

# Altmetrics data providers: A meta-analysis review of the coverage of metrics and publication

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## Abstract

The aim of this paper is to review the current and most relevant literature on the use of altmetric providers since 2012. This review is supported by a meta-analysis of the coverage and metric counts obtained by more than 100 publications that have used these bibliographic platforms for altmetric studies. The article is the most comprehensive analysis of altmetric data providers (*Lagotto*, *Altmetric.com*, *ImpactStory*, *Mendeley*, *PlumX*, *Crossref Event Data*) and explores the coverage of publications, social media and events from a longitudinal view. Disciplinary differences were also analysed. The results show that most of the studies are based on *Altmetric.com* data. This provider is the service that captures most mentions from social media sites, blogs and news outlets. *PlumX* has better coverage, counting more *Mendeley* readers, but capturing fewer events. *CED* has a special coverage of mentions from *Wikipedia*, while *Lagotto* and *ImpactStory* are becoming disused products because of their limited reach.

## Keywords

Altmetrics; Coverage; Data providers; Social media; *Lagotto*; *Altmetric.com*; *ImpactStory*; *Mendeley*; *PlumX*; *Crossref Event Data*; *Wikipedia*; Review.

## 1. Introduction

Altmetric data providers play a key role in altmetric research, to the point that much of this research topic relies on these providers in order to carry out most of their studies. The importance of these platforms is not only due they are fundamental tools for altmetric research, but also that data from these services are increasingly being used to evaluate articles, authors and organisations. It is worth remembering that *Altmetric.com* has mainly based its business on supplying metrics and indicators to academic publishers. Similarly, *PlumX* has found in the institutions the way to develop its activity, offering a dashboard to track the social impact of their outputs. This commercial activity has inserted their altmetric counts into the scholarly publishing environment prior to being tested as reliable and significant research indicators, causing considerable misinterpretation about their meanings and importance (Bornmann, 2014).

In this sense, altmetrics is obliged to test the reliability of these services both to verify that the scientific results are based on trustworthy sources and to audit the authenticity of these services as data providers. This vigilant attitude is even more motivated because these platforms are not exactly scientific instruments for bibliometric studies, but commercial suites focused on providing visibility to academic journals and organisations. Altmetrics should therefore be undertaken as an independent and authoritative instrument that assesses the technical suitability of these tools for supplying and processing altmetric counts. The clearest expression of this inspection attitude is the *NISO Alternative assessment metrics (Altmetrics) initiative* which aims to standardise and ensure transparency of the way in which data aggregators obtain and process their information (NISO, 2016).

However, and despite all these platforms agreeing to report their sources and how they process their metrics, important points still need more clarification. For example, aggregators should improve their reporting of the complete list of sources covered, mainly blogs and news media; how they manage the intentional manipulation of metrics (i.e., bots on *Twitter*); and how the links to events are curated and updated when they are moved or eliminated (Ortega, 2019b). These limitations are evident when the resulting metrics are compared and the counts differ significantly, although many of them come from the same source such as *Twitter*, *Mendeley* or *Wikipedia*. These discrepancies raise doubts about the reliability of these platforms when they come to extract information and count metrics.

This instability in the metrics provided by each data aggregator justifies a meta-study to collect all the figures captured from these providers at different times and from different samples, enabling an accurate picture of how these services are evolving in time and a general overview of the coverage and working of each platform. It is interesting to note that this type of analysis is uncommon in bibliometric studies, even more when referring to a quantitative discipline. In altmetrics, we can highlight the study by Bornmann (2015a), who analysed the published correlations between tweets, blogs and readers. But, perhaps, the most exhaustive meta-analysis was performed by Erdt *et al.* (2016b). These authors reviewed the literature about altmetrics and performed a cross-metric validation of altmetric indicators. However, no meta-study has explored the evolution and coverage of altmetric data providers. This study attempts to fill this gap by reviewing the current altmetric literature and analysing the numbers obtained by these studies.

## 2. Objectives

The principal objective of this work is to review and analyse the scholarly literature that has used an altmetric provider to conduct its studies. The aim is to check and contrast the figures obtained to build a general picture of the coverage and metrics supplied by each altmetric provider. From this analysis, we aim to:

- describe the proportion of indexed publications (coverage) in each provider;
- present the proportion of documents in each provider by metric;
- depict the average counts of each metric; and
- display disciplinary differences by metric and provider.

## 3. Methods

### 3.1. Altmetric providers

Within the context of big data and its technological revolution, altmetric data providers or aggregators are platforms that capture, collect and quantify in a single venue different events about scholarly publications produced in distant places on the Web. According to commercial agreements or open endpoints, these secondary services are adding up events generated in social networks, specialised databases, citation indexes, blogs and news outlets. Using specific document identifiers (doi, isbn, uri, *Pubmed id*, etc.), these platforms track the footprint of a publication on each website that they monitor. In addition, these platforms sometimes produce indicators and reports from the information gathered, offering added value to the data provided. *Mendeley* is a special case because it is not strictly a data provider, but an online reference manager. However, this service is included because many studies have used this platform as a principal source for counting reader numbers.

#### *Mendeley*

<https://www.mendeley.com>



It was created by three PhD students in 2008 with the aim of exporting the *Last.fm* model to the scholarly world. That is, that each user could share their favourite publications with other members (Ortega, 2016). This became *Mendeley* the most important reference manager on the Web. In 2013, it was acquired by *Elsevier* for integration with its products. *Mendeley* is also a social network in which users “read” the publications. The number of readers of a publication is a measure used for altmetric studies to evaluate the academic impact of a publication (Mohammadi; Thelwall, 2014; Mohammadi *et al.*, 2015).

#### *Lagotto*

<http://www.lagotto.io>



*Lagotto* was the first altmetric data provider and was created in March 2009 by the publisher *Public Library of Science (PLOS)*. Although it is an open tool that can be used by any publisher, this instrument is not widespread, and only three publishers (*PLOS*, *Copernicus* and *Public Knowledge Project*) have implemented this provider. The last API version (*Lagotto 4.0*) dates from April 2015, an indication of its brief development.

### Altmetric.com

<https://www.altmetric.com>



*Altmetric.com* was launched in 2011 by Euan Adie, with the support of *Digital Science*. *Altmetric.com* is centred in the publishing world, signing agreements with publisher houses to monitor the altmetric impact of their publications. This information is accessible through a public API on the Web. Today, *Altmetric.com* captures over 60 million events and tracks the social impact of close to 9.5 million research papers (*Altmetric.com*, 2019).

### ImpactStory

<https://profiles.impactstory.org>



This aggregator was developed by Jason Priem and Heather Piwowar in 2011. Unlike other providers, *ImpactStory* is focused on building personal profiles that illustrate the altmetric impact of a researcher. Using *Orcid* and a *Twitter* account, this tool enables the creation of a profile with the list of publications mentioned on the Web. Up to 2015, this tool offered a public API to retrieve data, but this endpoint is now closed. To date, around 18,000 profiles have been created (*ImpactStory*, 2019).

### PlumX

<https://plu.mx/plum/g/samples>



*PlumX* is a provider of alternative metrics created in 2012 by Andrea Michalek and Michael Buschman from *Plum Analytics*. This product targets the institutional market, offering altmetric counts of publications for specific institutions. *PlumX* is the aggregator that offers more metrics, including usage metrics (i.e. views and downloads). It covers more than 52.6 million artefacts and is the largest altmetric aggregator (*Plum Analytics*, 2019). In 2017, *Plum Analytics* was acquired by *Elsevier* and now tracks the online presence of any article indexed in the *Scopus* database. *PlumX* also offers their customers an API to extract data.

### Crossref Event Data (CED)

<https://www.crossref.org/services/event-data>



*CED* is the youngest service. Created in 2016, it is still in beta. Unlike *Altmetric.com* and *PlumX*, *CED* is not a commercial site and provides free access to data through a public API. Another important difference is that it does not provide metrics, but only displays information about each altmetric event linked to a doi identifier. For instance, it shows information about an article mention on *Twitter* (date, user, tweet, etc.), but does not show a count of the number of tweets. For that reason, *CED*'s data would have to be processed to be comparable with the other services. This provider is only accessible via API.

## 3.2. Indicators

One of the most important challenges of a meta-study is the selection and standardisation of the various observations for comparison and analysis. The observation date, when available, was used instead of the publication date to fairly compare different observations over time. In certain cases, although some metrics are not available in the paper, it includes enough information for that metric (percentages and proportions) to be calculated. In these cases, metrics were calculated and added to the study. Three main indicators were defined:

**Coverage (%):** percentage of documents indexed in one provider. This percentage is available when an external sample was selected in the study and compared with the coverage of an altmetric service. This indicator reports the size of a data provider. Another way to refer to this metric are items with data scores (*Gorraiz et al.*, 2018), nonzero altmetric events (*Didegah et al.*, 2018) and nonzero scores (*Thelwall*, 2018).

**Metrics proportion in each provider (%):** percentage of publications with at least one event from one metric in relation to the publications included in the provider. In this case, this indicator shows the weight of a metric over all the metrics gathered by one provider. This indicator is also named Percent nonzero (*Thelwall; Nevill*, 2018).

**Average of events per publication:** ratio of the total count of events by the number of indexed publications. This metric reports the frequency of each metric and is also named Geometric mean (*Thelwall; Nevill*, 2018) or Density (*Zahedi et al.*, 2014b; *Costas et al.*, 2015a; *Gorraiz et al.*, 2018; 2019).

## 3.3. Search criteria

*Google Scholar* and *Scopus* were searched to obtain the sample of publications. The search criteria in both databases was a generic query "altmetric\*" to obtain the largest number of results. After a first round, other precise queries were performed to identify papers that have used a data provider. For example, "altmetric" OR "altmetric.com" for *Altmetric.com*, "plumx" OR

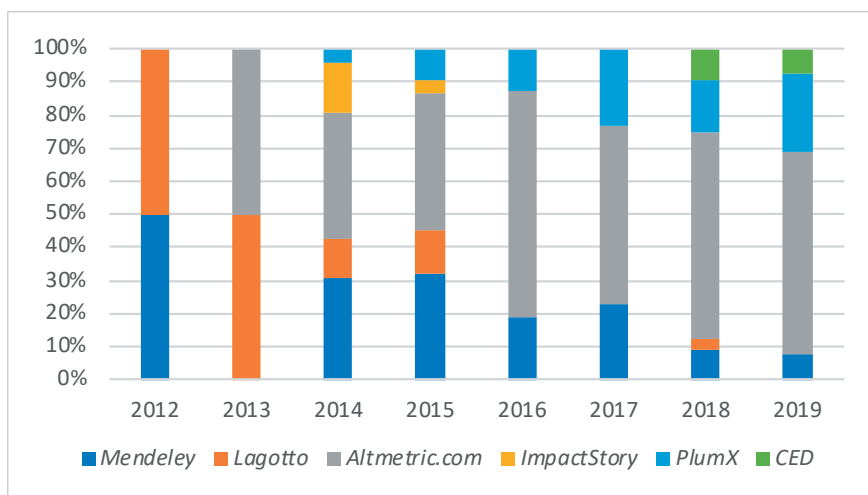
“Plum Analytics” for PlumX, “impactstory” for ImpactStory, “lagotto” OR “PLOS” for Lagotto, “crossref event data” OR “CED” for Crossref Event Data and “mendeley” for Mendeley. These results were filtered to search for papers that had used an altmetric data provider for their analysis, had calculated some of the previous indicators or had published any data that would allow us to compute them. A total of 107 articles published between 2012 and 2019 were selected for the study.

