# Determinants of Research Citation Impact in Nanoscience and Nanotechnology[1]

**Fereshteh Didegah, Mike Thelwall**
*Statistical Cybermetrics Research Group, School of Technology, University of Wolverhampton, Wulfruna Street, Wolverhampton WV1 1LY UK*
*E-mail: f.didegah@wlv.ac.uk m.thelwall@wlv.ac.uk*

**This study investigates a range of metrics available when a nanoscience and nanotechnology article is published to see which metrics more correlate with the number of citations to the article. It also introduces the degree of internationality of journals and references as new metrics for this purpose. The journal impact factor, the impact of references, the internationality of authors, journals and references and the number of authors, institutions and references were all calculated for papers published in nanoscience and nanotechnology journals in the Web of Science from 2007 to 2009. Using a zero-inflated negative binomial regression model on the data set, the impact factor of the publishing journal and the citation impact of the cited references were found to be the most effective determinants of citation counts in all four time periods. In the entire 2007-2009 period, apart from journal internationality and author numbers and internationality, all other predictor variables had significant effects on citation counts.**
**Keywords: Research citation impact; ZINB model; Nanoscience and Nanotechnology**

## Introduction

This study investigates properties of an article as a text document when it is published to find the determinants that associate with the number of citations to the article. Knowledge of these factors could be useful to science evaluators to help them to make early estimates of the number of citations that a set of published articles is likely to receive. Although the use of citations in research assessment has been criticised, they have long been the main source of indicators for the impact of individual articles (Bornmann & Daniel, 2008; Wilson, 1999; Baird & Oppenheim, 1994; Cole & Cole, 1971). In support of this, previous studies have found that high quality articles tend to be cited more often (Patterson & Harris, 2009; Lawani, 1986).

Despite the complex nature of citation motivations, some article properties are known to associate with the citation impact of individual papers. Some factors result from authors' intellectual perceptions of an article and these reasons have been explored through questionnaires or interviews. Owing to the time-consuming nature of qualitative research and the complex and discipline-dependent nature of citers' motives, such qualitative studies usually involve only a small sample of scholars. Content or context analyses employing semantic content analysis and text analysis methods are two other approaches to explore citers' motives. Some other factors influencing citation rates include attributes of the cited paper's authors, abstract, journal, field, and references. These factors are sometimes called *extrinsic* because they are properties of the article other than its intellectual contribution to research. Extrinsic factors can be used to predict future citation impact, particularly when they can be quantified and calculated easily on a large scale (see below). Extrinsic factors may not directly determine future citation counts, but can provide indirect evidence of likely future citation impact. In contrast, the rate of downloading a paper is a factor which can directly contribute to predicting citation counts but it cannot be gauged at the time of publication and needs a longer time interval (Chen, 2012). The same is true for using early citations to predict eventual citations (Levitt & Thelwall, 2011). Although a number of

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studies have investigated extrinsic factors in some subject areas, many areas and some factors have not yet been examined.

Nanoscience and nanotechnology, the focus of this article, is a fairly well-established field that connects to many other disciplines, such as physics, chemistry, material sciences, life sciences and electrical engineering (Huang, Notten, & Rasters, 2011). The current study assesses common extrinsic factors that have been previously found to influence the citation impact of individual papers in subject fields. It also introduces a new factor in the area of the determinants of citations: internationality. The purposes are to contribute to citation theory and to aid science policy makers by identifying independent variables for the citation impact of nanoscience and nanotechnology papers.

## Background literature

The reasons for citing a particular document at a particular time and in a specific field of science vary widely (Case & Higgins, 2000). Some reasons, like those involved in the persuasional nature of citations, are intangible and not measurable. A pioneering work by Garfield (1965) provides many reasons for citation; some reasons are hard to identify, like ‘paying homage or giving credit’, but others are more easily detected, like the aim of criticizing or correcting the works of others. However, it is hard to identify the reasons behind citation counts as they do not yield insights into the motivations of citing authors or the reasons for citing a specific part of an article (Brooks, 1985).

Citing motives also vary considerably between researchers and between cited works. The study of researchers’ motives for citing has been mostly conducted via surveys or interviews. The aim of persuading audiences about the findings of an article has been found to be the main citing motivation of authors (Brooks, 1985, 1986). In chemistry, the necessity for a literature review has been found to be the main reason for citing (Vinkler, 1987). Perceiving the cited work as a classic reference written by a well-known researcher in the field and using a comprehensive overview of previous literature are two other recognised motivations (Case & Higgins, 2000; Shadish, Tolliver, Gray, & Sengupta, 1995), showing that the intellectual content of a paper may not be the only reason why it is cited.

## Factors associated with higher citation counts for papers

Bornmann and Daniel (2008) reviewed citation behaviour studies and found that some extrinsic factors besides researchers’ motivations may be reasons why a paper is cited. They divided the extrinsic factors affecting the citation impact of an article into seven categories: *Author, Article, Journal, Time, Field, Availability* and *Technical problems-related*.

