Open Access to Scientific Literature – Increasing Citations as an Incentive for Authors to Make their Publications Freely Accessible

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Abstract

In recent years the scientific journal market faces significant evolutions that may cause major changes in the way of publishing research results. In this connection, open access is the prime alternative to publishing in traditional journals, whose subscription-based business model inhibits the distribution of scientific knowledge. But despite strong support for open access among researchers, today this new paradigm is realized only in a few disciplines. A main reason for this lies in the lack of individual incentives for authors to make their publications freely accessible. In this paper we focus on the argument that open access articles are cited more often than articles in traditional journals. Based on a simulation of the citation network, which emerges on the scientific publishing market, we demonstrate how an individual author can increase her citations, and thus her standing in the community, when switching to open access. Especially first movers may benefit from the change of their publication behavior.

1. Introduction

The market of scientific publishing faces several forces that may cause a major change in the way research findings are distributed among scientists. First, the increase in digitalization brought a shift towards electronic publication, and second, shrinking library budgets in combination with a constant rise of journal prices result in massive cancellations of journal subscriptions (the so called "serials crisis") [1, 2]. In order to regain broad access to research findings, alternative ways of publishing scientific literature have been developed and receive increasing attention. These new models are summarized under the term "Open Access" [3].

In 2001 the Budapest Open Access Initiative (BOAI) formulated the initial definition of the new paradigm, which is today broadly accepted: "The literature that should be freely accessible online is that which scholars give to the world without expectation of payment. (…) By "open access" to this literature, we mean its free availability on the public internet, permitting any users to read, download, copy, distribute, print, search, or link to the full texts of these articles, crawl them for indexing, pass them as data to software, or use them for any other lawful purpose, without financial, legal, or technical barriers other than those inseparable from gaining access to the internet itself" [4].

Two main approaches of realizing open access in terms of this definition have emerged [5, 6]. On the one hand, new open access journals are brought to being, either through transformation of traditional journals or through creation of new titles. This approach is referred to as the "Golden Road to Open Access". The Gold model bases on the traditional publication system, but shifts the financial model of a journal: Instead of generating revenues through subscription fees, an author (or sponsor) pays to publish the article, which in turn is made freely accessible. On the other hand, authors may self-archive their articles in institutional or subject-based repositories, a model referred to as the "Green Road to Open Access". In the simulation model presented in this paper we focus mainly on this Green model.

The realization of the open access paradigm differs between research disciplines. The prime example of an adoption of open access is arXiv.org, a subject-based repository, which is primarily used by physicists and mathematicians. Researchers in these "open access communities" self-archive their articles on the arXiv server (so that everyone has free access to their work), and often additionally submit the papers to regular peer-reviewed journals [7]. In contrast, the majority of scientists from other disciplines do not make use of (green or gold) open access publishing, even though most of them strongly support this paradigm and recognize the advantages of open access in terms of a rapid and wide dissemination of new findings [8, 9, 10]. Obviously there is a lack of incentives for authors to switch their behavior from traditional publishing to open access.

Our research aim is twofold: First, based on the interactions between scientists, journals, and libraries, we develop a computational model of the traditional scientific publishing market which we use to simulate the emergence of complex citation networks. Second, against the background of empirical evidence that open access articles are cited more often than articles published only in traditional journals, we focus on the research question, which effect a change in publication strategy has for a scientist in a "non-open access community". In particular, with the use of the citation network simulation, we show how an individual author can increase her citation count, and thus her standing in the community, when switching to open access.

The remainder of the paper is structured as follows. In section 2 a literature overview is given with the focus firstly on approaches to answer the question why scientists balk open access models, and secondly on empirical studies concerning the effect of open access on the citation impact of research articles. In section 3 we characterize citation networks and describe the role of "preferential attachment" in regard of the network evolution. Section 4 presents the simulation model and in section 5 the simulation results are depicted. The paper ends with an interpretation of the findings in section 6.

