Persistence of journal hierarchy in open access publishing

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Abstract
The recently proposed *Plan S* envisions a shift to an academic publishing system that is fully open access. The plan has led to heated debates on many aspects of academic publishing. There are for example concerns that high-quality journals will no longer be viable. The argument is typically that journals can increase their profits by lowering their quality standards. We here investigate this argument by analysing a simple model of the publishing system. We find that journals continue to have an incentive to maintain a certain quality in order to attract more submissions. Hence, a distinctive journal hierarchy persists, even if article processing charges (APCs) are capped to a maximum. Nevertheless, a cap on APCs may have significant consequences. The lower the cap, the smaller the quality differences between journals.

Introduction
Open access has been on the rise for quite some years. Recently, eleven European research funding agencies proposed *Plan S*[i], in which they announce that all research they fund should be published in open access journals, and more funding agencies have joined since. Plan S does not allow publishing in hybrid journals, which combine an open access model and a subscription model, except for a transitionary period. This raised concerns about the continuing existence of high-quality journals, and academic society-owned journals in particular. For example, the Global Young Academy (2018) argued that in a negative scenario “there is a strong profit incentive for publishers to favour quantity over quality”. Similarly, a number of scholars claimed that Plan S “stimulate[s] accepting as many papers as possible—regardless of their quality” (Research Community, 2018). Other academic societies argued that Plan S “actually incentivizes publishers to go after more and more papers” (Brainard, 2019).

We here focus on the possibility of dwindling qualities of journals as a result of Plan S. Many other issues from Plan S are being debated, such as the issue of copyright, the effect on scientific careers for young scholars, the access to publishing for poorer nations and the claimed restrictions on academic freedom. We do not address these issues here, although they should of course play a role in the discussion on Plan S.

We propose a relatively simple model of open access publishing, which is sufficiently realistic to be useful. We restrict ourselves to open access publishing in which authors need to make a payment to publish their article, commonly called an article processing charge (APC). This form of open access publishing is often referred to as gold open access. Other options, such as self-archiving, sometimes referred to as green open access, or open access journals without APCs, sometimes referred to as platina open access, will have different dynamics. We believe our model is useful in sharpening the ideas about possible consequences and effects of Plan S. We first introduce the model, then show some dynamics and outcomes of the model, and finally discuss the implications for Plan S.

Model
Let there be n different journals 1, ..., n, each with an associated quality threshold q_j. We assume there are N articles, and the quality of each article is drawn from some distribution. Authors benefit from publishing their articles in high-quality journals, and they therefore try to publish in these journals. However, different authors have different perceptions of the quality of journals. For each article, the author of the article assesses the quality of each of the

n journals in which he or she could try to publish the article. An author's perceived quality u_j of journal j equals

$$u_j = \beta q_j + \epsilon_j,$$

where all ϵ_j are assumed to be independently distributed according to the Gumbel distribution, for which $\Pr(\epsilon_j > s) = e^{-e^{-s}}$. An author will first submit his or her article to the journal j with the highest perceived quality u_j. The probability that journal j has the highest perceived quality u_j is a standard result in discrete choice theory (Anderson, Palma, & Thisse, 1992). This probability equals

$$\frac{e^{\beta q_j}}{\sum_{i=1}^{n} e^{\beta q_i}}.$$

If an article is rejected by this journal, it will be submitted to the journal k with the next-highest perceived quality u_k, and so on. We can again work out the probability that an article will be submitted to journal k after it has been rejected by some other journal j. For $\beta = 0$, journal quality effectively does not play a role in the order in which authors submit their articles to different journals. For $\beta \to \infty$, authors always submit in the order of decreasing journal quality.

When an article is submitted to journal j, the journal accepts the article if the article quality is above the threshold q_j. Generally, the probability that an article has a quality higher than q_j is $\Pr(Q > q_j)$, where Q is the random variable denoting the quality of an article. We assume that $Q \sim \text{LogNormal}(-\frac{1}{2}, 1)$, so that the average Q is 1.