Journal prestige, mainly measured by the journal Impact Factor, has been identified as the most important determinant of future citation impact for articles in some scientific fields (Bornmann & Daniel, 2007; Boyack & Klavans, 2005; Van Dalen & Henkens, 2005; Callaham, Wears, & Weber, 2002). Moreover, the degree of internationalization of authors and editorial boards is a characteristic of journals which moderately correlates with their Impact Factor (Yue, 2004; Zitt & Bassecoulard, 1998).

Articles citing high impact works will be themselves more cited (Lancho-Barrantes, Guerrero-Bote, & Moya-Anegon, 2010; Boyack & Klavans, 2005). Similarly, Bornmann, Schier, Marx, and Daniel (2012) used the h-index to measure the impact of an article's references and found that the impact of its references correlates with the citation impact of the article.

Research works with a higher number of references will be cited more (Vieira & Gomes, 2010; Webster, Jonason, & Schember, 2009; Haslam et al., 2008; Lokker, Mckibbon, Mckinlay, Wilczynski, & Haynes, 2008; Kostoff, 2007; Walters, 2006; Peters & van Raan, 1994; Moed, Burger, Frankfort, & van Raan, 1985). An interpretation of this result could be that references make the work more visible (e.g., via citation-based searching in databases that allow it, such as Google Scholar and the Web of Science). The 'Tit-for-Tat' hypothesis may also apply here: that authors tend to cite the works of their ex-citers (Webster, Jonason, & Schember, 2009). In chemical engineering, the number of references was found to be a more significant determinant of citation impact than the recency of the references, as measured by the Price Index (Peters & van Raan, 1994). However, the Price Index has been shown to associate with the citation scores of publications in a number of natural and life sciences (Moed, 1989).

The number of authors has shown no correlation with the citation counts of papers in chemistry (Bornmann, Schier, Marx, & Daniel, 2012), but positively correlated in a wide variety of other subject areas and disciplines (Gazni & Didegah, 2010; Borsuk, Budden, Leimu, Aarssen, & Lortie, 2009; Sooryamoorthy, 2009; Lokker et al., 2008; Kostoff, 2007; Glänzel, Debackere, Thijs, & Schubert, 2006; Leimu & Koricheva, 2005a&b). Multinational papers have also been found to be more highly cited (Persson, 2010; Sooryamoorthy, 2009; Schmoch & Schubert, 2008; Aksnes, 2003; Glänzel, 2001; van Raan, 1998; Katz & Hicks, 1997; Narin, Stevens, & Whitlow, 1991), although some studies have found a negative correlation between countries per paper and citation impact (Gazni & Didegah, 2010). Furthermore, a higher number of institutions contributing to a paper will positively affect its citation impact (Gazni & Didegah, 2010; Sooryamoorthy, 2009; Narin & Whitlow, 1990).

The size of the field in terms of number of publications and authors could influence the impact of individual papers (Moed, Burger, Frankfort, & van Raan, 1985). Articles in smaller fields normally receive fewer citations than those in more general fields (King, 1987). Type of field (Bornmann, Schier, Marx, & Daniel, 2012; Kulkarni, Busse, & Shams, 2007; Peters & van Raan, 1994) and type of document are also related to the number of citations received by articles in some subject fields (Amin & Mabe, 2000; Peters & van Raan, 1994). Research from non-English-speaking countries is less cited than research conducted by native English speakers; this is referred to as the effect of country affiliation on the impact of research in science. Moreover, researchers from high ranked institutions receive more citations to their papers than those from low ranked institutions (Leimu & Koricheva, 2005a). In terms of research approaches, study design and study topic are also significantly associated with citation impact (Willis, Bahler, Neuberger, & Dahm, 2011; Bhandari et al., 2007). Table 1 summarises the factors that are known to associate with citation impact for individual articles.

As no prior work has explored the extrinsic determinants of future citation impact in nanoscience and nanotechnology research, the current study fills this gap by identifying some determinants of citation counts in this important area. In addition, this study introduces and assesses a new determinant of the citation impact of papers: the internationality of the journal containing the article and the internationality of the article's references. Six other common factors associating with differing citation impact introduced above are examined: journal impact, the impact of the journals containing the cited references, the number of authors, institutions, and references and the internationality of the authors. These properties were chosen as they have been significant determinants of citations in many previous studies. The research questions are as follows:

- What are the main extrinsic determinants of citation impact for papers in nanoscience and nanotechnology?
- Do the main determinants of citation impact vary over time?
- Does the degree of internationality of journals and references associate with increased citations for papers in nanoscience and nanotechnology?

## Methods

We searched for nanoscience and nanotechnology publications in the Web of Science (WoS), calculated a range of metrics for them and used regression to determine the significant variables of citation counts.