2. Related Literature

2.1. Why authors face a lack of incentives to make open access

As stated above, despite the high level of support, the realization of open access in most disciplines is rather low. In literature, little is known about the reason of this discrepancy. In the following we will describe two recent approaches, which aim to reveal the deeper causes of the lack of incentives to perform open access. Mann et al. (2008) built a survey based on the Unified Theory of Acceptance and Use of Technology (UTAUT), which aimed on finding out the determinants of the intention of authors to use open access models (here seen as a "new technology") [10]. 481 scientists from the disciplines Information Systems, German Literature, and Medical Science were included in the analysis. Besides of the attitude towards open access, Mann et al. identified two other constructs, which are important in regard of the author's decision whether to use open access or not: expected performance of open access and peer use. Particularly the latter is of interest, because it reveals that scientists exhibit a "wait-and-see behavior" and intend to make open access not until enough other researchers in the same field do so.

In regard to this critical mass problem, the approach by Hanauske et al. (2007) is also of interest [11]. The authors use a game theoretical model to describe the paradoxical situation of non-open access communities in which, on the one hand scientists realize that they would benefit, if all players adopt open access, but on the other hand no player has an individual incentive to change. Starting from a general 2-players-game, where two authors have to decide whether they perform open access or not, different possible game settings are developed, which all lead to the same result: Although the payoff (more precisely the reputation) for both players would be higher, if they both choose the open access strategy, they are stuck within the Nash equilibrium of traditional publishing. The situation is similar to the well-known prisoner's dilemma game. If in a non-open access community (where reputation is primarily gained by publishing in top journals, which prohibit open access to their articles) only one of the two players switches to the open access strategy, she looses her reputation to the second player. Thus the dominant strategy is to "wait-and-see".

2.2. The effect of open access on citation impact

A main argument of open access advocates is that freely accessible scientific papers are cited more often in comparison to articles published only in traditional non-open access journals [12, 13]. In this connection, several authors have studied this influence of open access on the citation impact – most of them found a positive correlation. Lawrence (2001) investigated the citation impact of conference articles in computer science and reported higher citation rates for open access texts compared to non-open access articles [14]. Similar findings have been reported by Odlyzko (2002) in mathematics [15] and Kurtz et al. (2005) in astrophysics [16, 17]. Harnad and colleagues (2004, 2005) used a twelve-year sample including 14 million papers in the Institute for Scientific Information (ISI) database to measure the impact of open access articles across all disciplines and across time. Their findings reveal a citation advantage of open access articles for all fields [18, 19].

Later research has focused on the reasons of this open access citation advantage. Three postulates have been proposed to cause citation differences between open access and non-open access papers [20]. The "Open Access Postulate" simply suggests that open access articles are cited more often because they are more likely to be read. The "Early View Postulate" refers only to the Green model of open access, where an article is posted in a repository before it is finally published in a journal. The period between the archiving of the article and the appearance in the journal thus allows for earlier citation. Furthermore, the "Selection Bias Postulate" suggests that the most influential authors are more likely to make their work freely accessible, and that they are more likely to do so with their most important/citable articles. In other words, within the group of open access articles, high quality work may be overrepresented.

3. Characteristics of scientific citation networks

A main goal of academic research is the diffusion of new research results. This is achieved by interaction between scientists in terms of reading and citing other authors' work. In doing so, complex citation networks emerge, on which we focus in the following.

3.1. Structure of the network

In a citation network the vertices represent the articles, whereas the edges between the vertices depict the citations from one article by another. The following characteristics are typical for citation networks and differentiate them from other networks like the WWW or co-authorship networks [21]:

- the edges of the network are *directed*,
- the network *evolves* over time, meaning with every new article published, a new vertex (together with the corresponding link) is added to the network (therefore citation networks underlie a constant growth),
- the network is *acyclic* (there are no loops), because a new article can only cite previously existing articles/vertices (citations of forthcoming papers are rare and therefore negligible).

Figure 1 schematizes the citation network with inclusion of the vertex types „journals" and „authors", which in turn are assigned to specific articles. Some journals and authors are displayed with a "closed edge", which starts and ends in the same vertex. These edges represent self-cites. For the purpose of clarity, conference papers are not explicitly displayed in this scheme. They can be subsumed under the vertex type "journals".