In a system of gold APC-based open access publishing, the expected total revenue of a journal j is simply the expected number of accepted articles $E(A_j)$ times the APC charged by the journal. Following suggestions made in Plan S, we assume that a cap is imposed on APCs. Since APCs are paid by research funders, not by individual authors, each journal will have an incentive to set its APC equal to this cap. We therefore assume that each journal has the same APC. This APC equals the cap. The total expected revenue of a journal is then equal to $\text{APC} \cdot E(A_j)$. We assume that the cost of running a journal consists of some fixed costs c_f, some variable cost c_s that scale with the number of submissions, and variables costs c_a that scale with the number of accepted articles. These costs are all independent of the quality threshold q_j. The expected profit is then

$$E(X_j) = \text{APC} \cdot E(A_j) - c_f - c_s \cdot E(N_j) - c_a \cdot E(n_a)$$

It is possible to calculate for each journal j the expected number of submitted articles $E(N_j)$ and the expected number of accepted articles $E(A_j)$ (i.e. published articles). We do not include these calculations here for reasons of brevity.

Quality evolution

We assume that journals are focused on maximizing their profit. Each journal adjusts its quality threshold q_j in order to increase its expected profit. We consider it unrealistic to assume that the quality threshold can be set to an arbitrary level. There is a high degree of inertia in the journal system, and authors are likely to respond to realized quality, rather than the quality threshold q_j. In order to model this, we assume that a journal is only able to slightly adjust its quality threshold. In particular, we assume that a journal adjusts its quality threshold q_j according to the gradient of the profit

$$\frac{\partial E(X_j)}{\partial q_j}.$$

We again do not include the calculations here for reasons of brevity.

One may object that journals are not purely driven by profit. Some journals may have an intrinsic drive to uphold a certain quality, simply to contribute to high-quality science. Of course, such an intrinsic drive will be easier to uphold when it is aligned with pressure exerted by considerations of profitability. Hence, even though we acknowledge the existence of such an intrinsic desire for quality, we believe that for many journals it will be difficult to sustain a certain quality on the sole basis of this motivation in the setting of gold APC-based open access. Academic publishing is a market with high profit margins and clear commercial interests, which are unlikely to play only a minor role. Moreover, exactly because of the high degree of inertia mentioned above, and the vested interests many researchers have in publishing in leading journals that are often owned by commercial parties, it is likely that commercial considerations will continue to exert considerable pressure on journals.