***Collecting data***

All nanoscience and nanotechnology publications published in nanoscience and nanotechnology journals listed in the Journal Citation Reports (JCR) 2007-2009 were retrieved from the Web of Science (WoS). A total of 50,162 publications was found for this search in the time period 2007-2009. Previous studies have used various strategies to find documents related to a topic, including simple term searching, keyword searching (searching several terms in the title, abstract and keywords of documents), and reference searching (Chen, 2012). These strategies are particularly suitable when no topic has been specifically devoted to the desired subject area in citation databases. Nanoscience and Nanotechnology is a specific WoS subject category and in our judgement seemed to give a reasonable coverage. The Thomson Scientific database (Formerly ISI) was used in preference to other popular citation databases, including Scopus and Google scholar, since neither Scopus nor Google scholar contains a specific subject category for nanoscience and nanotechnology. The time period 2007-2009 was selected to ensure that documents would have had enough time to be cited but would be recent enough to give relevant findings in this fast moving area.

***Outcome and predictor variables***

The outcome or criterion variable in this study is citation counts and the predictor variables are the internationality, impact and the frequency of various attributes of the papers (see Table 2).

To measure the internationality of journals, the Gini Coefficient was calculated. The internationality of a journal in a year was gauged in terms of geographic dispersion of authors publishing in the journal in the same year[2].

There are absolute and relative approaches to measure the internationality of journals (Zitt & Bassecoulard, 1998). Relative approaches try to normalize national size biases and are complicated to gauge (Zitt & Bassecoulard, 1998) but absolute approaches can employ indices, such as the Gini Coefficient, that are easily calculated. This study implements the absolute approach with the Gini Coefficient. Scientometricians have borrowed this coefficient from economics to measure the internationality of journals (He & Liu, 2009; Buela-Casal, Perakakis, Taylor, & Checa, 2006). This coefficient ranges between 0 and 1; zero is perfect equality (from one country) whilst 1 is absolute inequality (totally international). More generally, journals with a Gini coefficient close to 1 are more international, revealing that authors publishing in these journals are geographically diverse. The Gini coefficient for a journal is as follows, where N is the number of distinct countries contributing to the journal and, for the *i*th country, $X'_i$ is cumulative proportion of countries with authors contributing articles to the journal (therefore $X'_i$, = i/N), $Y'_i$ is cumulative proportion of of authors publishing in the journal from countries 1 to i, where the countries are arranged in descending order of the number of authors contributing to the journal:

$$\mathrm{G} = \left| 1 - \sum_{\mathrm{i}=1}^{\mathrm{N}} (\mathrm{X'}_{\mathrm{i}-1} - \mathrm{X'}_{\mathrm{i}})(\mathrm{Y'}_{\mathrm{i}-1} + \mathrm{Y'}_{\mathrm{i}}) \right|$$

To measure the internationality of references, we gauged the internationality of the journals of the references. The internationality of a journal was again measured in terms of the geographic dispersion of the publishing authors. The journal Gini coefficient was

[2] In previous studies, the internationality of journals has been measured in terms of the geographic variety of their authors, readers, and editorial boards (Brice & Bligh, 2004; Rey-Rocha & Martin-Sempere, 2004; Yue, 2004; Braun & Bujdoso, 1983).

calculated for each reference and an average of the Gini coefficient for all references was reported for each article in the data set. Figure 1 clearly visualizes the calculation process of the internationality of references.

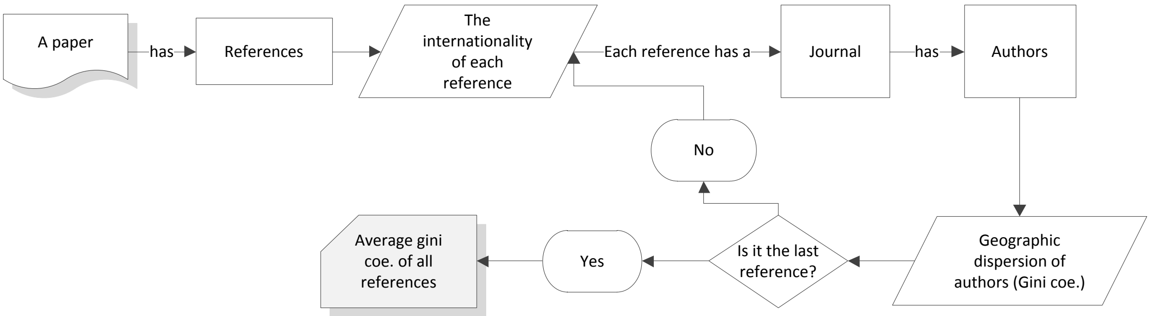


Figure 1. Calculation process of the internationality of references

To measure the internationality of authors, the number of country affiliations of the authors contributing to a paper was calculated.

The journal impact factor was used as the indicator of journal impact. To gauge the impact of the references, the average number of citations to the matched references of each paper from other WoS papers published from 2000 to 2009 was calculated. To measure the internationality and impact of references, reference matching was conducted to find the original documents in a data set of 2000 to 2009. We did not have access to data about references before 2000 so only references dated between 2000-2009 were analysed. In addition, almost half of the references were not indexed in WoS. Therefore, a number of references could not be analysed and they were ignored for references internationality and impact purposes.

