Benefits of cooperative peer review

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3 authors:

Jose A. Garcia
University of Granada

Rosa Rodriguez-Sánchez
University of Granada

J. Fdez-Valdivia
University of Granada

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J. A. García, [*]
Rosa Rodriguez-Sánchez, [†]
J. Fdez-Valdivia. [‡]

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Abstract

An authors' satisfaction is apparently influenced by the duration and quality of the scientific peer review process. In a research field, where multiple peer-reviewed journals offer the publication of articles and share a common scientific interest, an opportunity exists for them to cooperate in the often costly investment needed to maintain the peer review system. In a cooperative peer-review scenario, academic journals would share a submission management system, a reviewer database, a reviewer selection process, a recommended set of standards for reporting reviews, a review quality instrument, and a model for reviewer compensation. However, the final decision on what to publish in each journal would rest solely with the journal editor. This paper aims to apply peer review theory to the exploration of cooperative peer review. Thus, game theory is used to describe and model how peer review agents behave. A set of strategies for those agents is an equilibrium if each represents a best response to the other strategies. If all the players are playing the strategies in an equilibrium,

[*]Departamento de Ciencias de la Computación e I. A., CITIC-UGR, Universidad de Granada, 18071 Granada, Spain. Address correspondence to J. A. Garcia at jags@decsai.ugr.es. Jose A. Garcia ORCID iD `https://orcid.org/0000-0001-7742-7270`

[†]Departamento de Ciencias de la Computación e I. A., CITIC-UGR, Universidad de Granada, 18071 Granada, Spain. Address correspondence at rosa@decsai.ugr.es.

[‡]Departamento de Ciencias de la Computación e I. A., CITIC-UGR, Universidad de Granada, 18071 Granada, Spain. Address correspondence at jfv@decsai.ugr.es.

they have no unilateral incentive to deviate, since their strategy is the best they can do given what others are doing. The equilibria of these games can predict how actual journals, authors and reviewers will behave when confronted with situations analogous to the peer-review game being studied. In particular, cooperation between peer-reviewed journals is more likely when each journal's prospective benefits outweigh that journal's prospective costs. Therefore, in this paper, we compare a Benchmark scenario of competition between journals and a cooperative scenario to further analyze the impact of incorporating cooperative peer review in the academic publishing process. We find that a cost-sharing scheme in cooperative peer review helps the academic journals offer a higher review quality than they would otherwise be able to achieve individually. A key insight from our results is that if a cost-sharing factor is properly specified, cooperative peer review can benefit the competing academic journals and help increase their profit levels, quality standards for accepting articles and review quality.
Keywords: Peer Review; Scholarly Journals; Cooperative Peer Review; Review Quality; Standards for Accepting Articles; Journal Profits; Peer Review Theory.

1 Introduction

In the scientific peer review process, the duration and number of review rounds and the time journals take to manage these rounds are important for a manuscript's author as these aspects determine how much time may be lost until they are informed of the final editorial decision (Huisman and Smits, 2017; Solomon and Bjork, 2012). In fact, one of the most important criticisms of the peer review system is that it is much too slow (Lotriet, 2012). This is so because the duration of the peer review process may have increased in recent decades (Ellison, 2002; Azar, 2007; Alberts et al., 2008; Huisman and Smits, 2017).

Lotriet (2012) suggested that among journal editors there is a growing concern that the quality and duration of the review processes are being negatively affected as "referees are stretched thin by other professional commitments". This often leads to "challenges in finding sufficient numbers of reviewers in a timely manner" (Lotriet, 2012). However, once reviewers have been found, other problems may emerge, such as poor reviewer agreement on submissions (Peters and Ceci, 1982; Onitilo et al., 2014) or ethical problems

(Resnik et al., 2008). Constructive comments by reviewers may substantially contribute to the quality of scientific papers, while low quality and contradictory referee reports can be a major source of frustration among authors (Nicholas et al., 2015; Huisman and Smits, 2017). Resnik et al. (2008) mention reviewers asking authors to include (in order of frequency) "unnecessary references to their publication(s), personal attacks, reviewers delaying publication to publish a paper on the same topic, breach of confidentiality and using ideas, data, or methods without permission".