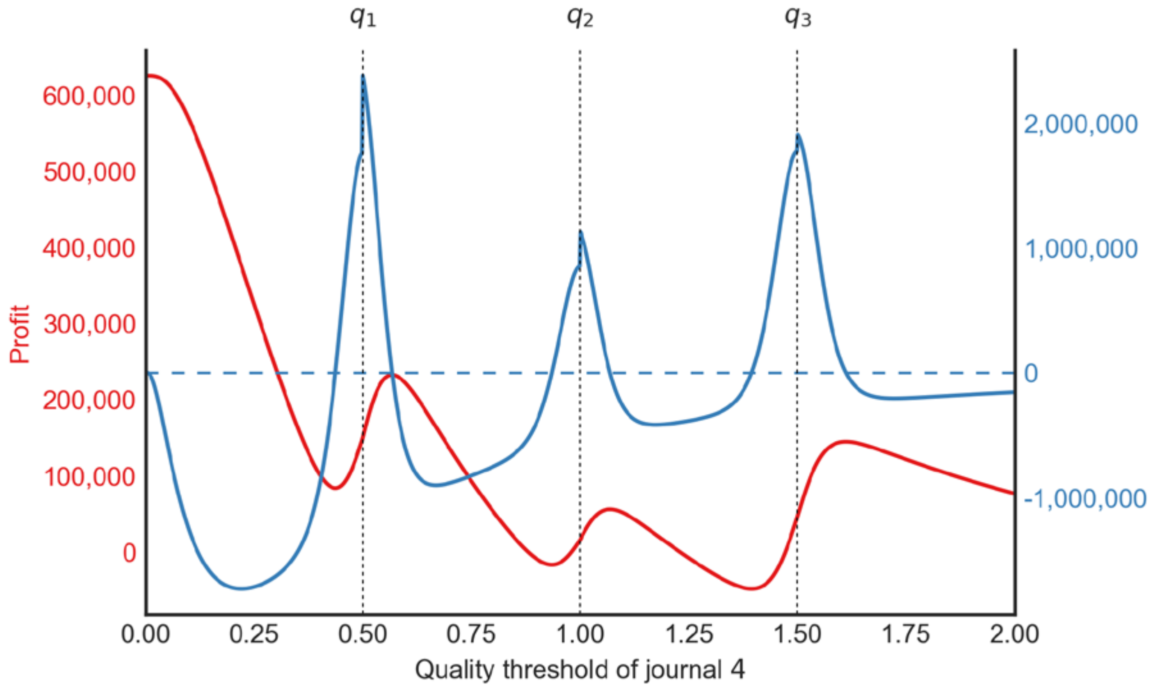

Figure 1. Profit versus quality threshold. The figure shows the profit of journal 4 for a certain quality threshold (in red), given the quality thresholds of three other journals. It also shows the rate of change of the profit for a certain quality threshold (in blue). We set APC = $\mathbf{2000}$, $\boldsymbol{c_f = 10000}$, $\boldsymbol{c_s = 100}$, $\boldsymbol{c_a = 400}$, $\boldsymbol{\beta = 30}$ and $\boldsymbol{N = 1000}$.

Results

We first illustrate the model by plotting for a specific journal how the profit and the rate of change of the profit depend on the journal's quality threshold (Figure 1). We assume there are four journals, of which the first three have quality thresholds of $q_1 = 0.5$, $q_2 = 1$ and $q_3 = 1.5$. Figure 1 shows (in red) the profit of the fourth journal as a function of its quality threshold q_4. Overall, the profit is highest for q_4 near 0. However, if the journal can adjust its quality threshold only slightly, it will adjust its quality threshold depending on the current value of the threshold. For example, assume that the quality threshold q_4 is slightly less than 1. The journal then has an incentive to increase its quality threshold so that it becomes slightly larger than 1, thereby attracting more submissions of sufficiently high quality. These submissions would have otherwise gone to journal 2, which has a quality threshold of $q_2 = 1$. When q_4 is slightly higher than 1, journal 4 no longer has an incentive to change its quality threshold. If the journal decreases its quality threshold, it will attract fewer submissions, thereby decreasing its profit. If it increases its quality threshold, it will not attract substantially more submissions, but it will accept fewer articles, thereby decreasing its profit. This can also be seen by the rate of change in Figure 1 (in blue). When the rate of change is positive, journal 4 can increase its profit by increasing its quality threshold, and when the rate of change is negative, the journal can increase its profit by decreasing its quality threshold. This illustrates how journal 4 adjusts its quality threshold. However, the other three journals will make similar adjustments, and the overall dynamics are therefore more complex.

With two journals that both adjust their quality thresholds, the dynamics are already quite complex. In Figure 2, we show the dynamics from three different perspectives. In Figure 2A, we show for each combination of q_1 and q_2 the local direction in which the two journals adjust their quality thresholds to try to increase their profits. Note that the dynamics are entirely symmetrical, and the upper left part of the plot mirrors the lower right part. We show how the dynamics play out from one particular starting point $q_1 = 0.4$ and $q_2 = 0.3$. In Figure 2B, we show the temporal evolution of the quality thresholds starting from this particular starting point $q_1 = 0.4$ and $q_2 = 0.3$. In Figure 2C, we show the temporal evolution of the expected profits. Journal 1 initially increases its quality threshold, while journal 2 immediately decreases its quality threshold. At some point, journal 1 also starts to decrease its quality threshold, while at some later point journal 2 starts to increase its quality threshold again. Although one may expect that the profits always increase, this is not the case. At first the profits increase for both journals, but after some time they decrease again, which is most clearly visible for journal 1. This happens because journal 2 increases its quality threshold, resulting in a lower profit for journal 1.

The dynamics for more journals become more complex, as shown in Figure 3. Even though differences in the quality thresholds of journals may decrease, there is a persistent hierarchy of journals in terms of quality standards. The ranking of journals relative to each other is preserved over time. Figure 3A shows that the highest quality journal converges to a distinctively higher quality threshold than the second-highest quality journal. Journals clearly do not have an incentive to continue decreasing their quality thresholds in order to increase their profits. Finally, it may be of some interest to note that the highest-quality journals have the highest profits, as shown in Figure 3B. The highest quality journals are also the ones with the highest rejection rates (between 80-90%), which seems quite realistic. Perhaps somewhat unrealistically, high-quality journals publish most articles, and many of the low-quality journals publish only a small number of articles.