***Statistical procedures***

To identify the determinants of citation impact, regression models were used since they can deal with multiple simultaneous and overlapping factors. As the outcome variable (the number of citations) is count-type data, the Poisson regression model is an appropriate type and is commonly used. The assumption behind this model is that the outcome variable is discrete count data with a Poisson distribution. Nevertheless, the Poisson model is deficient for overdispersed outcome data, where the variance exceeds the mean (Cameron & Trivedi, 2001). In contrast, negative binomial (NB) regression is a model controlling for overdispersion. Moreover, the zero inflated negative binomial regression (ZINB) controls for both overdispersion and excess of zeros in the dependent variable (Hilbe, 2007; Long, 1997). The Vuong test can be used to compare the ZINB model with the NB model to show which model fits the data best. When the z-value is significant, the Vuong test suggests using the zero-inflated model rather than the standard NB model (Vuong, 1989).

The dataset used here was found to be overdispersed. Moreover, the dataset suffers from an excess of zeros, so the zero-inflated model was used and all eight variables were included in the model. The Vuong test confirmed that the zero-inflated model was a significant improvement on the standard NB model. The results of ZINB model comprise two parts: the count model (NB model) and the logit model for predicting excess zeros. The analysis of the citation factors was conducted in four time periods (2007-2009 separately and accumulated). To examine the ZINB model for the entire three years, publication year has been included in the model as a logarithmically transformed year of publication.

## Results

The determinants of citation impact for publications in nanoscience and nanotechnology were examined in 2007, 2008 and 2009 separately and also for the three years together.

Table 3 reports the ZINB model for the effect of predictor variables on citation outcomes in 2007. The ZINB model not only identifies variables that are significant in predicting future citations but also identifies the *relative contribution* of each independent variable to the citation counts of papers. The ZINB model assumes two latent groups in the data: a "not always zero" group and "always zero" group. Essentially, for the citation model, the always zero group is a set of articles that is predicted to have zero citations, whereas the not always zero group is a set of articles (the remainder) with citations that conform to a negative binomial regression model, in which some will be predicted to receive zero citations and some will be predicted to receive more citations. The first step of the ZINB model identifies the variables that help to predict the number of citations that an article will receive and also the relative contribution of each variable to the number of citations while all other variables are kept constant. The second step of the model predicts estimates how many additional articles will have zero citations based on the first model. The results of the first step show that in 2007 the journal impact factor was a significant determinants of citations given to nanoscience and nanotechnology publications. In addition, references also associate with the citation counts of papers: impact, frequency, and internationality all significantly associated with the number of citations.

%StdX assesses the percentage change in the value of the dependent variable for a change in one standard deviation in the value of the independent variable. A positive or negative sign for %StdX implies that the higher values of the independent variable associate with increased and decreased citations, respectively. Keeping all other variables constant, the percentage change in the exponent of the x-standardized coefficient for the impact factor implies that a one standard deviation increase in the impact factor associates with a 39.1% increase in citations to papers in 2007. Moreover, a one standard deviation increase in the impact of references associates with a 34% increase in the number of citations. The number of authors, number of institutions and internationality of authors had less effect in comparison with the other significant variables. The second step of the model determines the factors that associate with zeros or the situation of no citations. As shown in Table 3, the internationality of the references, the number of authors and the journal internationality are three factors that significantly associate with zero citations. The first two also contributed, although less significantly, to an increase in non-zero citations.

The results for 2008 show that the author internationality (i.e., the degree of international collaboration) and number of authors were not found to be significant determinants of citation counts (p-value > 0.05). The journal impact factor and the impact of references are significant determinants of citations given to nanoscience and nanotechnology publications in 2008. The journal internationality and number of references also correlated with the number of citations. The number of institutions and internationality of references are two other factors that contribute marginally to increased citations to publications. The percentage change in the exponent of the x-standardized coefficient (%StdX) for impact factor implies that a one standard deviation increase in the impact factor predicted a 52.7% increase in citations to papers and a one standard deviation increase in the impact of references predicted a 35% increase in the number of citations. The second step of the model determines that journal internationality associated with zero citations to publications (i.e., a larger always 0 group) (%StdX= 32.1%) but an increased citation count (%StdX= 17.1% for the not always 0 group) (Table 4), which is opposing evidence and so the overall significance of journal internationality in this year is unclear.

In 2009, author internationality, journal internationality and number of authors are not significant determinants of citation counts of publications in nanoscience and nanotechnology (p-value> 0.05). Similar to the results of 2007 and 2008, the journal impact factor and impact of references have significant effects in the ZINB model. A one standard deviation increase in the journal impact factor and impact of references contributed to a 59.2% and 29.2% increase in citation counts of publications respectively, if the other variables were held constant (Table 5).

In the whole three years of publications in nanoscience and nanotechnology, the number of authors is not a significant determinant of citation counts (p-value> 0.05) but the other seven factors contributed to increased or decreased rates of citations given to publications. The journal impact factor and the impact of references associate with citation counts more strongly. The other two features of references - number and internationality - also contributed to increased citations; a one standard deviation increase in these two variables predicted a 19.2% and 17.3% increase in the citation counts, respectively. However, the internationality of references increased the zero citations group, and so the overall evidence of internationality of references for the full three years is unclear. The negative signs of journal and author internationality are associated with decreased citation counts (Table 6). The overall results are summarised in Table 7 in terms of significant associations rather than association strengths.