Several suggestions have been made to make it more attractive for scientists to act as reviewers. Thompson et al. (2010) found a statistically significant reduction in review duration when referees were paid for their efforts. They thought it likely that if the length of referee reports was an indication of quality, payment might even have led to an increase in reports' quality (Thompson et al., 2010). Previous studies by (Hamermesh, 1994) for seven journals in 1989 also found an increase in timely referee reports for journals offering payments. Garcia et al. (2020b) show that the motivational aspects of traditional peer review mechanisms are not sufficient in relation to the reviewer's effort required to reach the best level for the journal, because this method of compensation for the reviewer's side is overly mismatch cost focused. They also show that if this compensation is extended to reward the reviewer based on the manuscript quality achieved, the journal will be able to align the interests of all parties involved (i.e, authors, reviewers and journal editors).

In (Huisman and Smits, 2017), to assess the independent associations between the characteristics of the peer review process and the satisfaction of authors, a multivariate regression analysis was performed with the overall rating of the process as dependent variable. This analysis showed that even when the other variables were taken into account, a shorter duration of the initial review round, and a lower number of total review rounds were associated with a significantly higher overall rating of the experience. Huisman and Smits (2017) also found that authors rate the peer review process more positive if they receive more referee reports, especially after a long first review round and when the manuscript is rejected. This indicates that "authors appreciate the work of reviewers and the feedback given on their manuscripts." In short, Huisman and Smits (2017) found that an authors' satisfaction is likely influenced by the duration and quality of the scientific peer review process. That is to say that in general shorter peer review processes are rated more positively by authors. They also show that editors can enhance author satisfaction by taking "an independent position vis-à-vis reviewers and by communicating well with authors."

The problem is that peer-reviewed journals and their editors often experience significant costs of constructing and maintaining a quality peer review system. However, in the same field, where multiple peer-reviewed journals offer the publication of research and share a common scientific interest, an opportunity exists for them to cooperate in the often costly investment needed to offer and maintain the peer review system. Cooperation in social dilemmas in general has long been conceptualized as a function of perceived payoffs (Yuan et al., 2019). Thus, cooperation among peer-reviewed journals is more likely when a journal's prospective benefits outweigh that journal's prospective costs. One notable example is the submission management system that streamlines and eases out the collection, tracking and management of electronic submissions. In a cooperative scenario, even though peer-reviewed journals in the same field may still compete in their quality standards for accepting papers, they would cooperate by sharing, for example, a reviewer database, a reviewer selection process and a model for reviewer compensation.

This paper aims to apply peer review theory to the exploration of cooperative peer review in a research field. Peer review theory usually focuses on particular sets of strategies known as equilibria, assuming that players act rationally in peer review, (Garcia et al., 2015a, 2020a,b). Therefore, game theory is often used in peer review theory to describe and model how peer review agents would behave. A set of strategies for those agents is an equilibrium if each represents a best response to the other strategies. If all the players are playing the strategies in an equilibrium, they have no unilateral incentive to deviate, since their strategy is the best they can do given what others are doing. The equilibria of these games can predict how actual journals, editors, authors and reviewers will behave when confronted with situations analogous to the peer-review game being studied. The payoffs of the peer-review game are generally taken to represent the utility of journals, editors, and so on.

Therefore, like other prototypical papers on peer review theory, we will begin by presenting a game that is an abstraction of a particular situation in the academic publishing process. One or more solution concepts are then chosen, and we demonstrate which strategy sets in the presented game are equilibria of the appropriate type. While the basic assumptions do not always hold true in the real-world, we treat peer review theory as a reasonable scientific ideal akin to the models used by economists. That is, peer review theory aims to produce useful models. In particular, we compare a Benchmark scenario of competition between journals and a cooperative peer-review scenario in order to further analyze the impact of incorporating peer-review cooperation in the academic publishing process. We find that a cost-sharing scheme in cooperative peer review helps the academic journals offer a high review quality that they would otherwise not be able to achieve individually. A key insight from our formal results is that cooperative peer review can benefit competing academic journals and help increase their profit levels, standards for accepting articles and review quality.