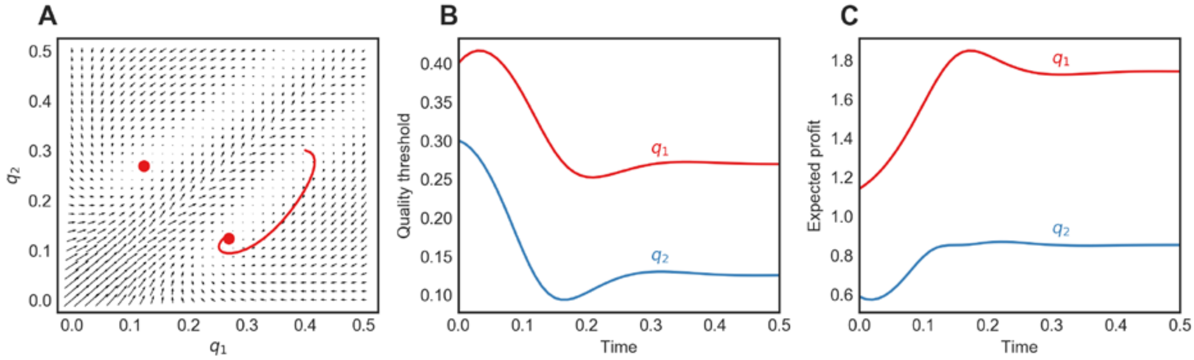

Figure 2. Dynamics of two journals that adjust their quality thresholds in order to try to increase their profits. We set APC $= 5$, $c_f = 0$, $c_s = 1$, $c_a = 1$, $\beta = 10$ and $N = 1$.

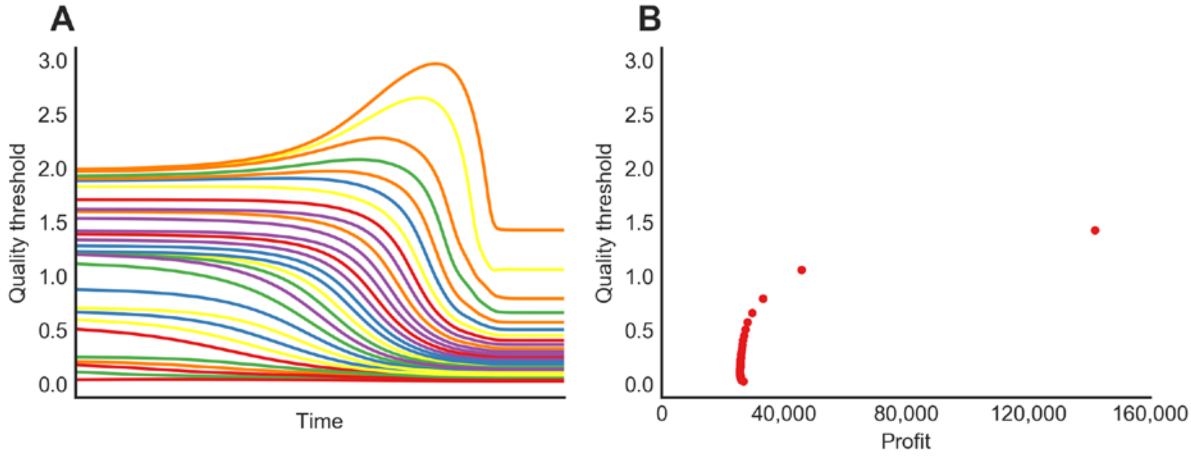

Figure 3. Dynamics for 30 journals for some random initial condition, and the profits of all journals after the dynamics have converged. We set APC $= 2000$, $c_f = 10000$, $c_s = 100$, $c_a = 400$, $\beta = 30$ and $N = 1000$.

Finally, in Figure 4, we analyse the effect of the APC level on the quality thresholds to which four journals converge. If the APC is insufficiently high, all four journals converge to a quality threshold of zero. At this point, the APC is lower than the cost of receiving submissions and publishing articles, so that all journals make a loss. When the APC is sufficiently high, a journal hierarchy emerges. Higher APCs result in an increasingly distinctive journal hierarchy.

Discussion

The debate on open access has received an impulse by the recently proposed Plan S. One particular concern is whether high-quality journals may continue to exist in the publishing system envisioned in Plan S.