**Discussion and conclusions**

For nanoscience and nanotechnology publications in all three years both separately and cumulatively, the journal impact factor and the impact of references are the most important factors associating with citations of publications. Prestigious journals presumably receive increased attention due to a perception that they contain higher quality content. This agrees with a number of studies which also found that journal impact is the most important determinant of citations in a range of other scientific fields (Bornmann & Daniel, 2007; Kulkarni, Busse, & Shams, 2007; Boyack & Klavans, 2005; Callaham, Wears, & Weber, 2002).

Also in agreement with previous studies (Bornmann, Schier, Marx, & Daniel, 2012; Lancho-Barrantes, Guerrero-Bote, & Moya-Anegon, 2010; Boyack & Klavans, 2005), the impact of references also significantly associated with an increased number of citations to publications in nanoscience and nanotechnology. Hence nanoscience and nanotechnology articles citing high-impact works tend to be more cited. Two possible explanations for this are that papers with high impact references are citing more important works and tackling more significant problems, or that papers with high impact references are in subfields with high citation norms.

A higher number of references also correlated with higher citation counts in all three years. A higher number of citations to works with more references is expected for two reasons: first, the comprehensiveness of the paper; and second, the large size of the related field since the size of the field may affect the impact of single papers (Moed, Burger, Frankfort, & van Raan, 1985). Moreover, it has been found that a large field size will positively correlate with the impact of its publications only when the publications are characterized by a large number of references (Lovaglia, 1989).

Another feature of references - internationality - is also a significant factor of citation counts in each year and during the entire time period, but in 2007 and 2007-2009 the evidence is contradictory because more international references are also associated with a larger size for the always zero group.

The internationality of the publishing journal has previously been found to moderately correlate with the journal impact factor (Yue, 2004; Zitt & Bassecoulard, 1998) but did not contribute to increased citations to the individual papers in nanoscience and nanotechnology; this factor contributes to a decrease in citations to publications in 2007 and the whole three-year period, although the evidence is ambiguous for 2008 and 2009. Journal internationality gauges how globally widespread the journal is. Therefore, international journals in terms of their authors were expected to complement the impact factor and positively influence the citation impact of the related paper but our findings do not confirm this hypothesis. It seems possible that some national journals in nanoscience and nanotechnology, perhaps mainly in the USA, are relatively prestigious and help articles to attract citations.

The number of institutions collaborating to produce a paper also slightly associates with an increased rate of citations to publications in each year separately and in the entire examined period. A positive correlation between this factor and citations to papers has been reported in previous studies (Gazni & Didegah, 2010; Sooryamoorthy, 2009; Narin & Whitlow, 1990).

Author numbers do not clearly associate with citation counts in any of the periods studied: the results are only significant in 2007 and in this year they are contradictory. Author internationality marginally contributes to decreased citation counts in just one year (2007) and overall, perhaps because national collaboration in the large and research intensive US may be similar in character to international collaboration in Europe, creating an anomaly in the calculation of internationality. The value of individual and international team collaboration in science and technology research has been pointed out by several studies (Gazni & Didegah, 2010; Persson, 2010; Borsuk et al., 2009; Lokker et al., 2008; Kostoff, 2007; Schmoch and Schubert, 2008; Aksnes, 2003; Glänzel, 2001), but the results of this study do not concur, so nanoscience and nanotechnology may be different in this regard.

In conclusion, this study revealed that the impact of the publishing journal and references are the main extrinsic factors of the citation impact of individual papers in nanoscience and nanotechnology. The main factors examined in this study had approximately the same effects on the citation impact of publications in all four time periods. The impact of the publishing journal and references are fixed prominent factors in each year and the entire three-year period (2007-2009). Journal internationality, author numbers and author internationality are three factors whose positions changed in different time periods while the other factors had approximately the same effect. One new proposed factor, the internationality of references with respect to journals, may significantly associate with citation impact but the results were ambiguous. The other proposed factor, the internationality of a journal with respect to its authors, may also be a significant factor of citation impact, although its results seem counterintuitive since increased internationality tended to associate with fewer citations. Journal internationality could also be measured with respect to readers and editors (Yue, 2004; Zitt & Bassecoulard, 1998). In addition, the internationality of references could be gauged in terms of the geographic distribution of authors. Therefore, further studies are needed to explore the relationship between the internationality indicator measured in other ways and the citation impact of papers in nanoscience and nanotechnology.