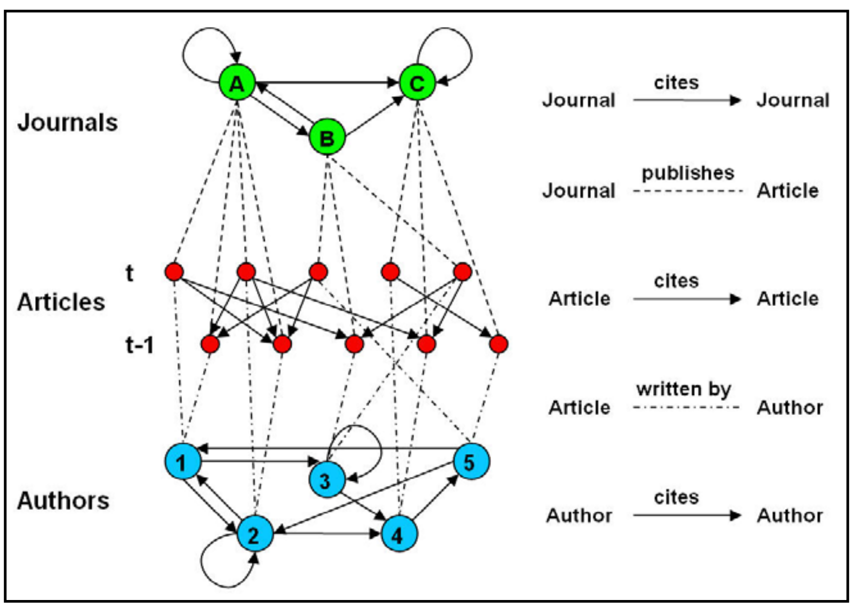

Figure 1 Schematic structure of a citation network with the vertex types "journals", "articles", and "authors".

3.2. Empirical findings concerning the distribution function of citation networks

Within the scope of the analysis of real citation networks, several authors independently found a typical form of the citation distribution [22, 23, 24]. Figure 2 depicts the findings of Redner (1998), who investigated two different citation networks, namely 783,339 papers listed in the ISI database in 1981 and cited between 1981-1997, and 24,296 papers which were published in volumes 11 through 50 in the journal Physical Review D. What is remarkable is the asymptotic "long tail" of the citation distribution, which is caused by the fact that the majority of articles is cited only once or not at all, whereas only few papers are cited frequently.

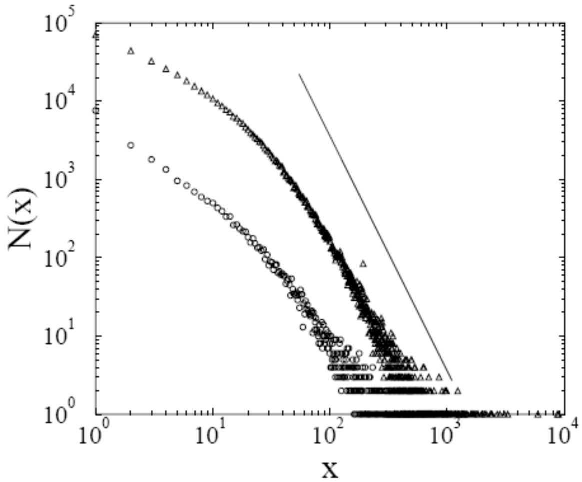

Figure 2 Citation distribution of two real citation networks (∆= ISI database, o= Physical Review D) in double logarithmical representation; with x = number of citations, and N(x) = number of articles with x citations. [22]

Although the distribution functions of different citation networks look almost the same, scholars differ in interpreting the exact analytical expression of the function. However, they agree with each other in the point that a large part of the citation distribution (particularly the asymptotic tail) can be described by a power-law of the form $N(x) \sim x^{-\alpha}$. Redner found a best fit value for exponent α close to 3. Thus, for visual reference, a straight line of slope -3 is also displayed in figure 2 [22].

3.3. The mechanism of Preferential Attachment

During the evolution of the network the mechanism of "preferential attachment" plays a critical role. This dynamic phenomenon was for the fist time introduced under the name "Matthew effect" by sociologist Robert K. Merton in the year 1968 [25]. Based on a quote in the biblical Gospel of Matthew ("For unto every one that hath shall be given, and he shall have abundance: but from him that hath not shall be taken away even that which he hath") Merton described the effect that an eminent scientist will usually get more credit for the similar work than a comparatively unknown researcher.

