor contributes to a 21% increase in the zero citations.

Table 2. The results of hurdle models for citation counts

	Citations			
Logit model	Coef.	Exp (Coef.)	% change in the zero	Sig.

[1] http://incites.isiknowledge.com/common/help/h_field_category_oecd_wos.html

			counts per unit increase	
No. authors	0.001	1.001	0.1	0.020
No. countries	0.098	1.103	10.3	0.002
Institution impact	0.023	1.024	2.4	0.000
Journal IF	0.253	1.288	28.8	0.000
Open access	-0.212	0.809	-19.1	0.000
Field type	-0.003	0.997	insignificant2	0.968
cons.	0.929	2.532	-	0.000
NB model	Coef.	Exp (Coef.)	% change in the positive counts per unit increase	Sig.
No. authors	0.001	1.001	0.1	0.000
No. countries	0.106	1.111	11.1	0.000
Institution impact	0.033	1.034	3.4	0.000
Journal IF	0.095	1.100	10	0.000
Open access	-0.037	0.963	-3.7	0.000
Field type	-0.050	0.951	insignificant	0.113
cons.	1.364	3.912	-	0.000
Alpha	0.451	1.569	-	0.000

5.2 Altmetric events: Twitter posts, Facebook posts, and Mendeley readers

Twitter posts: Regarding the negative binomial part of the hurdle model for Twitter posts, all factors except for institution impact are significant factors of Twitter posts. International collaboration, journal impact factor, journal open accessibility, and field type associate with increased Twitter posts and a unit increase in each factor contributes to 5.6%, 11.4%, 46%, and 12.3% increase, respectively, whereas individual collaboration associates with a decreased number of posts. With respect to the logit model, none of the factors except for international collaboration and journal impact factor are significant factors of zero Twitter posts. International collaboration and journal impact factor is significantly associated with decreased zero posts and a unit increase in each factor contributes to 7.7% and 7% decrease in the zero posts, respectively (Table 3).

Facebook posts: The negative binomial part of the model shows that only journal impact factor, journal open accessibility, and field type are the significant determinants of Facebook posts. All three factors significantly associate with increased Facebook posts and a unit increase in journal impact factor, open accessibility, and field type contributes to 7%, 36.6%, and 25.7% increase in the Facebook posts, respectively. Regarding the logit model, institution impact and journal open accessibility are not significant factors of zero Facebook posts. International collaboration, journal impact factor, and field type associate with decreased zero posts, while individual collaboration and institution impact associate with increased zero posts (Table 3).

Mendeley readers: With respect to the negative binomial model, institution impact and journal open accessibility are the only insignificant factors of Mendeley readers. International collaboration, journal impact factor, and field type significantly associate with increased Mendeley readers and a unit increase in each factor increases the Mendeley readers by 4.5%, 7.6%, and 19.2%, respectively. Individual collaboration significantly associates with decreased Mendeley readers. Regarding the logit model, none of the factors except for institution impact and journal impact are significant factors of Mendeley readers. While institution impact contributes to increasing zero readers, journal impact factor decreases the zero readers by 23.8% (Table 3).

[2] The level of significance of 0.05 is chosen in this study. Thus, Sig. (p-value)> 0.05 shows an insignificant association.

Table 3. The results of hurdle models for altmetric counts

	Twitter				Facebook				Mendeley			
Logit model	Coef.	Exp (Coef.)	% change in the zero counts per unit increase	Sig.	Coef.	Exp (Coef.)	% change in the zero counts per unit increase	Sig.	Coef.	Exp (Coef.)	% change in the zero counts per unit increase	Sig.
No. authors	-0.001	0.999	-0.001	0.391	-0.001	0.999	-0.001	0.015	0.000	1.000	insignificant	0.516
No. countries	0.074	1.077	7.7	0.016	0.032	1.032	3.2	0.021	-0.018	0.982	insignificant	0.536
Institution impact	-0.003	0.997	insignificant	0.310	-0.002	0.998	insignificant	0.470	-0.014	0.986	-1.4	0.000
Journal IF	0.068	1.070	7.0	0.000	0.064	1.066	6.6	0.000	0.214	1.238	23.8	0.000
Open access	0.075	1.078	insignificant	0.307	0.003	1.003	insignificant	0.869	0.028	1.029	insignificant	0.764
Field type	-0.042	0.959	insignificant	0.607	0.138	1.148	14.8	0.015	0.203	1.225	insignificant	0.179
cons.	1.789	5.982	-	0.000	-1.780	0.169	-	0.000	2.547	12.772	-	0.000
NB model	Coef.	Exp (Coef.)	% change in the positive counts per unit increase	Sig.	Coef.	Exp (Coef.)	% change in the positive counts per unit increase	Sig.	Coef.	Exp (Coef.)	% change in the positive counts per unit increase	Sig.
No. authors	-0.001	0.999	-0.001	0.004	0.000	1.000	insignificant	0.431	-0.001	0.999	-0.001	0.000
No. countries	0.056	1.057	5.7	0.000	0.023	1.023	insignificant	0.241	0.044	1.045	4.5	0.000
Institution impact	0.003	1.003	insignificant	0.213	-0.001	0.999	insignificant	0.848	0.002	1.002	insignificant	0.146
Journal IF	0.114	1.121	12.1	0.000	0.068	1.070	7	0.000	0.073	1.076	7.6	0.000
Open access	0.460	1.585	58.5	0.000	0.312	1.366	36.6	0.000	-0.004	0.996	insignificant	0.493
Field type	0.123	1.131	13.1	0.025	0.229	1.257	25.7	0.034	0.176	1.192	19.2	0.000
cons.	0.121	1.129	-	0.008	-1.182	0.307	-	0.005	2.123	8.352	-	0.000
Alpha	0.523	1.687	-	0.009	1.398	4.048	-	0.004	0.160	1.173	-	0.000

6 Discussion

In this section, the results will be discussed and the research questions will be answered factor by factor.