2 A Benchmark scenario: Competition between peer-reviewed journals

In this section, we consider a pair of peer-reviewed journals that compete in their quality standards for accepting papers as our baseline for study. The low acceptance rates of journals with high quality standards for accepting articles may reduce researchers' productivity (Aarssen et al., 2008; Haensly et al., 2009). Therefore, the level of competition for acceptance within the journal is one of the factors considered by researchers when selecting journals for publication (Halim and Khan, 2019). In our benchmark scenario, the peer-reviewed journals offer the publication of research and share a common scientific interest in the field. However, each journal determines its own level of review quality dedicated solely to its own submissions.

Professionalism of editors and reviewers determines the quality of the peer review process. In fact, authors value a quality manuscript evaluation, (Huisman and Smits, 2017), even if they are painful and time consuming in the moment, they are vital for minimizing the risk of problems in the future. More exacting peer review should ultimately lead to better articles, because quality peer review should remove substantial methodological and logical issues from the article. Authors who receive more referee reports also tend to be more positive about the process, (Huisman and Smits, 2017). Their perception might be that their manuscript has been dealt with more seriously and thoroughly. Following the key findings in (Huisman and Smits, 2017), a basic assumption in our model is that a higher review quality reduces an authors' disutility from a longer peer-review process.

In our model, the review duration refers to the time a manuscript is under the responsibility of the journal, i.e., the duration of the first and subsequent review rounds. When the duration of the first review round is shorter and there are fewer review rounds, authors tend to give the process a significantly higher rating, (Huisman and Smits, 2017). It is therefore not surprising that one of the most important criticisms of the peer review system is that it is much too slow (Lotriet, 2012).

In our model, each of the two peer-reviewed journals, indexed as $i = 1, 2$, follows a review duration standard w, and has a review quality of α_i. The quality standard for accepting articles within the journal i is given by p_i. Then, following the approach in (Yuan et al., 2019), the peer-reviewed journal i, with $i = 1, 2$, faces a manuscript arrival rate of

$$\lambda_i = B - hwe^{-\delta\alpha_i} - \beta_0 p_i + \theta(p_j - p_i) \tag{1}$$

where B is the maximum manuscript arrival rate in the research field, β_0 measures an author's sensitivity to quality standards for accepting articles, and $\theta > 0$ captures the intensity of competition for acceptance between the journals such that a larger θ indicates a more intense competition between them. Given that authors value the speed of the peer review process, in the above equation, h denotes the cost per unit of total review duration, which captures an authors' aversion to a long peer review process. As reflected in the manuscript arrival rate above, the review quality reduces an authors' disutility from time-consuming peer review processes such that each author has an effective waiting-cost rate of $he^{-\delta\alpha}$, where $\delta > 0$ measures the effectiveness of the review quality for this purpose. In providing a review quality of α_i, the journal i incurs a cost of $C(\alpha_i)$ which is convex increasing in α and we assume that

$$C(\alpha_i) = \frac{1}{2}c\alpha_i^2$$

where c is a positive constant, (Yuan et al., 2019).

The journal builds its manuscript processing rate, denoted as μ_i, at a marginal cost of γ. Apart from the time experts take to deliver their reviews, the total manuscript processing time of peer-reviewed journals is influenced by the duration of the various stages of manuscript handling at editorial offices. Given that they have limited resources and editors do this work in addition to busy academic careers, waiting times are often longer than strictly necessary (Huisman and Smits, 2017). For the sake of simplicity, we assume that manuscript arrivals follow a Poisson process, and each manuscript's processing time is exponentially distributed. The exponential and Poisson distributions arise frequently in the study of queuing. Therefore, such arrivals behave like random arrivals. That is, an observer from a Poisson arrival stream finds the same system state distribution as a random observer having nothing to do with the system. In queueing theory, an M/M/1 queue represents the queue length in a system where arrivals are determined by a Poisson process and job service times have an exponential distribution, (Guillemin and Boyer, 2001). The total review duration is therefore an $M/M/1$ queue (see Yuan et al. (2019) for further details).