Applied to a network, the phenomenon that "the rich get richer and the poor get poorer" means that a new vertex will be linked with a higher probability to those existing vertices, which already have many ingoing edges [26]. In other words, an article which has, at a particular time t, more citations than a comparable article in the network, also has a higher probability to get cited again in the future. Cole and Cole (1973) denote this characteristic of literature networks as "cumulative advantage" [27].

The emergence of power-law networks based on the mechanism of preferential attachment was primarily modelled by the physicists Barabasi and Albert (1999) [28]. They described how in a growing network a power-law degree distribution emerges, when new vertices/actors who enter the network prefer to relate to those existing vertices, which already have a high degree of ingoing edges. As Pujol et al. (2005) point out, the model of Barabasi and Albert (and the wide range of subsequent models, which were inspired by their work) has mainly been formulated in the tradition of network theories based on graph theoretic concepts. They consider the individual agent as a mindless actor ("node") in the game and disregard the explanation of the emergence of power-law structures as a consequence of plausible sociological microprocesses [29]. In the simulation model presented below, preferential attachment is not explicitly modelled, but results indirectly from the behaviour of the individual agents, which – in contrast to the models described above – do not have complete information about the structure of the whole network.

4. Simulation model

In the following our model for investigating citation networks will be introduced. The simulation program, written in Java and executable as a Java applet, integrates the actors on the scientific publishing market (scientists, libraries, publishers/journals) and the interactions within and between these groups. Market coordinating mechanisms are the reputation of scientists and journals as well as the journals' price and usage (how often do scientists read articles of a specific journal?).

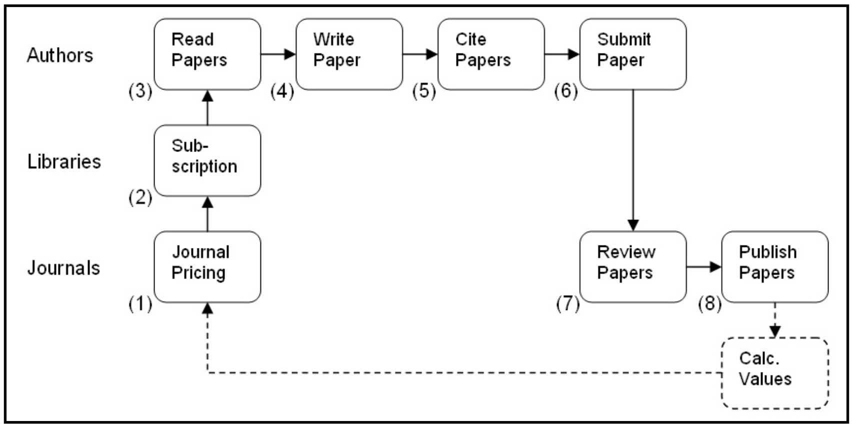

Figure 3 Simulation phases

Figure 3 depicts the phases, which are run through during one simulation period. At the start of a simulation period the publishers set the price of their journals (1). In this regard they can choose between different pricing strategies subject to the changes in the number of subscriptions to their journals (e.g., constant price increase over time, price decrease if subscriptions decrease, or price increase when journal subscriptions drop). The Libraries have a fixed budget per period, which they can use to subscribe to journals (2). In this context, it can also be specified, whether this budget is constant, decreases, or increases over time. No distinction is made between print and online journals.

At the authors' level the production process of a new article starts with reading a specific number of papers (3). In this connection, we assume that authors can only read those articles, which are published in a journal licensed by the author's library, or which are archived in an open access repository. The latter alternative comes into play, when we split the author group into traditional authors and open access authors, which self-archive their papers simultaneously to the publication in a journal (see next chapter). Furthermore, we proceed on the assumption that, when selecting articles for reading, authors mainly resort to journals with a relatively high reputation (i.e., which are publishing high quality papers).

The quality of a new written article varies from author to author (4). In the simulation model this is implemented by using a stochastic process based on a geometric Brownian motion, which determines the qualities of the articles of an author over time. Every author writes one article per period, so that the article network (and in consequence the citation network) grows constantly over time.