Individual collaboration: This factor is significantly associated with increased citation counts exhibiting that the more authors a paper contains, the higher the number of citations the paper receives. Nevertheless, the factor contributes to decreased Twitter posts and Mendeley readers and is an insignificant factor for Facebook posts. The positive association between the number of authors and citation counts is well documented (Chen, 2012; Franceschet & Costantini, 2010; Gazni & Didegah, 2010; Persson, 2010). A recent study also examined this factor for altmetric events (i.e. blog posts, twitter users, public Facebook shares, Google+, and news and mainstream media) and found that the number of authors was an important factor for altmetric events (Haustein, Costas, & Larivière, 2015), which contradicts the results of this work. This contradiction may be due to several reasons including that this study examines different altmetric events as compared to the earlier one, this work only investigates Finnish researchers, and also that the earlier study (Haustain, Costas & Lariviére, 2015) used simpler statistical tests to model the factors rather than simultaneously modeling the factors as was done in this work. It would seem that the number of authors may be an important factor for increased altmetric events when separately modeled, but when simultaneously tested with other factors it is not significant.

International collaboration: The results show that the more countries collaborating in a paper, the higher the number of citations to the paper. The same association was found for Twitter posts and Mendeley readers; as the number of countries increases, the number of Twitter posts and Mendeley readers also increase. The number of countries is not an important factor for Facebook posts, while it was a significant factor for increased Facebook users in Haustein, Costas, and Larivière (2015). Twitter posts and Mendeley readers are behaving the same ways as for citations for this factor, although the factor effect is lower for altmetric events than for citations.

Institution impact: As found in Didegah (2014), papers published by top ranked institutions receive more citations, but this is not important for altmetric events. This finding indicates that scholars have a propensity towards using and citing publications from prestigious institutions, while the publication institution is not important for tweeters, Facebook users, or Mendeley users. This difference between citations and altmetric events is (most likely) not due to different types of users, as previous work has found that Mendeley users are also scholars (Mohammadi, Thelwall, Haustein, & Lariviére, 2015) and that nearly half of the tweeters who tweet about research are part of the scholarly community (Tsou, Bowman, Ghazinejad, & Sugimoto, 2015). This difference could, however, be explained by other reasons including that social media are mainly used to share research about current trending topics and important events regardless of which institution was associated with the research, while scholars may cite publications from top institutions in order to lend more attention to their own work or to persuade journal editors or other authors about the high quality of their research. But in the case of Mendeley the result probably differs from citations due to a difference in application level, meaning that publications may be added to the Mendeley library but may never be read or used in research. It would appear that scholars add publications to their Mendeley libraries based on their relevance, not for the institutional prestige of the article.

Journal impact factor: As widely confirmed in previous studies (Didegah, 2014; Boyack & Klavans, 2005) journal impact is the most important determinant of citations. Similarly, it was found to be an important factor for both citations and altmetric events in the current study. In the case of citations, it is perceived that top journals contain higher quality content and thus they are cited more. Social media users also tend to choose higher quality content as high impact journals are more read on Mendeley, more posted on Facebook, and more tweeted on Twitter. It is interesting to note that the journal impact factor effect is even higher on Twitter posts than on citations.

Journal open accessibility: While open access publications are more mentioned on Twitter and Facebook than the non-open access ones, scholars do not show a great tendency towards citing and reading open access content. A paper published in an open access journal receives about 4% fewer citations than a paper published in a non-open access journal. Open accessibility is also not an important factor for Mendeley readers. With regards to Twitter and Facebook posts, the open accessibility of the journal is the most important and influential factor. Papers from open access journals are 58.5% and 36.6% more tweeted and posted on Facebook, respectively. Researchers' institutional access to a wide range of subscribed non-free journals does not limit them to open access journals in their field and thus, open accessibility does not necessarily favor citations; this result contradicts with the results of other studies (Vanclay, 2013; Lansingh & Carter, 2009; Eysenbach, 2006). On the contrary, Twitter and Facebook posts possibly favor open access research because they are available to a wider, non-academic audience.

Field type: Field type is not an important factor for citation counts, but it is significantly determining altmetric events. Publications from Social Sciences & Humanities have more mentions on Twitter and Facebook and are read more on Mendeley than publications from both Engineering & Technology and Medical & Natural sciences. This could be due to the readability of the research from the Social Sciences & Humanities as compared to studies from Physical & Natural science.

7 Conclusion

In conclusion, the findings show that the factors driving increased citations are different from those driving increased altmetric events. The altmetric events differ from each other in terms of a few factors. For instance, while individual and international collaboration do not matter for Facebook posts, they significantly associate with Twitter posts and Mendeley readers. The main result from this study is that most of the factors are significantly determining altmetric events. For example, all factors significantly associate with increased or decreased tweets except for institution impact.

With regards to the different results found in this work and the research by Haustein, Costas, and Larivère (2015), it is important to consider that there could be many reasons for this difference including the statistical tests used, the difference in samples, and differences in time frames. What is important is that these results point to the uncertainty that comes from studying altmetric events that are being captured from constantly changing ecosystems with a large, (mostly) invisible user base. As researchers continue to develop theoretical and methodological models to study this context, the different results found in this early stage of research should be made clear. What is apparent is that more research is needed using different models, theories, and populations to study these phenomena.

The findings from this study can contribute to the continued development of theoretical models and methodological developments associated with capturing, interpreting, and understanding altmetric events. This work can also aid research policy makers with identifying important factors driving altmetric events.

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