#### 4. Results

First, the results describe the number of providers used, the coverage of publications and the percentage of papers mentioned in the most important metrics. Next, the number of counts of each metric in each provider will be presented, and lastly a disciplinary study will point out thematic differences among the aggregators.

##### 4.1. Providers

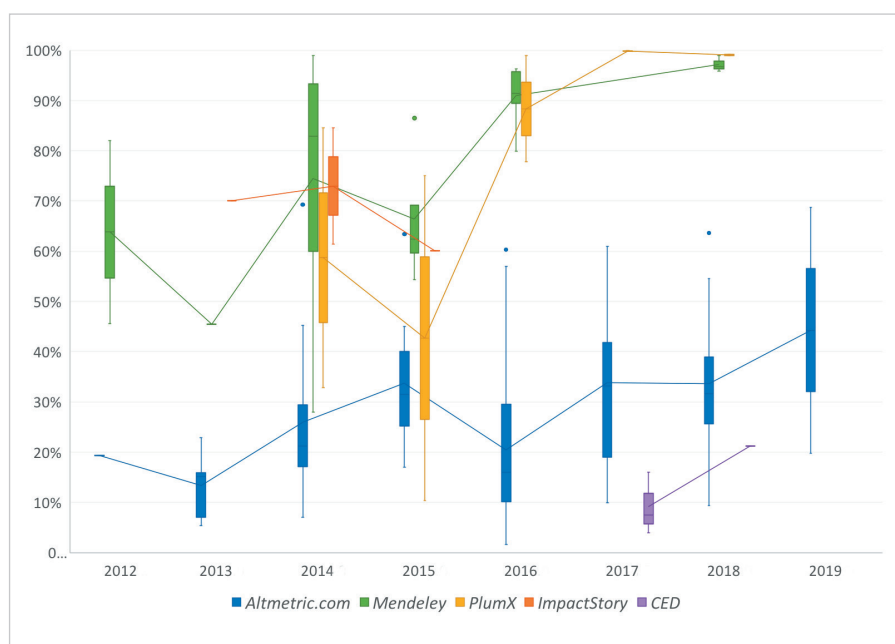
Graph 1 illustrates the proportion of altmetric data providers used in the academic literature since 2012. This picture allows us to visualise how different providers gain market share and others fall into disuse. For example, the initial studies were done with Mendeley (50%) and Lagotto (50%). The first gives the source of the readers and the second the first altmetric provider. In 2013, Altmetric.com appeared as an altmetric source and began dominating the market. 2014 and 2015 are the years with more providers used with the coming of ImpactStory and PlumX. However, from 2016 to 2017 only three services were used, Mendeley, Altmetric.com and PlumX. Because Lagotto is not implemented in important publishers other than PLoS, it became a limited tool for altmetric studies and was used only in one-time cases (Zahedi; Costas, 2018). ImpactStory stops provide a public API, making it hard to obtain random representative samples. In 2018, a new data provider, Crossref Event Data, began being used and was the first non-commercial open product. Overall, the three main data sources are Altmetric.com (54%), Mendeley (18%) and PlumX (13%), Altmetric.com being by far the most used service.



Graph 1. Proportion of data providers used in altmetric studies by year

##### 4.2. Coverage

Graph 2 depicts the distribution of publications covered in each data provider grouped by year. Lagotto was excluded due to absence of data. This trend was displayed using the data collection date, instead of the publication year because this is the closest date to the observation. However, not all the articles include that information and, in those cases, the publication date was selected, which could distort the results to some extent. We must therefore understand the data in an illustrative way. Another problem is that not all the observations were taken in the same way. Many are limited to specific disciplines, publication windows or regions, thereby provoking a high dispersal in annual distributions.



Graph 2. Yearly evolution of the coverage of the providers analysed

*Altmetric.com*, the platform with most observations, shows a generalised, paused increase in the coverage of publications. Studies during the 2012-2013 period show a coverage between the 19.3% of **Knight** (2014) and the 15.1% of **Costas et al.** (2015a). In 2014, these percentages slightly increased to a mean coverage of 28%, where we can highlight the outlier 69.3% (**Bornmann**, 2014a) caused by a sample of recommended papers in Biomedicine from *F1000Prime*. From 2015 to date, the mean coverage has stabilised around the 31.5% of 2015, the 33.2% of 2017 and the 29.9% of 2018. There was a fall in 2016 to 16% caused by some local studies about Brazilian publications (**Eléspuru-Briceño; Huaroto**, 2016; **Maricato; Filho**, 2018) where the indexation and mention of local publications was clearly insufficient (**Alperin**, 2015). In 2018, **Orduña-Malea** and **Delgado-López-Cózar** (2019) found the outlier 9.4%. These authors used the full database of *Dimensions* to detect publications from *Altmetric.com*, with no time limit, including pre-2000 print documents that could not be mentioned in social networks. However, they reached 21.6% and 21.8% when they limited the sample to papers published in 2016 and 2017, respectively. Two recent studies (**Wooldridge; King**, 2019; **Wolcott et al.**, 2019) place the coverage of *Altmetric.com* at 44% in 2019. The limited coverage observed in the literature is caused mainly by the fact that *Altmetric.com* only indexes publications previously mentioned in some social networks (*Twitter*, *Facebook*, *Google+*, etc.) (**Haustein et al.**, 2015; **Bar-Ilan et al.**, 2019). This indexing strategy has resulted in the steady growth of coverage since 2014.

*Mendeley*, the second service by number of observations, describes a positive trend with continuous growth since 2013, reaching percentages of over 90% in 2016. This high coverage is explained because the *Mendeley Web Catalog* is fed by important sources such as *Pubmed*, *Scopus* and their own users (**Ortega**, 2016), which brings an extensive number of publications. Thus, in 2012, *Mendeley* collected a mean of 63.8% of publications, ranging from the 82% of **Bar-Ilan et al.** (2012) to the 45.6% of **Mohammadi et al.** (2015). This considerable difference could be because the first study used a reduced sample of bibliometricians, which could overrepresent the number of readers. **Mohammadi et al.** (2015), however, take articles from 2008, when *Mendeley* was created. This early date could indicate that many articles are still not indexed in the platform. Later studies found similar percentages. **Zahedi et al.** (2014a; 2014d) also detected a coverage of 45.5% and 47.4% in a multidisciplinary sample. **Mohammadi** and **Thelwall** (2014) yielded low percentages: 28% for Humanities and 58% for Social Sciences. **Haustein** and **Larivière** (2014), on the contrary, found 65.9% in Biomedicine papers, which points to disciplinary differences in favour of the natural sciences. However, in mid-2014 an important change occurred in *Mendeley's* database because from that moment onwards the coverage percentages were always beyond 80%. The most likely reason is the effective integration of the *Scopus* index in the *Mendeley Web Catalog*, which led to increased coverage of *Mendeley* (**Bonasio**, 2014; *Scopus*, 2014). In August 2014, **Peters et al.** (2014b) already detected 84.2% of coverage, while **Bornmann** and **Haunschild** (2015) found 99% from *F1000* papers. Subsequent studies (**Thelwall; Wilson**, 2016; **Bornmann; Haunschild**, 2016b) reported percentages over 90%. In 2015, some disciplinary studies (**Pooladian; Borrego**, 2016; **Aduku et al.**, 2017) showed that this high coverage is not the same in Computer Sciences (63.5%), Engineering (54.3%) or Library Sciences (61.4%). From 2016, all the studies verified the elevated coverage of *Mendeley* with values higher than or around 90% (**Bornmann; Haunschild**, 2017; **Didegah et al.**, 2018; **Zahedi; Van-Eck**, 2018).

*PlumX* describes a growing trend motivated mainly by its integration into Elsevier's products such as *Scopus*, *Mendeley* and *ScienceDirect* from 2017. Until 2014, no studies used *PlumX* as a data source. The first was **Peters et al.** (2014b), who compared the coverage of several data providers using a sample of publications from *Leibniz Association*, finding 84.6% of publications indexed in *PlumX*. However, this same team (**Peters et al.**, 2016) observed 32.9% when only datasets were considered. This percentage descended (10.4%) when they repeated the same study one year later (**Peters et al.**, 2015). From 2016 to 2019, coverage increases considerably to nearly 100% (**Meschede; Siebenlist**, 2018; **Zahedi; Costas**, 2018; **Ortega**, 2018a; **Ortega**, 2019; **Gorraiz et al.**, 2019). The only exception is **Torres-Salinas et al.**, (2017a), who obtained a coverage of 77.7% because their sample was limited to books.

Studies on *ImpactStory* cover a short time-window (2013-2015). During this period, *ImpactStory* showed a mean coverage of between 70% in 2013 (**Zahedi et al.**, 2014b), 73% in 2014 (**Peters et al.**, 2014a; 2014b) and 60% (**Kraker et al.**, 2015) in 2015. *CED* also describes a short activity period (2017-2018), but with significant increases. Thus, in 2017, it showed an average coverage of 9.1% (**Ortega**, 2018a; 2018b; **Zahedi; Costas**, 2018), which rose to 21.2% in 2018 (**Ortega**, 2019).

### 4.3. Coverage of metrics

This section analyses the coverage of six of the most important metrics (tweets, readers, *Wikipedia* citations, *Facebook* mentions, blogs and news) according to each provider.