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## Tables 1-7

Table 1. Significant determinants of citation impact based on previous studies

| Factors and sub factors | Measure/What associates with higher citation | Prior literature |
|---|---|---|
| **Impact of attributes** | | |
| Impact of journal of publication | Higher impact factor | [*The most significant factor in:* Bornmann & Daniel, 2007; Callaham, Wears, & Weber, 2002] [*But not in:* Kulkarni, Busse, & Shams, 2007; Boyack & Klavans, 2005] |
| Impact of references | Higher h-index/ Average number of citations | [*The most significant factor in:* Bornmann, Schier, Marx, & Daniel, 2012] Lancho-Barrantes, Guerrero-Bote, & Moya-Anegon, 2010; Boyack & Klavans, 2005 |
| Impact of country of affiliation | English speaking country | Leimu & Koricheva, 2005a |
| Impact of institution of affiliation | Top ranked institution in Shanghai ranking system | Leimu & Koricheva, 2005a |
| **Frequency and size of attributes** | | |
| Number of authors | More authors | Gazni & Didegah, 2010; Borsuk et al., 2009; Sooryamoorthy, 2009; Lokker et al., 2008; Kostoff, |

| | | |
|---|---|---|
| | | 2007; Glänzel, Debackere, Thijs, & Schubert, 2006; Leimu & Koricheva, 2005a&b |
| Number of references | More references | Vieira & Gomes, 2010; Webster, Jonason, & Schember, 2009; Haslam et al., 2008; Kostoff, 2007; Lokker et al., 2008; Walters, 2006; Peters & van Raan, 1994; Moed, Burger, Frankfort, & van Raan, 1985 |
| Number of countries of affiliation | More countries | Persson, 2010; Sooryamoorthy, 2009; Schmoch and Schubert, 2008; Aksnes, 2003; Glänzel, 2001; van Raan, 1998; Katz & Hicks, 1997; Narin, Stevens, & Whitlow, 1991 |
| Number of institutions of affiliation | More institutions | Gazni & Didegah, 2010; Sooryamoorthy, 2009; Narin & Whitlow, 1990 |
| Size of field | Number of publications and scientists | King, 1987; Moed, Burger, Frankfort, & van Raan, 1985 |
| **Recency of attributes** | | |
| Recency of references | Higher Price Index | Moed (1989) |
| **Type of attributes** | | |
| Type of field or topic | Physical, inorganic, & analytical chemistry (Bornmann et al, 2012); Oncology (Willis et al, 2011); Cardiovascular Medicine & Oncology (Kulkarni et al, 2007); Biomedical Research (Peters & van Raan, 1994) | Bornmann, Schier, Marx, & Daniel, 2012; Willis, Bahler, Neuberger, & Dahm, 2011; Kulkarni, Busse, & Shams, 2007; Peters & van Raan, 1994 |
| Type of document | Reviews | Amin & Mabe, 2000; Peters & van Raan, 1994 |
| Study design | Randomized Controlled Trial design | [*The most significant factor in:* Willis, Bahler, Neuberger, & Dahm, 2011; Bhandari et al., 2007] |

Table 2. Dependent and independent variables

| Variables | Measure |
|---|---|
| **Dependent variable** | |
| Citation count | |
| **Independent variables** | |
| **Internationality of properties** | |
| Internationality of author | No. of countries of affiliation |
| Internationality of publishing journal | Geographic dispersion of publishing authors using Gini Coe. |
| Internationality of references | Geographic dispersion of publishing authors of the journals of the references using Gini Coe. |
| **Impact of properties** | |
| Impact of publishing journal | Impact Factor (IF) |
| Impact of references | An average of number of citations to the cited references |
| **Number of properties** | |
| Number of authors | - |
| Number of institutions | - |
| Number of references | - |

Table 3. The results of the ZINB model for publications in 2007*

| Factor (X) | b | z | p | e^b | e^bStdX | %StdX | SDofX |
|---|---|---|---|---|---|---|---|
| Count model: Factor and percentage change in expected count for the not always 0 group. | | | | | | | |
| Journal Impact Factor | 0.108 | 44.316 | 0.000 | 1.115 | 1.391 | 39.1 | 3.044 |
| Impact of references | 0.002 | 26.561 | 0.000 | 1.002 | 1.34 | 34 | 158.46 |
| No. of references | 0.007 | 15.54 | 0.000 | 1.008 | 1.188 | 18.8 | 23.11 |
| Internationality of references | 1.320 | 17.293 | 0.000 | 3.743 | 1.182 | 18.2 | 0.127 |
| No. of authors | 0.004 | 3.329 | 0.001 | 1.004 | 1.059 | 5.9 | 13.009 |
| No. of institutions | 0.025 | 4.322 | 0.000 | 1.025 | 1.059 | 5.9 | 2.343 |
| Internationality of authors | -0.053 | -4.436 | 0.000 | 0.949 | 0.949 | 5.1 | 0.996 |
| Journal internationality | -1.217 | -13.104 | 0.000 | 0.296 | 0.893 | -10.7 | 0.093 |
| Logit model: Factor and percentage change in odds of being in the always 0 group | | | | | | | |
| Internationality of references | 2.154 | 3.999 | 0.000 | 8.62 | 1.313 | 31.3 | 0.127 |
| No. of authors | 0.019 | 2.651 | 0.008 | 1.019 | 1.279 | 27.9 | 13.009 |
| Journal internationality | 1.987 | 3.241 | 0.001 | 7.291 | 1.202 | 20.2 | 0.093 |
| Internationality of authors | -0.216 | -1.844 | 0.065 | 0.806 | 0.807 | -19.4 | 0.996 |
| No. of institutions | -0.171 | -3.884 | 0.000 | 0.843 | 0.67 | -33 | 2.343 |
| Journal Impact Factor | -0.178 | -3.447 | 0.001 | 0.837 | 0.581 | -41.9 | 3.044 |
| No. of references | -0.086 | -6.527 | 0.000 | 0.917 | 0.136 | -86.4 | 23.11 |
| Impact of references | -0.118 | -5.542 | 0.000 | 0.889 | 0 | -100 | 158.46 |
| Vuong Test = 10.51 (p=0.000) favouring ZINB over NB | | | | | | | |