In the citation phase the author cites a specific number of papers from the current period as well as papers she has read in past periods (5). The probability of an article to be cited decreases with the age and increases with the number of citations the article has received in the past (preferential attachment). The last phase at the authors' level is the submission of the new paper to an appropriate journal (6). The decision where to submit depends firstly on the relation between the quality of the article and the average quality of the articles published in a specific journal, and secondly on the expected gain in reputation if the article is accepted.

Subsequently the review phase starts (7) and the journals accept a given number of articles, which then are immediately published (8). At this point, in order to avoid too much technical complexity of the simulation program, the following assumptions are made: the review process is accomplished within one period, the accepted articles are published in the period of acceptance, and rejected articles can not be resubmitted. If the number of submitted articles is higher than the acceptance capacity, the journal selects those articles with the highest quality until the actual issue is complete. At the end of a period the new values (cites per author and journal, reputation/quality of authors and journals, journal usage, etc.) are calculated and forwarded into the next simulation period.

5. Results

5.1. Parameter setting and validation

The following findings base upon simulation runs with 200 authors, 9 journals (which publish up to 10 papers per period/issue), and 3 libraries. The simulation duration is 100 periods. Assuming a journal publishes six issues per year, within this setting approximately 16 years would be simulated. It is further assumed that all authors cite exactly 10 papers out of the network when writing a new article.

In period t=20, 25 authors switch to the open access strategy, meaning they deposit their papers (no matter if accepted by a journal or not) additionally in a repository, to which all authors in the network have unrestricted access.

Moreover, the library budget is stated as constantly decreasing (1% per period) and the pricing strategy of the publishers is set in such a way that the journal price varies dependent on the subscriptions to the journal (price decrease when subscriptions decrease, otherwise constant price increase). Here it has to be remarked that today in reality decreasing journal prices are rarely observable. Most of the publishers increase the prices of their journals if the subscriptions drop, in order to maintain their distribution margin [30]. But if choosing this economically questionable strategy for the simulation, it gets obvious that in connection with decreasing library budgets this strategy always leads to a collapse of the system in the long term: all subscriptions are cancelled until only one journal survives.

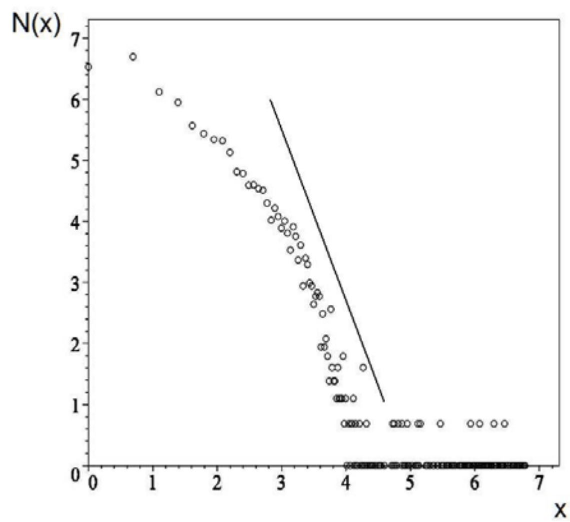

Figure 4 Distribution of the citation network evolving during the simulation; double logarithmical representation with x = number of citations and N(x) = number of articles with x citations; for visual reference a straight line of slope -3 is also shown.

The configuration described above results in a typical citation distribution as depicted in figure 4. Compared to the distribution of real citation networks (see figure 2), it can be stated that the simulation outcome reflects the empirical data very good (the structure of the evolving citation network depends only marginally on the inclusion of the open access authors, therefore the comparison with the empirical data, where no differentiation between free and toll-access papers is made, is valid). Especially, the asymptotic tail of the distribution shows the typical power-law characteristics with exponent α close to 3.

5.2. Effect of open access on the author's rank in the citation network

Focussing on the initially raised research question, how open access affects the standing of authors in their community, the view has to be changed from "citations per paper" to "citations per author". By cumulating the citations to the articles an author has published over the simulation time, a citation ranking can be generated. The more citations an author collects in comparison to her colleagues, the higher is her rank (with 1 as the highest rank). Similar to the citation distribution on the article level, a typical "long tail" distribution can be observed when plotting the ranked authors against the cumulated number of citations (see figure 5). A few authors collect most of the citations, whereas the majority of authors is seldom cited. The longer the simulation runs, the more obvious this structure becomes.