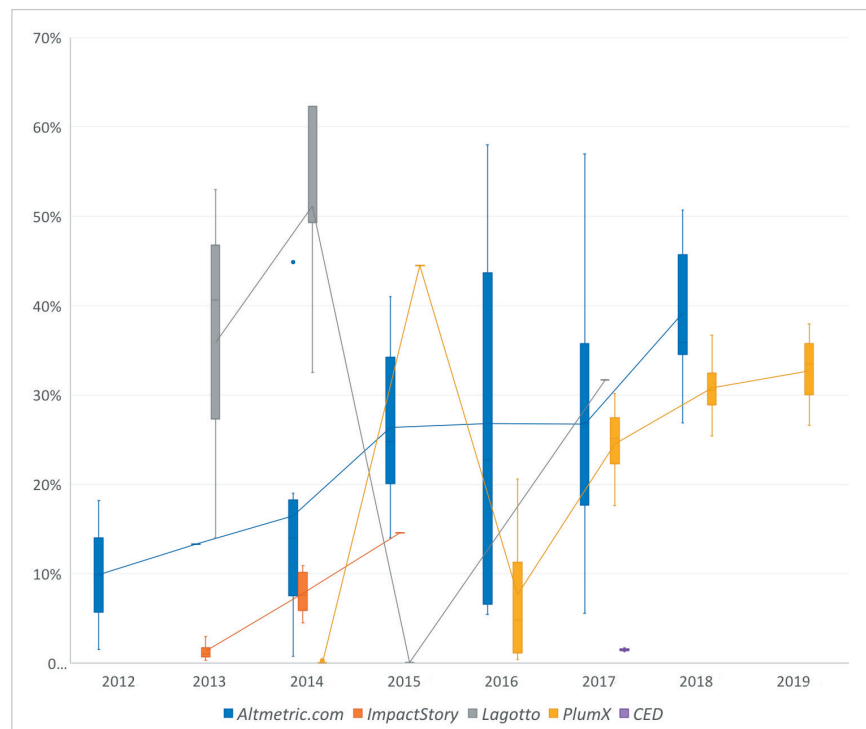
#### 4.3.1. Tweets

Tweets are the most studied metric in the literature (62.3%) because *Twitter* is the principal source of analyses of the dissemination and social impact of scholarly publications. Overall, Graph 3 shows that *Altmetric.com* is the platform that has continued for longer and with better mean percentages of tweets. Next, *PlumX* also shows a constant rise in tweets since 2016 but under *Almetric.com* counts. Other services such as *Lagotto* and *ImpactStory* present specific observations in short time periods.

*Altmetric.com* presents a better and growing coverage of tweets, ranging from 10-15% in 2012-2014 to 40% in 2018, on average. Coverage is better even though *Altmetric.com*'s definition of the metric is restricted (it only counts the number of different users that tweeted a publication to avoid intentional manipulations), which a priori would produce lower values. The first studies were performed by **Knight** (2014), who detected 18.2% of tweeters for articles on solid organ transplantation in 2012. However, **Adie and Roe** (2013), analysing the full *Altmetric.com* database, reported that the coverage of tweets was still low (1.6%). In 2013, **Costas et al.**, (2015a) observed 13.3% of tweeters in a random sample of 500,000 *WoS* journal articles. In 2014, average observation rose to 16.5%, highlighting the outliers of

**Haustein et al.** (2014a) (44.9%) and **Alperin** (2015) (0.8%). The first was because the authors analysed 84,000 articles deposited in the online repository *arXiv*, which would favour the tweeting of these pre-prints. Contrary to this result, **Alperin** (2015) studied almost 400,000 articles from *SciELO*, a local database for Latin-American academic publications, evidencing the poor altmetric impact of Latin-American science or the incomplete coverage of *Altmetric.com* of local events in Spanish and Portuguese. In 2015, the coverage of tweets increased again (26.4%), from 14% of publications about History in **Htoo and Na** (2015) and 41% in **Scott et al.**, (2015) from *Pubmed* articles. 2016 presents a similar mean percentage (26.8%). Particularly noteworthy are the poor results of **Eléspuru-Briceño and Huaroto** (2016) (5.4%) about documents deposited in the local repository of the *Peruvian University of Applied Sciences (UPC)* and those of **Torres-Salinas et al.** (2018b) (5.6%) limited to publications from Spanish universities. Both studies based in local samples again provide evidence of the reduced impact on *Twitter* of local, non-English publications. At the other extreme, **Wang et al.** (2016) found 58% of tweeted articles in a sample of Biotechnology articles authored by Chinese authors outside of China. This result could be explained by a research area exposed to social networks and that Chinese abroad could be inserted in prestigious groups and institutions. In 2017, the average proportion of tweeted documents (25.4%) also caused by the presence of extreme values dropped slightly. **Htoo and Na** (2017) found low percentages for Business (5.6%) and Law (8.1%), confirming the low impact on *Twitter* of Humanistic disciplines. On the other hand, the highest values are for **Zahedi and Costas** (2018) (57%), who used sample *PLoS* articles, which could indicate a greater exposure of *PLoS* journals on *Twitter* than other publications. In 2018, *Altmetric.com* increased considerably with a mean coverage of 40.8% of publications in *Twitter*. This observation encompasses the 26.9% of Economics and the 50.7% of Communication captured by **De-Filippo and Sanz-Casado** (2018). This result demonstrates the important disparity within the Social Sciences.

Next, *PlumX* also describes a positive evolution, starting from a mean of 6.6% in 2016 to 33.5% in 2019. The first observations about tweets on *PlumX* were done by **Peters et al.**, (2014b) when they compared the presence of the *Leibniz Association's* publications in several aggregators. The results show insignificant percentages (<1%), which suggested that *PlumX* had technical problems to retrieve mentions from *Twitter*. However, one year later, **Kraker et al.** (2015), exploring the altmetric impact of datasets in *PlumX* and *ImpactStory*, uncovered a great proportion of files mentioned on *Twitter* (44.5%). This dramatic improvement could be due to the employment of *Gnip*, the official provider of *Twitter* (**Allen**, 2015). Even so, this figure seems excessive and could be caused by bias due to the small sample size (757 datasets). This perception is based on the following percentages from 2016 onwards, more continued in time and less variable. That year, the mean percentage was 7.7%, which fits with the 8.2% of **Ortega** (2016b), who studied the tweeting of articles from authors on *Twitter*. However, other studies showed different numbers. **Meschede and Siebenlist** (2018) detected 20.6% when they compared a random sample of *WoS* articles in *PlumX* and *Altmetric.com*, whereas **Torres-Salinas et al.** (2017a; 2017b) perceived a very low percentage in two samples of books (1.4% and 0.4%). This indicates that the mention of books on *Twitter* is scarcer than journal articles. In 2017, the mean percentage rose considerably (24.5%). That year, the lowest value was found by **Ortega** (2018b) when analysing 67,000 articles from *PlumX* (17.6%), while **Bar-Ilan et al.** (2019) noticed 30.2% in 2,700 articles from the *Journal of the Association for Information Science and Technology*.



Graph 3. Yearly evolution of the percentage of tweets in each provider

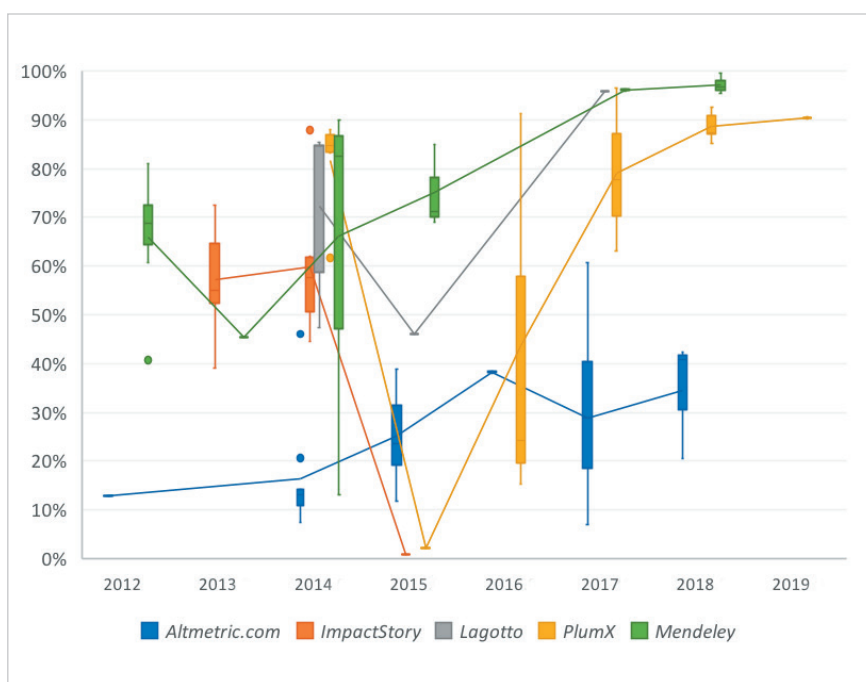
This result suggests that Information Sciences could gain more attention on *Twitter* than the average. In 2018, the mean percentage was 30.8%, thanks to **Gorraiz et al. (2018)**, who analysed the Austrian publications in *PlumX* and found 25.4% and 36.7% for publications mentioned on *Twitter* for 2014 and 2016, respectively. The last observation, in 2019, was repeated by these same authors (**Gorraiz et al., 2019**), but only with regard to *University of Vienna* publications. The result (32.7%) is just slightly higher than the previous year.

*ImpactStory* shows observations only in the 2013-2015 period. The trend was steady and homogenous, starting from an average percentage of tweeted papers of 1.3% in 2013 (**Zahedi et al., 2014b**) and 7.8% in 2014 (**Peters et al., 2014b**) to 14.6% in 2015 (**Kraker et al., 2015**). *Lagotto* also includes only a few observations, although it reached an average of 35.8% in 2015 and 51.1% in 2014. This elevated proportion is due to the fact that *Lagotto* is almost solely implemented in *PLoS* journals. *PLoS one*, the multidisciplinary journal, has considerable exposure on *Twitter*, thereby giving rise to these high percentages. For example, **Fenner (2013)**, analysing only the journal *PLoS biology*, detected just 14% of tweeted articles. **Zahedi et al. (2015a)** detected the derisory 0.1% of tweeted articles in *Lagotto* using a random sample of *Crossref*. For *CED*, only the studies by **Ortega (2018b)** and **Zahedi and Costas (2018)**, carried out in 2017, can be mentioned. Both found very low percentages: 1.3% for **Ortega (2018b)** and 1.7% for **Zahedi and Costas (2018)**.

#### 4.3.2. Readers

Another of the most studied metrics is the number of *Mendeley* readers with a publication (54.7%). The reason for this interest is the strong association of this metric with bibliographic citations (**Mohammadi; Thelwall, 2014**) and its possible utilisation as an indicator of early scientific impact (**Thelwall; Nevill, 2018**). Graph 4 depicts an increasing evolution in every provider, more defined from 2016 onwards. *Mendeley* is obviously the platform that has a better coverage of readers, with a continued rise in readers since 2014. Next, *PlumX* is the service with better percentages in relation to *Altmetric.com*, mainly from 2016.