*b=unstandardized coefficient; z=Z-score for test of b=0; p=significance level; e^b=X-standardized coefficient; e^bStdX=exponent of X-standardized coefficient; %StdX=percentage change in expected count for 1 SD increase in X; SDofX=standard deviation of X.

Table 4. The results of the ZINB model for publications in 2008*

| Count model: Factor and percentage change in expected count for the not always 0 group. | | | | | | | |
|---|---|---|---|---|---|---|---|
| Factor (X) | b | z | p | e^b | e^bStdX | %StdX | SDofX |
| Journal Impact Factor | 0.142 | 48.479 | 0.000 | 1.152 | 1.527 | 52.7 | 2.976 |
| Impact of references | 0.001 | 30.241 | 0.000 | 1.001 | 1.349 | 35 | 169.27 |
| Journal internationality | 1.427 | 18.705 | 0.000 | 4.167 | 1.171 | 17.1 | 0.11 |
| No. of references | 0.005 | 12.255 | 0.000 | 1.005 | 1.126 | 12.6 | 22.481 |
| No. of institutions | 0.04 | 7.163 | 0.000 | 1.041 | 1.098 | 9.9 | 2.306 |
| Internationality of references | 0.494 | 6.097 | 0.000 | 1.639 | 1.062 | 6.3 | 0.123 |
| Internationality of authors | -0.013 | -1.155 | 0.248 | 0.986 | 0.986 | -1.3 | 0.997 |
| No. of authors | -0.002 | -1.757 | 0.079 | 0.997 | 0.97 | -2.9 | 12.838 |
| Logit model: Factor and percentage change in odds of being in the always 0 group | | | | | | | |
| Journal internationality | 2.516 | 5.86 | 0.000 | 12.385 | 1.321 | 32.1 | 0.11 |
| No. of authors | 0.005 | 0.597 | 0.55 | 1.005 | 1.074 | 7.4 | 12.838 |
| Internationality of authors | 0.011 | 0.131 | 0.896 | 1.011 | 1.011 | 1.2 | 0.997 |
| No. of institutions | -0.078 | -1.94 | 0.052 | 0.924 | 0.835 | -16.5 | 2.306 |
| Impact of references | -0.006 | -2.196 | 0.028 | 0.99 | 0.36 | -64 | 169.27 |
| No. of references | -0.084 | -9.004 | 0.000 | 0.919 | 0.15 | -85 | 22.481 |
| Journal Impact Factor | -1.296 | -12.96 | 0.000 | 0.273 | 0.021 | -97.9 | 2.976 |
| Internationality of references | -0.396 | -0.82 | 0.412 | 0.672 | 0.952 | -4.8 | 0.123 |
| Vuong Test = 10.51 (p=0.000) favouring ZINB over NB | | | | | | | |

*b=unstandardized coefficient; z=Z-score for test of b=0; p=significance level; e^b=X-standardized coefficient; e^bStdX=exponent of X-standardized coefficient; %StdX=percentage change in expected count for 1 SD increase in X; SDofX=standard deviation of X.

Table 5. The results of the ZINB model for publications in 2009*

| Count model: Factor and percentage change in expected count for the not always 0 group. | | | | | | | |
|---|---|---|---|---|---|---|---|
| Factor (X) | b | z | p | e^b | e^bStdX | %StdX | SDofX |
| Journal Impact Factor | 0.133 | 37.039 | 0.000 | 1.142 | 1.592 | 59.2 | 3.501 |
| Impact of references | 0.001 | 23.849 | 0.000 | 1.001 | 1.293 | 29.2 | 214.723 |
| Internationality of references | 1.019 | 10.287 | 0.000 | 2.77 | 1.137 | 13.7 | 0.126 |
| No. of references | 0.005 | 10.317 | 0.000 | 1.005 | 1.121 | 12.1 | 23.735 |
| No. of institutions | 0.024 | 3.981 | 0.000 | 1.025 | 1.061 | 6.1 | 2.436 |
| Journal internationality | 0.006 | 0.068 | 0.946 | 1.006 | 1.001 | 0.1 | 0.112 |
| No. of authors | 0.000 | -0.141 | 0.888 | 1 | 0.998 | -0.3 | 13.694 |
| Internationality of authors | -0.008 | -0.635 | 0.525 | 0.992 | 0.992 | -0.8 | 1.021 |
| Logit model: Factor and percentage change in odds of being in the always 0 group | | | | | | | |
| No. of authors | 0.016 | 1.184 | 0.236 | 1.016 | 1.241 | 24.1 | 13.694 |
| Journal internationality | 0.791 | 1.566 | 0.117 | 2.205 | 1.093 | 9.3 | 0.112 |
| Internationality of references | -0.028 | -0.056 | 0.956 | 0.972 | 0.996 | -0.4 | 0.126 |
| Internationality of authors | -0.029 | -0.301 | 0.764 | 0.972 | 0.971 | -2.9 | 1.021 |
| No. of institutions | -0.16 | -3.32 | 0.001 | 0.852 | 0.678 | -32.2 | 2.436 |
| No. of references | -0.03 | -4.248 | 0.000 | 0.971 | 0.494 | -50.6 | 23.735 |
| Journal Impact Factor | -0.634 | -10.43 | 0.000 | 0.53 | 0.109 | -89.1 | 3.501 |
| Impact of references | -0.017 | -4.353 | 0.000 | 0.983 | 0.027 | -97.3 | 214.723 |
| Vuong Test = 10.51 (p=0.000) favouring ZINB over NB | | | | | | | |