To maintain an expected review duration of w, the journal i sets the manuscript processing rate μ_i at

$$\mu_i = \lambda_i + 1/w.$$

This manuscript processing rate ensures a steady-state expected review duration of $w = 1/(\mu_i - \lambda_i)$ in equilibrium, (Yuan et al., 2019). For the sake of simplicity, we assume that w is exogenous, which is consistent with the phenomenon of peer-reviewed journals announcing their review duration standards. An example of such a review duration announcement can be found at `https://www.springer.com/journal/11192/`.

Therefore, the journal's problem consists of choosing the quality standard for accepting articles p_i and the level of review quality α_i to maximize its expected profit represented by

$$\Pi_i = p_i\lambda_i - C(\alpha_i) - \gamma\mu_i$$

or equivalently

$$\Pi_i = (p_i - \gamma)\lambda_i - \frac{1}{2}c\alpha_i^2 - \frac{\gamma}{w}$$

since $\mu_i = \lambda_i + 1/w$.

For ease of exposition, the expected profit of journal i, with $i = 1, 2$, is rewritten as

$$\Pi_i = P_i\lambda_i - \frac{1}{2}c\alpha_i^2 - \frac{\gamma}{w}$$

where $P_i = p_i - \gamma$, and the manuscript arrival rate of journal i as

$$\lambda_i = D(\alpha_i) - \beta P_i + \theta P_j$$

where $D(\alpha_i) = B - \beta_0\gamma - hwe^{-\delta\alpha_i}$, and $\beta = \beta_0 + \theta$.

In our model, each peer-reviewed journal i, with $i = 1, 2$, simultaneously determines both its own standard for accepting articles and its review quality. We assume $2\beta_0 c - \delta^2(B + \theta p^M - \beta_0\gamma)^2 \geq 0$ in order to ensure that both journals' profit functions are jointly concave in $\alpha \geq 0$ and $\gamma \leq p^M$ for any $\theta > 0$, with p^M being the optimal quality standard for accepting articles in a scenario with a monopoly peer-reviewed journal, (Yuan et al., 2019). This assumption means that the effectiveness of review quality to reduce authors' disutility from time-consuming peer review, δ, cannot be overly large.

In the following proposition we characterize the equilibrium of this benchmark scenario of competition between journals, using the superscript C to represent the journals' decisions and performance under competition. In the proposition, each journal's utilization rate ρ^C is defined as the ratio of its manuscript arrival rate to its manuscript processing rate.

Proposition 1. *Under the benchmark setting of journal competition, each peer-reviewed journal chooses a level of review quality α^C that uniquely satisfies*

$$\delta hwD(\alpha) - (2\beta_0 + \theta)c\alpha e^{\delta\alpha} = 0$$

at $\alpha = \alpha^C$, and its optimal standard for accepting articles is

$$p^C = \frac{D(\alpha^C)}{2\beta_0 + \theta} + \gamma.$$

In the equilibrium of the benchmark scenario, each journal's manuscript arrival rate, utilization rate, and expected profit are

$$\lambda^C = (\beta_0 + \theta)\frac{D(\alpha^C)}{2\beta_0 + \theta}, \quad \rho^C = 1 - \frac{1}{w\lambda^C + 1}, \text{ and } \Pi^C = P^C\lambda^C - C(\alpha^C) - \frac{\gamma}{w},$$

respectively, and where $P^C = p^C - \gamma$.

Proof: See Appendix A.

As δ increases, the review quality becomes more effective in reducing authors' disutility from time-consuming peer review. Fig. 1(top) illustrates the impact of δ on the optimal review quality α^C and the optimal standard for accepting articles p^C under this setting. As δ increases, the peer-reviewed journal will increase the review quality and in turn can request a higher standard for accepting articles. Fig. 1(bottom) illustrates the impact of the review-duration standard w on α^C and p^C. As w increases, in a benchmark scenario of competition between journals, the academic journal will counteract long review durations by increasing the level of review quality α^C, and simultaneously, reducing the quality standard for accepting papers.