*Altmetric.com* is the service that presents a less average proportion of readers in comparison to the other aggregators. The first observation came in 2012 from **Knight (2014)**, who observed 12.9% of readers in Medicine papers from *Scopus*. But up to 2014, there is no study on the coverage of readers by *Altmetric.com*. In that year, the mean percentage of readers in *Altmetric.com* grew to 16.3%, although the observations vary considerably. **Hammarfelt (2014)** noticed that 7.4% of books have at least one *Mendeley* reader. **Robinson-García et al. (2014)** showed a little higher percentage (12%) in a very large random sample of 2.8 million papers from *WoS*. **Peters et al. (2014b)** detected a range of readers from 8.6% in Humanities to 20.6% in the Life Sciences. However, **Zahedi et al. (2014c)** observed a surprising 46% due, perhaps, to the sample being set up by *PLoS one* papers, which could indicate that multidisciplinary journals have more saves in *Mendeley* (**Zahedi et al., 2014b**). In 2015, the number of readers covered by *Altmetric.com* rose to 25.1%. Observations are now more stable and the 38.9% of readers in Psychology and the 11.8% in History are worth mentioning (**Htoo; Na, 2015**). Other studies present similar percentages (**Alhoori et al., 2015; Zahedi et al., 2015a; Nuredini; Peters, 2016; Thelwall; Nevill, 2018**). In 2016, the articles by **Meschede and Siebenlist (2018)** and **Torres-Salinas et al. (2018b)** reached very similar percentages: 38% and 38.5%, respectively, which confirms the increasing coverage of readers by *Altmetric.com*. In 2017, the mean percentage fell to 28.8%, as a result of the study by **Htoo and Na (2017)** about the disciplinary differences in altmetrics for Social Sciences, when they verified the low number of readers in some disciplines such as Business (6.9%) and Law (8.3%). Excepting this study, the percentages uniformly increase again, from the 40.1% of **Ortega (2018b)** and 40.8% of **Bar-Ilan et al. (2019)** to the 60.6% of **Zahedi and Costas (2018)**. This last high value is based on *PLoS* articles, which could pinpoint a bias in favour of *PLoS* articles in *Mendeley*, as was seen in **Zahedi et al. (2014c; 2014b)**. In 2018, these values remain stable between the 40.8% of **Repiso et al. (2019)** and the 42.4% of **Bar-Ilan et al. (2019)**. However, **Torres-Salinas et al. (2018a)** found 20.4% of readers in books, indicating the low coverage of books by *Mendeley*.



Graph 4. Yearly evolution of the percentage of readers in each provider

After *Mendeley*, *PlumX* is the aggregator with a better coverage of readers. In 2014, the first study with *PlumX* data (Peters et al., 2014b) already noted an elevated coverage from the 61.7% in Humanities to the 88.1% in Life Sciences. However, the study by Kraker et al. (2015), limited to *Figshare* objects, brought an anecdotal 2.2% of readers. In 2016, there was great variability between the results of Meschede and Siebenlist (2018) (91.3%) and the outputs of Torres-Salinas et al. (2017a; 2017b) (15.2%; 24.2%). The latter studies were restricted to books, indicating poor coverage and reading of books in *Mendeley* as in *Altmetric.com* (Torres-Salinas et al., 2018a). In 2017, the average number of readers grew dramatically (79.1%), thanks to studies by Bar-Ilan et al. (2019) (63.1%), Ortega (2018b) (77.7%) and Zahedi and Costas (2018) (96.6%). This trend was reinforced in 2018 (89.4%) and 2019 (88.7%) with the results of Ortega (2018b), Zahedi; Costas (2018), Bar-Ilan et al. (2019) and Gorraiz et al. (2018; 2019).

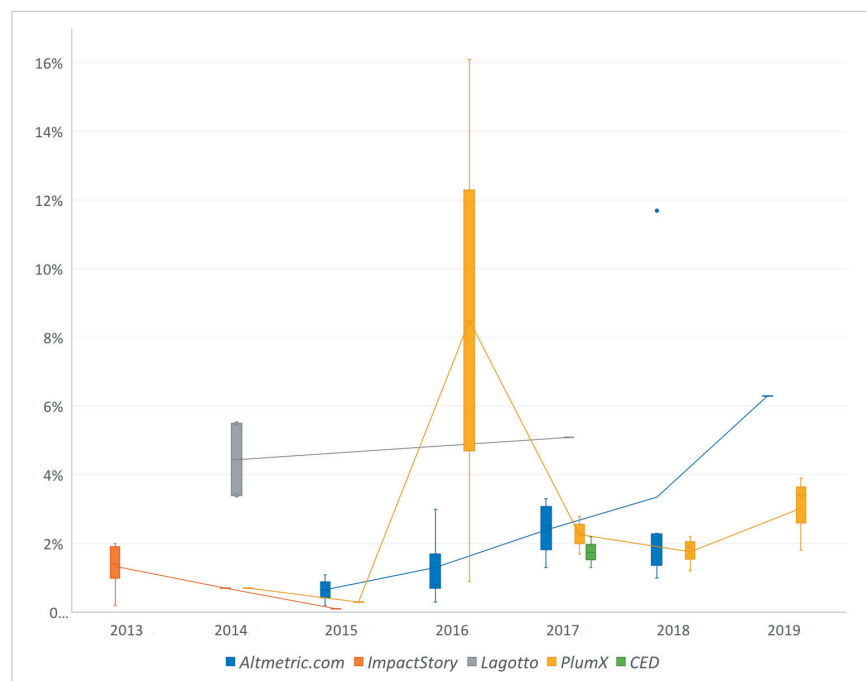
*Mendeley* is the service that produces the metric readers and, consequently, the coverage of papers in *Mendeley* (Graph 2) is similar to the trend of the number of papers with at least one reader (Graph 4). Even so, some studies have evidenced that not all the references included in *Mendeley* have readers, so these pictures would not match exactly (Mohammadi et al., 2015; Bornmann; Haunschild, 2016b; 2017). As mentioned in the section on coverage, *Mendeley* presents a low proportion of readers between 2012 and 2014, the mean being 65.9% in 2012 (Haustein et al., 2014b; Mohammadi et al., 2015) and 45.5% in 2013 (Zahedi et al., 2014a). As with coverage, the percentage of readers in *Mendeley* increases considerably in the middle of 2014, with values beyond 75% (Peters et al., 2014b; Bornmann; Haunschild, 2016b; Thelwall; Wilson, 2016). In 2015, the average of readers reached 75.1% and in 2016, 96.1%. Finally, in 2018 it was near to 100% (98.15%) (Didegah et al., 2018; Bar-Ilan et al., 2019; D'Angelo; Di-Russo, 2019).

Studies that used *ImpactStory* show a good coverage of readers. In 2013, Zahedi et al. (2014b) uncovered an average of articles with 57.3% of readers, more than the 45.5% of Zahedi et al. (2014a), using *Mendeley*. This difference could be attributed to different samples and ways of matching the data (i.e. articles with/without doi). Peters et al. (2014b) maintained this percentage in 2015 (59.8%) and Kraker et al. (2015) fell to 1% when they studied the readers of *Figshare* datasets. Lagotto showed a high 72.2% average of readers in 2014 (Zahedi et al., 2014c; Bornmann, 2014b; 2015). These elevated values are again due to *PLoS one*, which attracts more attention than average, distorting the coverage of this provider. In 2015, this percentage descended to 46% with the analysis by Zahedi et al. (2015a).

#### 4.3.3. Wikipedia

*Wikipedia's* citations are an important metric that describes the educational impact of scientific research (Kousha; Thelwall, 2017). However, it is a metric with a low prevalence because it requires the writing of an entry and an important selection of the most relevant bibliography. Graph 5 presents the evolution of the percentage of articles with a *Wikipedia* citation included in each provider. Percentages do not exceed 7% in all the aggregators. *Altmetric.com* and *PlumX* describe a steady increase since 2015, caused by the growth of the online encyclopaedia and the addition of different language versions. Thus, the first study on the coverage of *Wikipedia* citations in *Altmetric.com* was performed in 2015 by Nuredini and Peters (2016), who observed a 1.1% of papers with mentions, and Thelwall and Nevill (2018) with 0.2%. These proportions increased by 1.3% in 2016 and 2.4% in 2017. In 2018, there is a slight descent (1.7%) caused by the low percentages found by De-Filippo and Sanz-Casado (2018) (1.6% and 1%) and Repiso et al. (2019) (1.3%). These results are due to the fact they are analysing Social Sciences disciplines, which would indicate fewer *Wikipedia* mentions to that research area than to others (Zahedi et al., 2014b). In 2018, Torres-Salinas et al. (2018a) found a disproportionate 11.7% of *Wikipedia* mentions caused by a sample based on books from *Book Citation Index (WoS)*. This result suggests that books are specially mentioned in *Wikipedia*, due perhaps to the educational orientation of the monographs.

*PlumX* also describes a constant growth since the first observation by Peters et al. (2014b) (0.7%) in 2014 to the last by Gorraiz et al. (2019) (3%) in 2019. This signifi-



Graph 5. Yearly evolution of the percentage of *Wikipedia's* citations in each provider

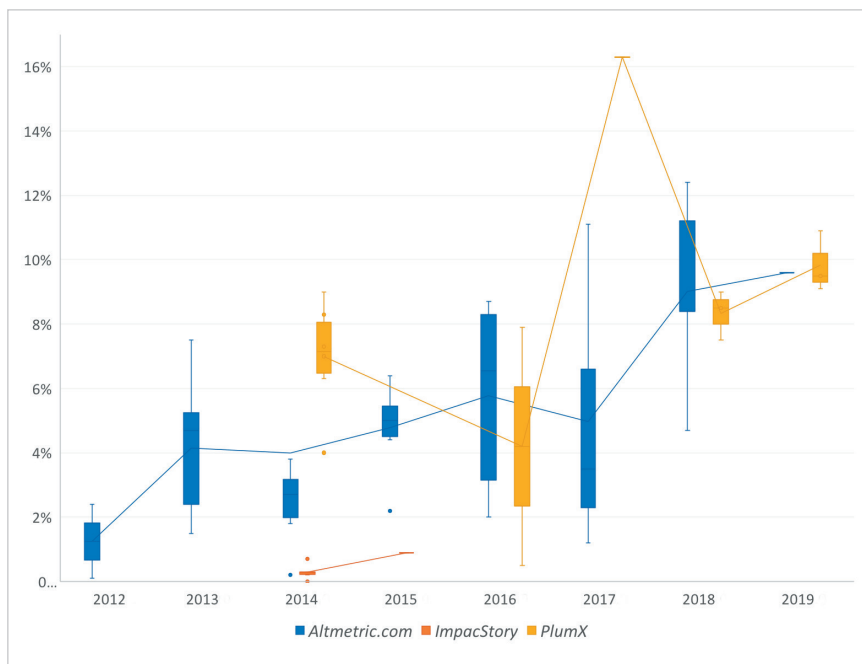


cant increase could be due to the indexation of entries in languages other than English (Allen, 2018). It is important to notice that in 2016 Torres-Salinas et al. (2017b) found the astonishing proportion of 16% of Wikipedia citations in a sample of books, close to the 11.7% in Altmetric.com (Torres-Salinas et al., 2018a), which would confirm that books are more cited in Wikipedia than research papers (Kousha; Thelwall, 2017). ImpactStory presents a downward trend, starting from a 1.3% of citations on average in 2013 to the 0.7% of Peters et al., (2014b) in 2014 and the 0.1% of Kraker et al. (2015). Lagotto again shows a high main percentage (4.5%) because it is only representative of PLoS journals. Lastly, CED was used in 2017 (Ortega, 2018b; Zahedi; Costas, 2018), resulting in an average of 1.7%, similar to PlumX and Altmetric.com in that year.