*b=unstandardized coefficient; z=Z-score for test of b=0; p=significance level; e^b=X-standardized coefficient; e^bStdX=exponent of X-standardized coefficient; %StdX=percentage change in expected count for 1 SD increase in X; SDofX=standard deviation of X.

Table 6. The results of the ZINB model for publications in 2007-2009*

| Factor (X) | b | z | p | e^b | e^bStdX | %StdX | SDofX |
|---|---|---|---|---|---|---|---|
| **Count model: Factor and percentage change in expected count for the not always 0 group.** | | | | | | | |
| Journal Impact Factor | 0.103 | 58.706 | 0.000 | 1.109 | 1.3955 | 39.5 | 3.2218 |
| Impact of references | 0.001 | 31.9 | 0.000 | 1.0013 | 1.2653 | 26.5 | 185.0936 |
| No. of references | 0.007 | 23.595 | 0.000 | 1.0076 | 1.1915 | 19.2 | 23.1448 |
| Internationality of references | 1.275 | 23.189 | 0.000 | 3.5811 | 1.1735 | 17.3 | 0.1254 |
| No. of institutions | 0.028 | 7.304 | 0.000 | 1.0286 | 1.0691 | 6.9 | 2.3656 |
| No. of authors | 0.001 | 1.334 | 0.182 | 1.0012 | 1.0153 | 1.5 | 13.2082 |
| Journal internationality | -0.231 | -4.021 | 0.000 | 0.793 | 0.9755 | -2.4 | 0.1068 |
| Internationality of authors | -0.037 | -4.637 | 0.000 | 0.9633 | 0.9631 | -3.7 | 1.0057 |
| **Logit model: Factor and percentage change in odds of being in the always 0 group** | | | | | | | |
| Journal internationality | 1.674 | 5.146 | 0.000 | 5.338 | 1.195 | 19.6 | 0.106 |
| Internationality of references | 1.332 | 4 | 0.000 | 3.792 | 1.181 | 11.2 | 0.125 |
| No. of authors | 0.007 | 1.488 | 0.137 | 1.007 | 1.1 | 10.9 | 13.208 |
| Internationality of authors | -0.028 | -0.434 | 0.664 | 0.971 | 0.971 | -2.9 | 1.005 |
| No. of institutions | -0.147 | -5.24 | 0.000 | 0.862 | 0.705 | -29.5 | 2.365 |
| Journal Impact Factor | -0.511 | -8.583 | 0.000 | 0.599 | 0.192 | -80.8 | 3.221 |
| No. of references | -0.083 | -11.43 | 0.000 | 0.919 | 0.144 | -85.5 | 23.144 |
| Impact of references | -0.039 | -5.492 | 0.000 | 0.961 | 0.0007 | -99.9 | 185.093 |
| Vuong Test = 10.51 (p=0.000) favouring ZINB over NB | | | | | | | |

*b=unstandardized coefficient; z=Z-score for test of b=0; p=significance level; e^b=X-standardized coefficient; e^bStdX=exponent of X-standardized coefficient; %StdX=percentage change in expected count for 1 SD increase in X; SDofX=standard deviation of X.

Table 7. Summary of the results of the ZINB model for all time intervals examined. Subject to the more detailed explanations below, + indicates higher overall citations associated with the factor and – associates with lower overall citations being associated with the factor.

| Factor (X)* | 2007 | 2008 | 2009 | 2007-2009 |
|---|---|---|---|---|
| Journal Impact Factor | ++ | ++ | ++ | ++ |
| Impact of references | ++ | ++ | ++ | ++ |
| No. of references | ++ | ++ | ++ | ++ |
| Internationality of references | +- | +. | +. | +- |
| No. of institutions | ++ | +. | ++ | ++ |
| No. of authors | +- | .. | .. | .. |
| Journal internationality | -- | +- | .. | -- |
| Internationality of authors | -. | .. | .. | -. |

*+ on the left indicates that higher citation counts are associated with higher X values; a + on the right indicates *fewer* members of the always zero group are associated with higher X values.
– indicates the opposite of + in both cases
. indicates that the association is not significant