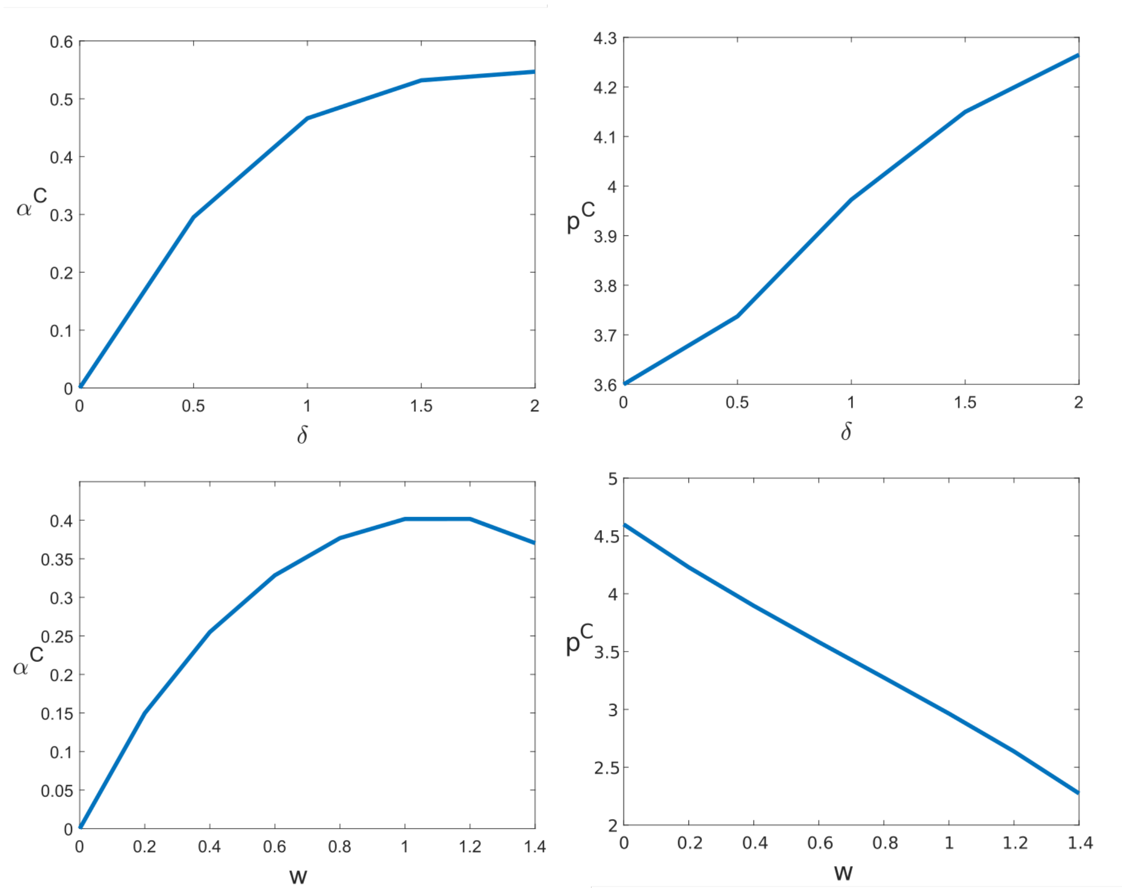

Figure 1: (top) as δ increases, in the benchmark scenario of competition between journals, the peer-reviewed journal will increase the review quality (α^C) and in turn can request a higher standard for accepting articles (p^C); (bottom) as w increases, in the benchmark scenario, the academic journal will counteract long review durations by increasing the level of review quality (α^C) and reducing the standard for accepting articles (p^C).

The following mathematical result finds the effect of higher competition in quality standards for accepting articles between journals (θ) on the optimal review quality and journal standard. That as competition becomes more intense, review quality becomes less effective to reduce the authors' disutility from long review processes. Then, both peer-reviewed journals respond by setting a lower quality standard for accepting articles and reducing the level of review quality. In the following section, in the case of cooperative peer review between competing journals, we present a contrasting result.

Corollary 1. *In the equilibrium of the benchmark scenario, as the intensity of competition in standards for accepting articles between journals, θ, increases, each peer-reviewed journal chooses a lower level of review quality and a lower standard for accepting articles, leading to a lower profit.*

Proof: See Appendix B.

From Corollary 1 we find that due to increased competition in standards between peer-reviewed journals, they must set lower quality standards for accepting articles and provide a lower level of review quality, leading to lower profits (see Fig. 2). Therefore, competition among peer-reviewed journals discourages higher levels of review quality. The net effect of the journals' decisions from authors' perspective is that they are now facing lower quality standards for acceptance, while experiencing a higher aversion to long peer review processes because of the lower review quality.