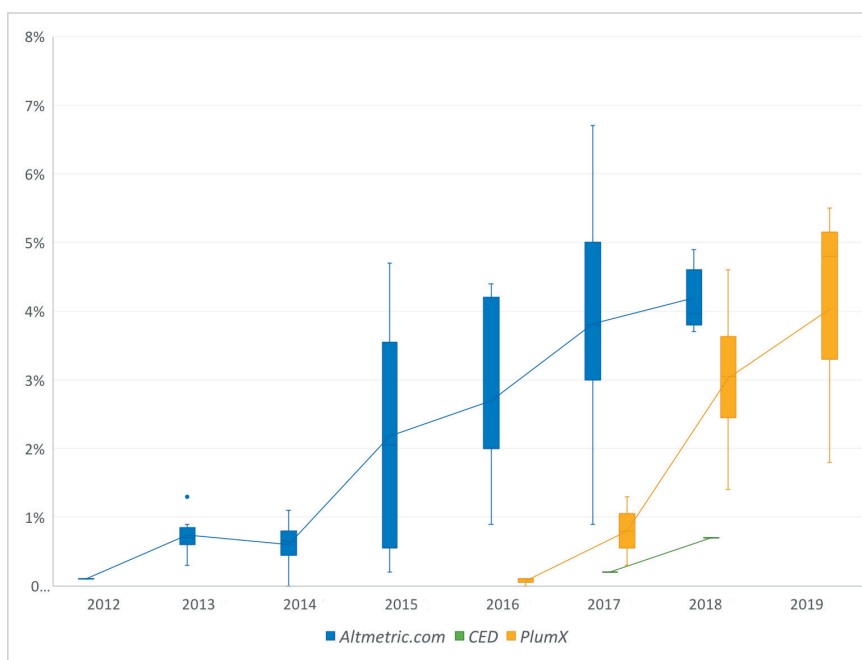
#### 4.3.4. Facebook

Facebook's mentions are other important metrics resulting from a generalist social network. It counts the number of mentions, shares and likes that a publication receives. However, when aggregators come to count Facebook mentions, there are differences between them, which could produce inconsistencies in the comparison. Altmetric.com only in-

cludes posts on a curated list of public pages, excluding likes and individual pages (Altmetric Support, 2019). PlumX and Lagotto, on the contrary, index and add likes, comments and shares in a single count (Allen, 2016; PLoS, 2019). Taking these facts into consideration, Graph 6 presents a constant increase of Facebook mentions, mainly in Altmetric.com and PlumX. Altmetric.com evolves positively from the average mentions of 1.3% in 2012 (Adie; Roe, 2013; Knight, 2014) to the 9.2% in 2018 (De-Filippo; Sanz-Casado, 2018; Repiso et al., 2019; Robinson-García et al., 2019) and 9.6% in 2019 (Wooldridge; King, 2019). PlumX follows a similar ascending pattern (on average, 7% in 2014 to 9.8% in 2018), but with more peaks and troughs. Thus, the highest outlier observation is the 16.3% found by Zahedi and Costas (2018), due to the use of a limited sample of PLoS articles. As we have seen before, articles from that publisher present higher than average values in social media metrics. It is interesting that despite PlumX counting more Facebook events, the percentage of articles mentioned is very similar to Altmetric.com. According to ImpactStory and Lagotto, the observations are anecdotal, with the 0.3% (Peters et al., 2014b) in 2014 and the 0.9% (Kraker et al., 2015) in 2015 of ImpactStory being the most noteworthy. Lagotto describes very high values (45.4% in 2014) arising from the fact that PLoS articles have a better presence in social networks. Lagotto figures are not depicted in the graph be-



Graph 6. Yearly evolution of the percentage of Facebook's mentions in each provider



Graph 7. Yearly evolution of the percentage of news' mentions in each provider

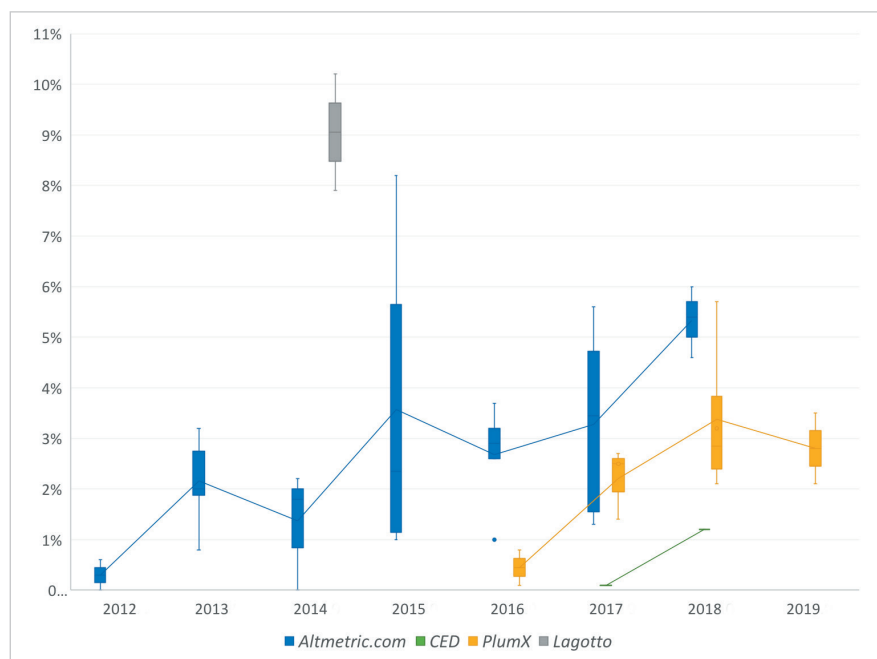
cause of the considerable distortion they cause.

#### 4.3.5. News

News mentions measures the number of times that a research publication is mentioned in a news outlet. Unlike the other metrics, this one is not based on a single source. Rather, it depends on the coverage of news media that each provider gets indexing, which can give rise to important differences between services. Graph 7 describes a steady increase of news events in each provider, especially in the last three years. Only three services (*Altmetric.com*, *PlumX* and *CED*) were used in the literature to extract news mentions. *Altmetric.com* presents a paused growth up to 2017, starting from the 0.1% of **Knight** (2014) in 2012 to the mean 3.8% in 2017. Graph 7 shows a jump from 2015, motivated by the new partnership with *Moreover.com* (**Williams**, 2015), which doubles the proportion of mentioned articles on news media. In 2018, the coverage of news increased to the mean of 4.2% (**Repiso et al.**, 2019; **Dardas et al.**, 2018; **Torres-Salinas et al.**, 2018a; **Ortega**, 2019; **Robinson-García et al.**, 2019). *PlumX* showed more continued growth, ranging from 0.1% in 2016 (**Meschede; Siebenlist**, 2018; **Torres-Salinas et al.**, 2017a; 2017b) to 4% in 2019 (**Gorraiz et al.**, 2019). According to *CED*, Ortega's papers show a coverage of 0.2% in 2017 (**Ortega**, 2018b) and of 0.7% in 2018 (**Ortega**, 2019), considerably lower than *PlumX* and *Altmetric.com*, which have similar percentages.

#### 4.3.6. Blogs

The last metric analysed is the number of references to scholarly outputs included in Blogs. In the manner of News, this indicator is also influenced by the list of sources managed by each provider. Graph 8 illustrates the evolution of the percentage of publications with that metric in each provider. Overall, the percentage of mentioned articles increased in every service during the period covered. *Altmetric.com* describes a constant rise in mentions, from 0.6% for **Knight** (2014) in 2012 to the 8.8% average mentions in 2018. Throughout this time span, worthy of notice is the 0% of Latin-American articles mentioned in 2014 by **Alperin** (2015), which illustrates the low presence of non-English literature in altmetric aggregators. Also interesting is the significant coverage of articles on Psychology (8.2%) reported by **Htoo and Na** (2015) and Business (6.4%) by **Nuredini and Peters** (2016) in 2015. This result could be due to the important presence of blogs specialising in Social Sciences subjects such as Psychology, Economics and Politics (**Ortega**, 2019c). The growth of the percentage of blog mentions in *PlumX* is also continuous. Since 2016, the mean percentage of blogs mentions has increased from 0.8% to close to 3% in 2019. In this period, the high value observed by **Ortega** (2019a) (5.8%) is noteworthy. According to other providers, *Lagotto* presents an elevated proportion (9%) due to the aforementioned high presence of *PLoS* journals on social media. *CED* describes an increasing coverage of publications from 0.1% in 2017 (**Ortega**, 2018b) to 1.2% in 2018 (**Ortega**, 2019a).



Graph 8. Yearly evolution of the percentage of blog mentions in each provider

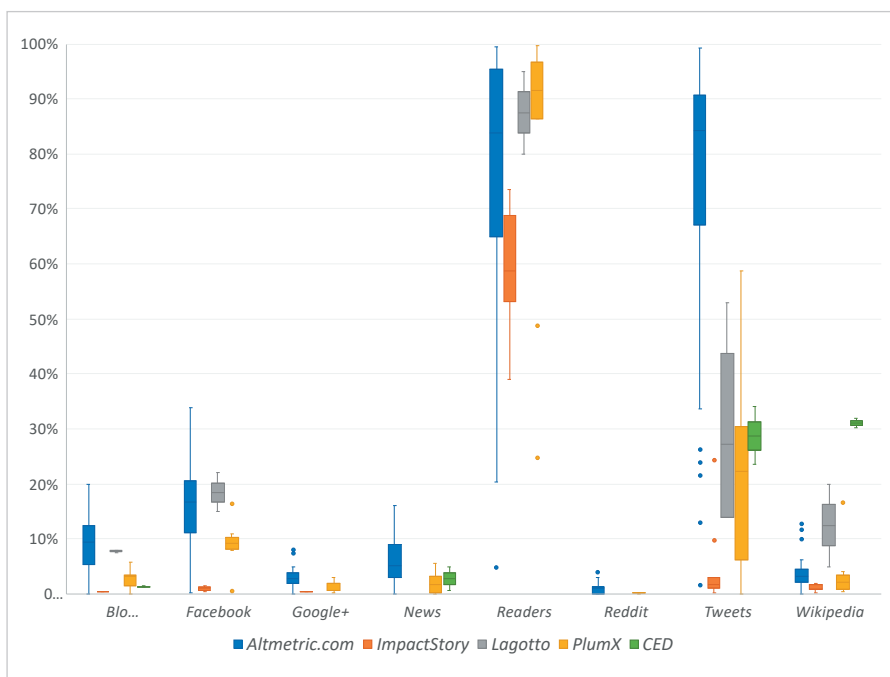
*PlumX* is also continuous. Since 2016, the mean percentage of blogs mentions has increased from 0.8% to close to 3% in 2019. In this period, the high value observed by **Ortega** (2019a) (5.8%) is noteworthy. According to other providers, *Lagotto* presents an elevated proportion (9%) due to the aforementioned high presence of *PLoS* journals on social media. *CED* describes an increasing coverage of publications from 0.1% in 2017 (**Ortega**, 2018b) to 1.2% in 2018 (**Ortega**, 2019a).