The upper diagram in figure 5 shows the citation distribution for the authors at simulation period t=20. At this point 12.5% of the authors switch their strategy from traditional publishing to open access. These authors (in the diagram marked with circles) are selected randomly, so that the mean rank of this group is 100. As the simulation continues, the citation network grows and the long tail distribution becomes more and more evident. The reason for this lies again in the mechanism of preferential attachment: If one author has more citations than another, the probability that she gets cited again is also higher.

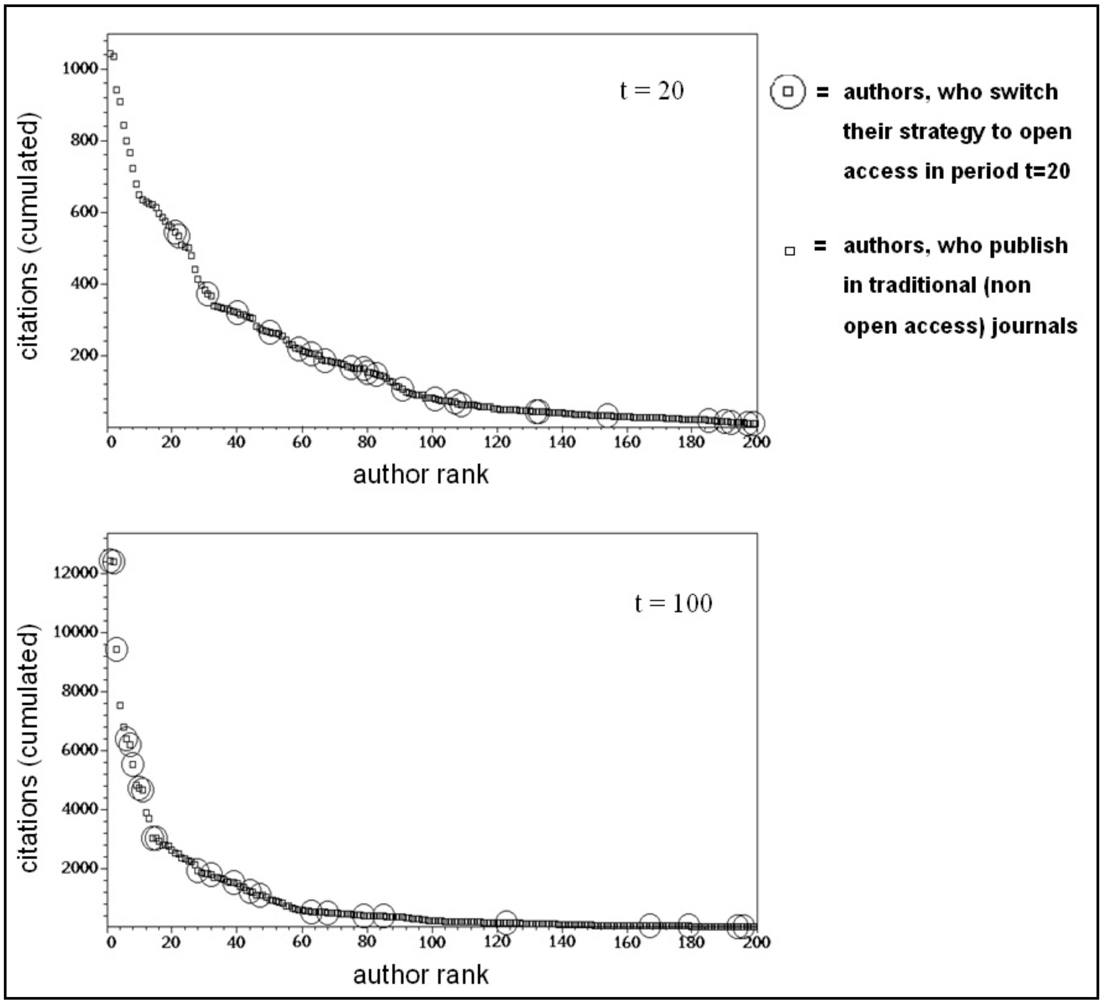

Figure 5 Evolution of the author citation ranking over time in a typical simulation run. Compared to authors, which publish only in traditional journals, authors, which switch their strategy to open access publishing in period t=20 (upper diagram) are cited more often and improve their position in the community (lower diagram: t=100) – their average citation rank changes from 100 (at time t=20) to 68 at the end of the simulation.