We have addressed this question using a theoretical model in which journals are assumed to gradually adjust their quality standards in order to increase their profits. We find that high-quality journals may continue to exist, provided that a cap imposed on APCs is sufficiently high. Possibly, the quality standards of journals may go down. However, journals will maintain certain quality standards in order to continue attracting submissions. This effect is the result of authors preferring to publish in high-quality journals, and preferably submitting their work there. The typical argument that journals will increase profits by simply accepting more articles, and hence lowering their quality standards, does not consider this effect. Given the theoretical nature of our model, it is difficult to obtain a concrete estimate of the cap on APCs that would be needed.

An issue that our model does not take into account is that many authors who are not funded by research funding agencies that support Plan S will consider the level of the APC of a journal when deciding where to submit their articles (West, Bergstrom, & Bergstrom, 2014). This may cause APCs to become more differentiated, with higher quality journals charging higher APCs than lower quality journals. If authors have no incentive to consider the level of the APC of a journal, for example because the APC will be paid by research funders that support Plan S, journals will simply raise their APCs until they hit the cap imposed by research funders. This creates a dilemma for research funders. If it is considered important to have high-quality journals, funders should set a relatively high cap on APCs. However, low-quality journals will then also benefit from high APCs, leading to a costly publishing system.

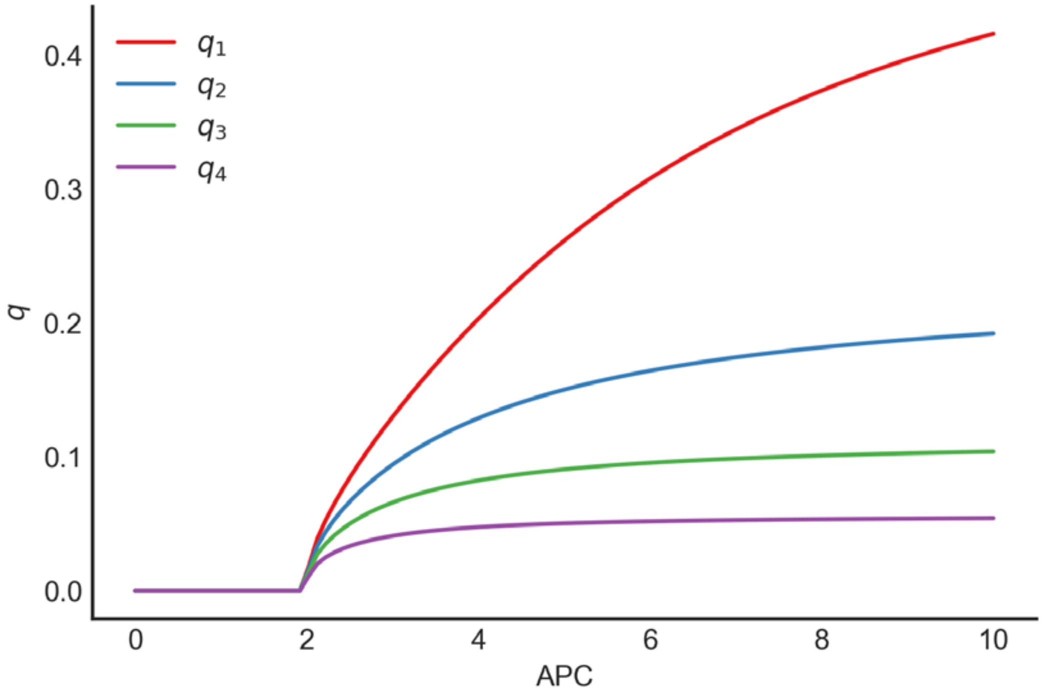

Figure 4. Journal hierarchies resulting for different APCs. We set $c_f = 0$, $c_s = 1$, $c_a = 1$, $\beta = 3$ and $N = 1$.

To reduce costs, funders could set the cap on APCs at a relatively low level. Although a journal hierarchy could then still persist, quality differences between journals will decrease and journals that have very demanding quality standards are unlikely to uphold them.

We would like to suggest two ways in which funders could deal with the above dilemma. First, funders could differentiate the cap on APCs based on the services provided by journals. This requires journals to be transparent about the services they offer and the associated costs. In the current Plan S implementation guidance, such transparency is indeed already required. Second, rather than covering APCs for all articles, funders could include a budget for APCs within the overall funding they provide to researchers. Researchers then have to weigh the APC against the quality of a journal when deciding where to submit their manuscript. This would make researchers more sensitive to the level of the APC of a journal, leading to more differentiated APCs.

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[i] https://www.coalition-s.org/