#### 4.4. Metrics proportion in each provider

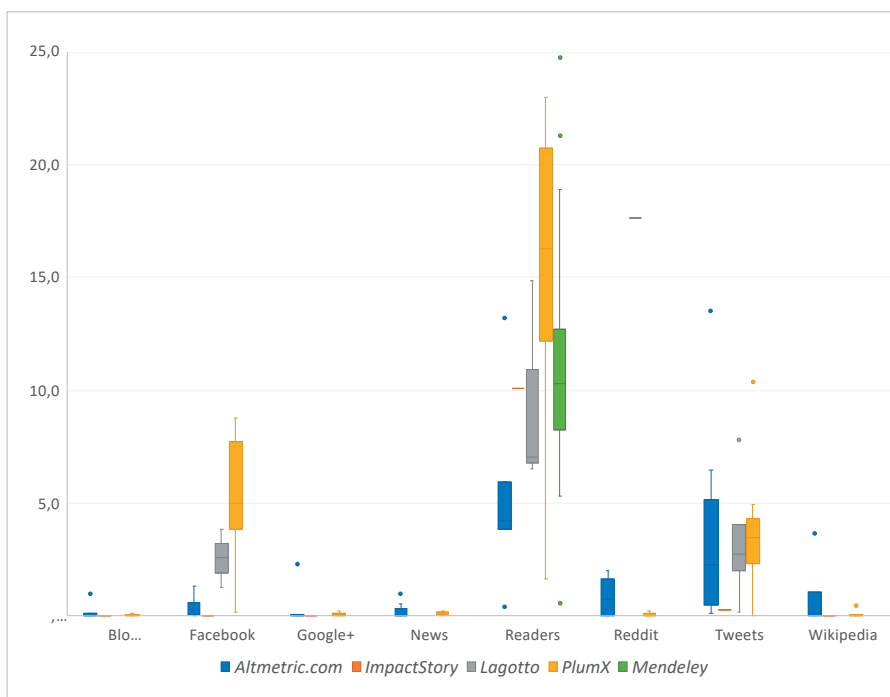
This section describes the coverage and weight of the different metrics in each provider. The aim is to observe differences between services when they come to capture each metric.

Graph 9 depicts the distribution of the percentages of the eight most important metrics observed in the literature by altmetric provider. In general, *Altmetric.com* presents higher coverage in every metric with the exception of *Facebook* mentions, *Mendeley* readers and *Wikipedia* citations. In the case of *Facebook*, *Lagotto* captures more mentions (18.5%) than *Altmetric.com* (15.6%) and *PlumX* (9%), caused mainly by the high coverage of *PLoS* articles in social networks (**Priem et al.**, 2012; **Fenner**, 2013; **Zahedi; Costas**, 2018). The distribution of *Mendeley* readers in each aggregator is skewed due to different sample size and type. This is especially significant in the study of books, where the proportion of readers is very

low with regard to articles (Torres-Salinas *et al.*, 2017b; 2018a). These authors found between 20.4% (Altmetric.com) and 48.8% (PlumX) of readers. Leaving these counts aside, PlumX is the platform that captures a higher proportion of Mendeley readers (93.8%), followed by Lagotto (87.5%) and Altmetric.com (80.9%). Mentions on Twitter also follow a skewed distribution with many outliers. In the case of Altmetric.com, it is important to notice the first observation of Adie and Roe (2013) when the service had just started (1.5%); tweets to books (Torres-Salinas *et al.*, 2018a) (26.2%); geographical and language biases in Spanish (Torres-Salinas *et al.*, (2018b) (13%) and Latin-American articles (Alperin, 2015) (24.2%); and disciplinary differences in nursing (Dardas *et al.*, 2018) (23.8%) and dentistry (Kolahi *et al.*, 2017) (21.5%). In spite of these values, Altmetric.com is by far the aggregator that gathers the most Twitter mentions (72.5%), followed by Lagotto (30.4%). PlumX gathers 29.2% on average, excepting books (Torres-Salinas *et al.*, 2017a; 2017b) and the study of Peters *et al.* (2014b), when PlumX did not yet use Gnip to extract Twitter citations. CED includes an average of 28.7% of tweeted papers. Lastly, the coverage of Wikipedia citations by CED is especially relevant because it is the service that has a greater percentage of articles cited on Wikipedia (31.2%). This is mainly because it harvests entries from across Wikipedia, with no language limitation (Ortega, 2018b; Zahedi; Costas, 2018).



Graph 9. Box plot of the most important metrics by altmetric provider



Graph 10. Box plot of the frequency of events by paper according to provider

#### 4.5. Average of events per publication

This indicator illustrates the frequency at which a paper is mentioned in different metrics. This measurement offers information on the prevalence of events in every metric. It is calculated as the number of total events divided by the number of publications in the sample.

This indicator describes a high level of scattering resulting from both the heterogeneous nature of the samples and time and disciplinary differences. However, it is more stable when it comes to compare results across platforms. For this reason, only multidisciplinary samples were used to analyse this measure. Graph 10 presents a low proportion of events in almost every metric, with the exception of Facebook mentions, Mendeley readers and tweets. The remaining metrics do not amount to 10 mentions on average. Altmetric.com is the service that has a better proportion of events

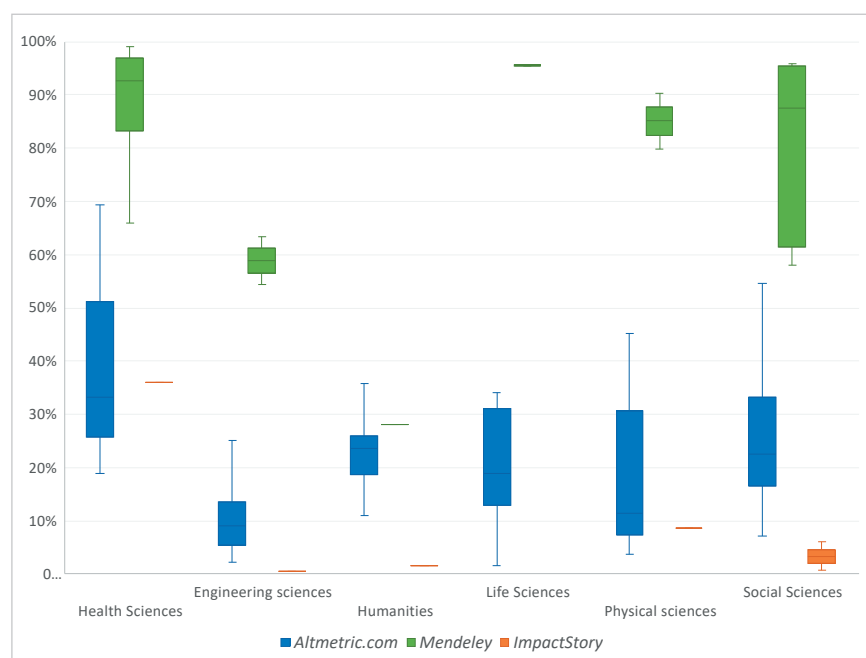
per publication across all metrics, excepting *Facebook* and readers. In the case of *Facebook* mentions, the average of events in *PlumX* (4.9) and *Lagotto* (2.6) is far greater than *ImpactStory* (0.03) and *Altmetric.com* (0.4). The reason for this discrepancy is that *PlumX* and *Lagotto* include likes and shares as *Facebook* mentions (Peters et al., 2014b; Allen, 2016; PLoS, 2019), causing an increase in the proportion of events by publication. More variability and higher complexity are found in the proportion of readers by provider. The average of events per publication in *Mendeley* (10.3) is lower than that observed in *PlumX* (15.5) and very similar to *Lagotto* (10.7) and *ImpactStory* (9.47). The higher proportion in *PlumX* is paradoxically explained by the fact that *PlumX* groups duplicated articles, causing the average of readers by publication to be higher than with non-merged references. However, worth noting is the outlier in *Mendeley* of **Alperin** (2015), who detected 0.6 of readers per publication in a sample of Latin-American publications. This low proportion could again suggest a bias detrimental to non-English papers. On the contrary, the proportion of 21.5 readers found by **Bornmann** and **Haunschild** (2016b) refers to review articles, which explains why this type of publication attracts a high proportion of readers. According to tweets, *PlumX* (3.5), *Lagotto* (3.4) and *Altmetric.com* (3.3) depict similar averages of mentions by publication, which suggests that these providers do not present significant differences in counting tweets per article. These percentages change when the most recent articles are observed (2018-2019). In this case, *PlumX* has 4.5 and *Altmetric.com* has 4 tweets per article. Nevertheless, some outliers influence these figures. **Bornmann** (2015) observed an elevated proportion of tweets (7.8) to recommended articles on *F1000*, a fact that could influence the mention of these articles on *Twitter*. Also interesting to note is the recent study by **Gorraiz et al.** (2019), who found 10.3 tweets per article in publications from the *University of Vienna*. This study confirms the increase in the number of tweets per article in recent years.