The lower diagram in figure 5 depicts the situation at the end of the simulation. It is obvious that most of the open access authors have improved their rank significantly (illustrated by the greater number of circles in the upper ranks near the y-axis). Within the framework of the used simulation specification, the group of open access authors increased their average rank from 100 in period t=20 to 68 at the end of the simulation (average values of 50 simulation runs). Some open access authors even manage to escape from the bottom of the long tail – one also can say that they escape from "scientific invisibility".

In a final step, we want to relate the simulation results to the causes of an open access citation advantage proposed in literature (see section 2.2). First, it can be stated that the increase in citations of open access papers in our simulation does not base on an "Early View Advantage". On the one hand, we assume an accepted article to be published immediately in the period of acceptance, on the other hand, self-archiving is implemented in such a way that the publication in a journal and the archiving of the article (if written by an author belonging to the open access group) also fall into the same period. Thus open access authors cannot benefit from earlier citations to their articles. Furthermore, the "Selection Bias Postulate" (suggesting that the best authors are more likely to make their articles available under an open access model, and that they are more likely to do so with their best work) is not directly implemented in the model.

The quality of an author (or more precisely, the evolution of the quality of her articles over time) is modelled as a stochastic element, and the selection of those authors, which switch their strategy to open access, is also completely randomized. Therefore, high quality work is not overrepresented in the open access repository.

In our model individual authors' access to journals is a driving force behind the open access citation advantage. During the simulation, the pressure of increasing journal prices provokes the libraries to cancel journals. If an author wants to read a paper published in a journal, which is at that time cancelled by her library, she can only do so, if the paper is written by an author belonging to the open access group, who deposits the paper simultaneously in the open access repository. Hence, the generally formulated "Open Access Postulate", which suggests that authors are more likely to read (and thus cite) open access articles, is supported by the simulation results. In combination with the mechanism of preferential attachment, it can lead to a significant improvement of the standing of authors, which make their work freely accessible. This applies particularly for scientific communities, where the majority of papers is published under the traditional model.

6. Conclusion

The goal of this paper was to investigate the effects of open access on the standing of an individual author in her community. First we developed a computational model of the traditional scientific publishing market, which we used to simulate the emergence of a citation network. Second, we used the simulation program to show how an individual author can increase her citation count by switching to an open access strategy. In this regard, we widened the scope from the article level to an author view, in order to make the potential benefits of open access more visible to scholars.

The results of the simulation support the empirical data regarding the increase in citations of articles, which are published under the open access paradigm. Especially in non-open access communities unrestricted access to her scientific work can broaden a scientist's impact – at least in terms of increasing citations. In this connection we want to point out, that besides of "access" to scientific work, the quality of a paper/ an author is an important determinant of the citation count. We agree with Craig et al. (2007), who argue that "the overriding determinant of lifetime citations of an article is the quality, importance, and relevance of the work reported in the article" [20]. Nevertheless, if two authors who produce articles of the same quality, the author who makes her work available under an open access model, is likely to receive more citations. Open access articles are downloaded/read more frequently than articles in traditional journals. The fact that downloads correlate with citations was for example empirically proven by Brody et al. (2006) who found a correlation of about 0.4 for an area of physics [31].

As explained in chapter 2.1, the majority of scientists have a positive attitude towards open access, but also face a lack of incentives to publish their papers in terms of these new models. Based on the simulation findings, which show that the higher visibility of open access articles in combination with the mechanism of preferential attachment can result in an increase of a scientist's standing in her community, we want to encourage authors to take advantage of this by making their articles freely accessible. This advantage over their colleagues certainly disappears, when all authors switch to open access, but because in most disciplines this is not to be expected in the medium term, "first movers" can benefit in the transition period.

Finally, it has to be remarked that an increase in citations is not automatically an increase in reputation. In many disciplines citation statistics of a specific author are rather irrelevant in terms of evaluation – instead, the focus is on the impact factors of the journals an author publishes in. From our point of view, both the impact/quality of the journals an author publishes in and the direct citations of her work should be taken into account when measuring the reputation of a scientist. This would clearly support the realization of the open access paradigm.

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