#### 4.6. Disciplines

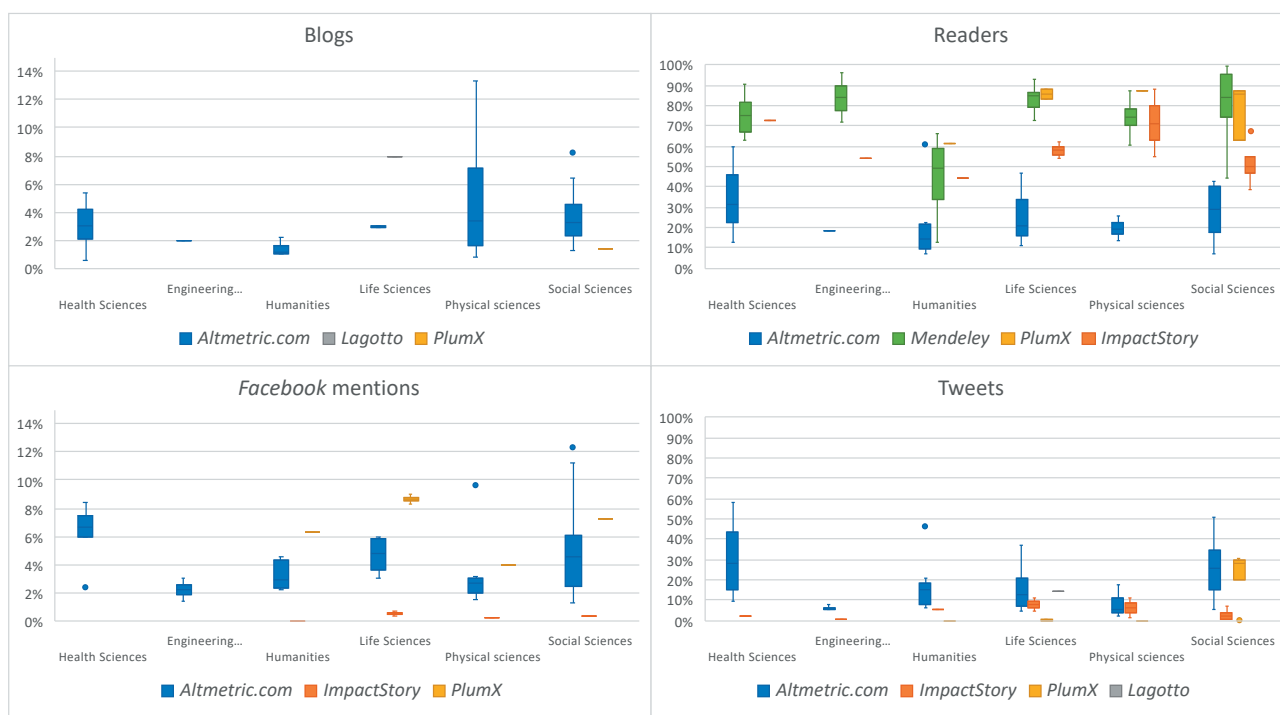
This section examines disciplinary differences in the coverage of publications in each provider and explores how each metric is distributed in different disciplines. *All Science Journal Classification (ASJC)* was used to group the different disciplinary studies (<https://pg.edu.pl/documents/611754/75313317/asjc>).

From this classification, Social Science and Humanities and Physical Sciences and Engineering were broken up to observe the specific behaviour of these categories: 52 (49%) articles from the sample show some disciplinary information and only 18 (17%) include data from providers other than *Altmetric.com*. This lack of data means that most of the results are only based on one or two observations, which could lead to inaccurate results and cautious interpretation.

The disciplinary coverage of publications has been studied in only three providers, *Altmetric.com*, *Mendeley* and *ImpactStory*. The remaining were used to track the coverage of specific metrics but not the general coverage of these platforms. The reason is that some providers were limited to specific sources (*Lagotto*) or to particular institutions (*PlumX*). Graph 11 presents the distribution of each research area according to the three providers analysed. In general, only two research areas present significant differences: Health Science and Social Sciences. Health Sciences describes higher coverage levels in all three providers. In the case of *Altmetric.com*, this proportion goes from the 19.3% of **Knight** (2014) to the 69.3% of **Bornmann** (2014a), with an average of 38%. *Mendeley* has better coverage, reaching 87.5% of articles. Interesting to note is the outlier of **Haustein** and **Larivière** (2014) with a 65.9%, due mainly to the fact that this study is previous to *Mendeley's* integration with *Scopus* (Bonasio, 2014; *Scopus*, 2014). In the case of *ImpactStory*, only one publication contained information about its disciplinary coverage (**Zahedi et al.**, 2014b). Thus, this platform captures 36% of Health Sciences papers. Interestingly, Social Sciences (25.7%) and Humanities (22.8%) have on average more publications included in *Altmetric.com* than the remaining areas. However, this pattern is not observed in *Mendeley*, where Life Sciences (95.7%) and Physical Sciences (85%) are the research areas that have more documents (Zahedi; Van-Eck, 2018). These differences between *Mendeley* and *Altmetric.com* could be because *Altmetric.com* only captures publications that have previously been mentioned in social



Graph 11. Box plot of the disciplinary coverage of publications by provider



Graph 12. Distribution of the disciplinary coverage of publications by altmetric provider according to four metrics: blogs, *Mendeley* readers, *Facebook* mentions and tweets

networks (**Haustein et al.**, 2015; **Bar-Ilan et al.**, 2019). Another reason could be that *Mendeley* readers could be distributed thematically as bibliometric indicators, owing to the strong correlation between these metrics (**Mohammadi; Thelwall**, 2014; **Mohammadi et al.**, 2015).

Graph 12 displays the distribution of the percentage of documents mentioned in four metrics: blogs, readers, *Facebook* mentions and tweets. The remaining metrics were not studied because of the absence of specific data on the coverage of these metrics from a disciplinary perspective. In fact, many of the observations in Graph 12 come from only one or two studies. This lack of data led us to carefully interpret and to limit the analysis to the most studied metrics. For example, the analysis of blogs shows a predominance of *Altmetric.com* data. In this sense, Physical Sciences (5.3%) and Social Sciences (3.6%) are the most mentioned disciplines in blogs according to *Altmetric.com*. This proportion coincides with the results of **Ortega** (2019c) about the disciplinary coverage of blog sites, which suggests a strong relation between the mention of articles by discipline and the thematic content of the sources.

*Facebook* mentions also depicts a majority of *Altmetric.com* observations, but now the disciplines with a greater mean proportion of mentioned publications are Health Sciences (6.2%) and Social Sciences (5%). This raised value for Social Sciences is due to the special presence of Sociology (12.4%) and Communication (11.2%) reported by **De-Filippo and Sanz-Casado** (2018). However, *PlumX* presents better percentages than *Altmetric.com* in every metric, particularly for Life Sciences (8.6%) and Social Sciences (7.3%) (**Peters et al.**, 2014b).

More data were found for readers. Obviously, *Mendeley* has a better mean percentage of publications than the other services, but *PlumX* presents very close percentages, which reveals that *PlumX* manages better duplicated records and that both services are now integrated into *Elsevier's* products, sharing bibliographic information. However, data about *PlumX* are taken only from two works (**Peters et al.**, 2014b; **Bar-Ilan et al.**, 2019), so these results should be read with caution. In general, it is interesting to note that Social Sciences is the discipline with the best coverage in all providers, with the exception of *ImpactStory*. This important presence of the Social Sciences was previously reported by **Haustein et al.** (2014b) when they detected 81% of readers in Psychology; **Htoo and Na** (2015) notice more than double the number of readers in Psychology (39%) than in History (11.8%) or Linguistics (17.6%); and **Zahedi et al.** (2017) perceived that Social Sciences, Humanities (18.1%), along with Life and Earth Sciences (18.6%), were the disciplines with more readers.

Finally, the coverage of tweeted papers by discipline presents an unlikely behaviour. In *Altmetric.com*, Health Sciences (28%) and Social Sciences (24.5%) are the research categories that attract more tweets on average, whereas *ImpactStory*, Life Sciences (7.6%) and Physical Sciences (6%) are the most tweeted disciplines. *PlumX* depicts a strong collection of Social Sciences publications (21.7%), although this result is obtained at the expense of the absence of more disciplinary data.

#### 4.7. Comparative

The existence of different services that provide similar metrics have led to the appearance of some studies that compare coverage and counts between services. However, the number of publications that address this issue is low: only seven studies comparing different providers were located in the literature. The first attempt was performed by **Zahedi et al.** (2014c) with data from February 2014. They randomly selected 1,000 articles from *PLoS one*. This sample allowed them to compare *Lagotto*, *Altmetric.com* and *Mendeley*. Their results showed that the data reported by these providers were not consistent and revealed important differences. *Mendeley* was the service that indexed more publications, *Altmetric.com* captured more tweets and *Lagotto* had a special coverage of *Facebook* mentions. A few months later, **Peters et al.** (2014b), with data from August 2014, analysed 1,740 publications from the *Leibniz Association*, a multidisciplinary research organisation from Germany. These publications were searched in four services: *Plum Analytics (PlumX)*, *ImpactStory*, *Altmetric Explorer (Altmetric.com)* and *Mendeley* (through *Webometric Analyst*). Because the publications could be classified in research areas, they were also able to perform a disciplinary study. The principal result was the verification of the great discrepancy between services, even when using the same sources. In this sense, they evidenced that *PlumX* barely provided information about tweets, but displayed high scores for *Facebook* mentions and *Mendeley* readers. *Altmetric.com*, on the contrary, was the platform with the best coverage of tweets. From a disciplinary perspective, these authors observed that Science, Technology and Medicine (STM) articles attracted more attention than other disciplines. **Kraker et al.** (2015) compared two altmetric aggregators: *PlumX* and *ImpactStory*, using a small sample of datasets (1000 items) from *Figshare*. They perceived that *PlumX* detected considerably more items in social media and also found higher altmetric scores than *ImpactStory*. In July 2015, **Zahedi et al.** (2015a) used a random sample of 30,000 articles from *Crossref* and *WoS* to check the same providers as in 2014 (**Zahedi et al.**, 2014c). Their results confirmed previous outputs about coverage and metrics. However, this is the first work that explored the counting differences between providers according to the same metric. Thus, they reported that in general *Mendeley* had a higher number of readers than *Lagotto* and *Altmetric.com*, *Lagotto* counted more *Facebook* mentions than *Altmetric.com*, and *Altmetric.com* collected more tweet counts.

Not until 2018 were there more systematic comparisons between altmetric aggregators. **Meschede and Siebenlist** (2018), with data from September 2016, analysed 50,000 dois from *WoS* in *Altmetric.com* and *PlumX*. They found that *PlumX* almost covered 100% (91%), while *Altmetric.com* only collected 38% of the sample. According to the metrics, publications on *Altmetric.com* have better scores than *PlumX* in all the metrics, with the exception of *Mendeley* readers and *Wikipedia* citations. From these results, it is interesting to note that *Altmetric.com* has slightly more papers mentioned in *Facebook* than *PlumX*, a result that contradicts other studies (**Peters et al.**, 2014b). In the same year, but with data from May 2017, **Ortega** (2018b) compared the coverage and counts of 67,000 papers extracted from *PlumX* in three altmetric data services: *Altmetric.com*, *PlumX* and *CED*. Although the sample could be biased in favour of *PlumX*, the coverage of *Altmetric.com* was above 40%, while *CED* included only 4% of publications with at least one metric. According to metrics, *PlumX* (98.6%) captured more documents with readers than *Altmetric.com* (95.7%), but much fewer articles with mentions on *Twitter* (22.3%) than *Altmetric.com* (38%). This last percentage in *PlumX* is lower than previous studies (**Kraker et al.**, 2015) but in line with recent analyses (**Meschede; Siebenlist**, 2018, 21%; **Zahedi; Costas**, 2018; 23.9%). Doubtlessly, the most complete analysis of the coverage of altmetric providers was performed by **Zahedi and Costas** (2018), who tested 31,000 *PLoS one* articles in June 2017 on five data platforms: *Altmetric.com*, *CED*, *Lagotto*, *PlumX* and *Mendeley*. Despite the fact that using data about only one journal could not be representative, their results were consistent with previous studies, though with higher proportions. Thus, for example, *PlumX*, *Lagotto* and *Mendeley* reached a coverage above 90%, while *Altmetric.com* obtained 61% and *CED* 7% —a percentage much greater than previous studies (**Zahedi et al.**, 2015a; **Ortega**, 2018b; **Meschede; Siebenlist**, 2018). A similar interpretation could be made with the high number of tweeted papers (57%) in *Altmetric.com*, much higher than the 38% of **Ortega** (2018) and the 36% of **Meschede and Siebenlist** (2018). The last study now comparing altmetric aggregators was published by **Bar-Ilan et al.** (2019). These authors examined 2,700 articles from the *Journal of the Association for Information Science and Technology* at two different moments —June 2017 and April 2018— in *PlumX*, *Mendeley* and *Altmetric.com*. The results were very similar to previous studies, confirming that *PlumX* (87%) and *Mendeley* (98.6%) have almost full coverage of readers. However, it is interesting to note that the number of tweets captured by *PlumX* (30%) is close to that of *Altmetric.com* (35%), which suggests that *PlumX* is addressing their disadvantages by capturing tweets.

## 5. Limitations

The realisation of a meta-analysis about the coverage and counting of altmetric providers has evidenced that the reviewed literature presents very different results, showing an elevated variability between similar observations. For example, Graph 2, on the evolution of the different services, depicts wide annual margins in the percentage of covered publications. This instance is perceived in the evolution of the different metrics (reads, tweets, *Facebook* mentions, etc.). This inaccuracy is mainly caused by the different ways of selecting the sample, which could produce a wide range of biases. For example, the use of some specific sources such as recommended articles from *F1000* (**Bornmann**, 2014; 2015; **Bornmann; Haunschild**, 2015; 2018) or articles from specific journals such as *PLoS One* (**Zahedi et al.**, 2014c; **De-Winter**, 2015; **Zahedi; Costas**, 2018) and *Journal of the Association for Information Science and Technology* (**Bar-Ilan et al.**, 2019) produce specific results that can hardly be generalised. Another important bias is introduced when local

studies are analysed, mainly from emergent regions such as Latin America (**Maricato; Filho, 2018; Alperin, 2015**) or from non-English-speaking countries such as Spain (**Torres-Salinas et al., 2016; Torres-Salinas et al., 2018b**), Peru (**Eléspuru-Briceño; Huaroto, 2016**) or China (**Wang et al., 2016**). The selection of specific formats such as books (**Hammarfelt, 2014; Torres-Salinas et al., 2017a; 2017b; Torres-Salinas et al., 2018a**) and datasets (**Peters et al., 2015; Peters et al., 2016; Kraker et al., 2015**) also limits the extrapolation of the results. This does not mean that these studies are biased; on the contrary, they contribute appreciated information about the limitation of altmetrics in specific regions, disciplines or formats. The problem with these results is that they increase variability when a general picture is drawn.

Perhaps, a possible solution would be to exclude those cases. However, this leads us to another significant limitation of this review: the absence of an important critical mass of results. Although this study is based on 107 outputs over seven years, a number far from negligible, many of them present partial analyses or limited information about the data. For example, the average events per publication (Graph 10) or the disciplinary analysis (Graphs 11-12) illustrate some distributions with barely one or two observations, which introduces great randomness and variability, causing the averages to be poorly representative and the trends to present peaks and troughs. Another factor is that many of the referenced studies lack systematic and standardised information on the sample. For instance, some publications do not provide a data extraction date, which hinders result grouping by year. In other cases, there is no clear information about the counts (for example, the percentage of the sample or percentage of the mentioned articles), or the indicators are not well explained or they use particular denominations (i.e. mean available, mean score, intensity). These inaccuracies make it difficult to understand the real meaning of these data, unfortunately leading to some results being discarded for meta-analysis. Finally, another important factor that hinders comparison is the time-window of the samples analysed, because there are important differences in the altmetric impact according to the publication date. This discretionary range of samples introduces more variability in the results.

## 6. Discussion

Despite the limitations mentioned above, this meta-analysis has reported important results about the use, coverage of publications and counting of metrics in the principal altmetric data providers. *Altmetric.com* is the most used platform for altmetric studies. Graph 1 illustrates how this service is gaining prominence in the scholarly community as an altmetric tool, being used in more than half the reviewed articles (54%). In fact, 43% of the articles use *Altmetric.com* as their only data source. This hegemony of *Altmetric.com* could be caused by its tendency to support altmetric research with a public API, research grants and a research data program (*Altmetric.com, 2019b; 2019c*). Another important advantage is that it is the service that captures more events from social networks, especially *Twitter* (Graph 3), news (Graph 7) and blogs (Graph 8), making this platform the favourite altmetric provider. However, these advantages do not exclude pointing out important limitations as an exclusive source. The most significant is the limitation of indexing only publications mentioned in social networks (**Haustein et al., 2015; Bar-Ilan et al., 2019**). As a result, only around 30-40% of the current scientific literature is included in *Altmetric.com* (**Torres-Salinas et al., 2018a; Robinson-García et al., 2018; Didegah et al., 2018; Ortega, 2019**). According to the coverage of metrics, *Altmetric.com* shows the worst performance capturing *Mendeley* readers (Graph 4), motivated by the non-aggregation of duplicated records (**Ortega, 2018b**), and the average number of *Facebook* mentions (Graph 10) due to a restrictive definition of this metric, which only indexes posts on *Facebook's* public pages (*Altmetric Support, 2019*).

*Mendeley*, though it could be considered an altmetric source, is not exactly a data aggregator because it only provides one metric produced by itself. Despite this, it is the second most used source for altmetric studies (18%). Its importance could be because, for readers, it is the metric that correlates better with citations and has been suggested as an early scientific impact indicator (**Mohammadi; Thelwall, 2014; Thelwall; Nevill, 2018**). Studies on this source have demonstrated that the coverage of scientific literature is close to 100%, mainly from mid-2014. This source is then widely representative and key to linking impact with the readership of scientific outputs. Its most serious limitation is that there is no integration of duplicated records.

*PlumX* is the second most used aggregator (17%) and is becoming the most serious competitor of *Altmetric.com*, mainly after being acquired by *Elsevier* (2017). Its principal advantage is the high coverage of publications, over 95% in recent years (**Meschede; Siebenlist, 2018; Zahedi; Costas, 2018; Ortega, 2018a; Ortega, 2019; Gorraiz et al., 2019**). This makes *PlumX* a comprehensive tool that enables tracking the impact of a wide range of materials, especially the performance of books (**Torres-Salinas et al., 2017a; 2017b**). However, *PlumX* has difficulties computing some metrics. The number of blogs and news mentions (Graphs 7 and 8), and the proportion of *Wikipedia* citations is lower than *Altmetric.com* (Graph 5). Nevertheless, *PlumX* is making up for these limitations and is improving their figures. A clear example is *Twitter* mentions. The literature has shown that *PlumX* initially captured a very low proportion of tweets (**Peters et al., 2014b**). However, after 2016, when *Gnip* was used, the proportion increased to more than 20% (**Ortega, 2018b; Meschede; Siebenlist, 2018; Zahedi; Costas, 2018**), and today, the latest studies confirm that *PlumX* gathers as many tweets as *Altmetric.com* (30%) (**Bar-Ilan et al., 2019**). This fact demonstrates the important growth of *PlumX* as an altmetric provider. In addition, coverage of readers is also noteworthy and is as good as *Mendeley* due to the

integration of duplicated records (Peters et al., 2014b; Ortega, 2018b; Bar-Ilan et al., 2019).

Another important result is the decreasing use of *ImpactStory* and *Lagotto*. Several reasons explain this disuse. In the case of *ImpactStory*, this service presents an acceptable proportion of covered documents (60-70%) (Zahedi et al., 2014b; Peters et al., 2014a; 2014b; Kraker et al., 2015) and a good percentage of *Mendeley* readers (50-60%) (Zahedi et al., 2014a; 2014b; Peters et al., 2014b). However, from 2015 their data were not easy to extract (there is no public API), leading to the disappearance of this service in altmetric studies. *Lagotto*, on the contrary, is scarcely used because it basically covers publications from *PLoS*. Due to the considerable differences between journals and publishers when they are present on social media (Ortega, 2017), the use of *Lagotto* introduces important biases. For example, the few studies that used this tool showed a disproportionate coverage of tweets (40-60%) (Bornmann, 2015; 2014b; De-Winter, 2015; Barthel et al., 2015), *Wikipedia* citations (4.5%) (Priem et al., 2012; Bornmann, 2015; Zahedi; Costas, 2018), *Facebook* mentions (45.4%) (Zahedi et al., 2014c; Bornmann, 2015) and blogs (9%) (Fenner, 2013; Bornmann, 2014b). These extreme values are caused by *PLoS one*, a multidisciplinary journal. These types of journals tend to show very high altmetric scores (Zahedi et al., 2014b).

Nowadays, new open and non-profit services are emerging as data providers that offer raw data about social events (*CED*, *Cobalmetrics*). *CED* is the most promising tool. Although the platform is new (created in 2016) and the coverage of publications is low (10-20%) (Ortega, 2018a; 2018b; Zahedi; Costas, 2018), it does collect a good proportion of tweets (28.7%) and *Wikipedia* citations (31.2%) (Graph 9). These results confirm the positive development of these open data providers.

## 7. Conclusions

In general, the main lesson that we can extract from this meta-analysis is that the results of using one altmetrics provider or another are very different. The coverage of publications, the selection of sources and the process of extraction and matching of events is so different that the information reported by each service is hardly comparable. The evidences compiled in this study warns of the individual use of only one tool for general altmetrics studies and suggests the use of different platforms to contrast and complement the results. For example, some formats (books and datasets) are unlikely to be covered and display different impact patterns. This limitation is greater with regard to local publications in non-English languages, whose impact is underrepresented by many altmetrics providers. The disparity of counts and sources provided by services reinforces the assumption that different data providers are necessary in order to display a comprehensive view of the altmetric impact of scholarly results.

Furthermore, the analysis performed has pinpointed the advantages and drawbacks of each service, making this study an initial guide to selecting the most appropriate tools for altmetric studies and for tracking the evolution of each platform. The results confirm that *Altmetric.com*, despite its limited coverage, is the service that captures most mentions from social networks, blogs and news outlets. *PlumX* has better coverage but captures fewer events than *Altmetric.com*. The strong point of *PlumX* is that it is the best service for counting *Mendeley* readers, in some cases, better than *Mendeley* itself. *CED* is a small but promising tool that has a special coverage of mentions from *Wikipedia*. *Lagotto* and *ImpactStory* are gradually falling into disuse because they have limited reach. *Lagotto* is limited to specific publishers (*PLoS*), and *ImpactStory* includes information from other providers (*Altmetric.com*).

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