3 A cooperative peer review scenario between journals that compete in their standards for accepting articles

In the cooperative peer review scenario, we again consider a pair of peer-reviewed journals that compete in their quality standards for accepting papers. However, in this case, journals cooperate in the often costly investment needed to offer and maintain the peer review system. In cooperative peer review, they would share a submission management system, a reviewer database, a reviewer selection process (Garcia et al., 2015b), a recommended set of standards for reporting systematic reviews, an established review quality instrument (Garcia et al., 2017), and, a model for reviewer compensation (Garcia et al., 2020b, 2021). We focus on the case in which the cost of providing the same level of review quality does not significantly increase when

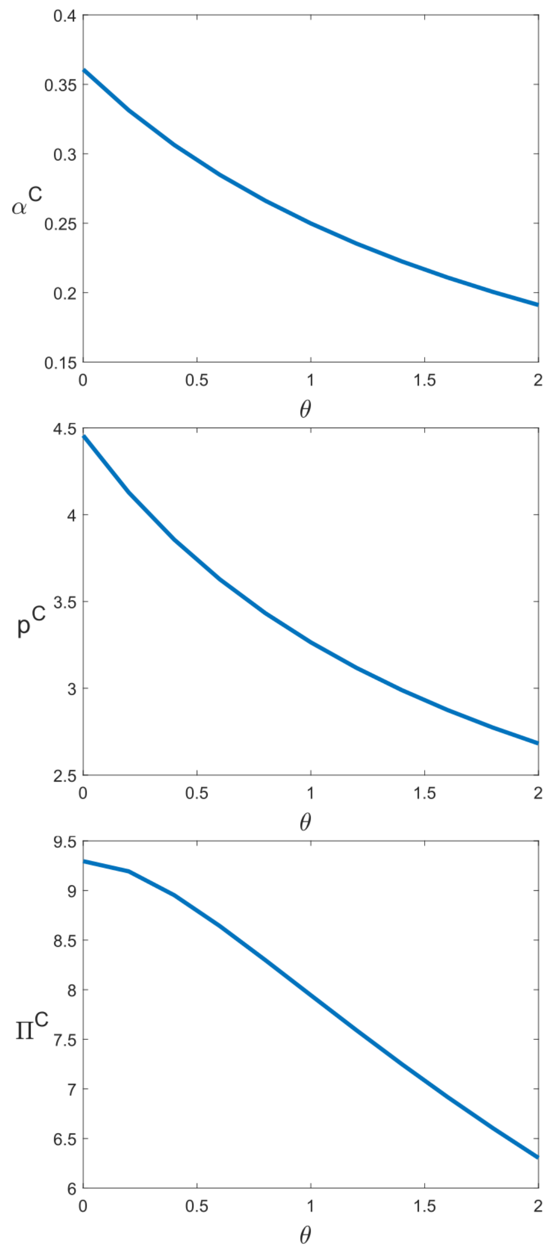

Figure 2: In the benchmark scenario of competition between journals, as θ increases, the two peer-reviewed journals must set lower quality standards for accepting articles (p^C) and provide a lower level of review quality (α^C), leading to lower profits (Π^C).

different academic journals share the peer review system. For instance, following (Garcia et al., 2015b), the reviewer compensation is made through the proportional increment of a reviewer factor, which measures the importance of reviewers to their field. Therefore, peer-reviewed journals jointly decide the level of review quality α, with a total cost of $C(\alpha) = \frac{1}{2}c\alpha^2$ that is shared among the academic journals that cooperate in peer review.

In the cooperative peer review scenario, the final decision on what to publish in journal i rests with the Editor of that journal. We assume that the editors are experts in their field and make independent decisions. Therefore, each journal i's manuscript arrival rate λ_i is $D(\alpha) - \beta_0 P_i + \theta(P_j - P_i)$, for $i, j \in \{1, 2\}$ with $i \neq j$, and where $P_i = p_i - \gamma$. The first term captures the effect of higher review quality on authors, $D(\alpha) = B - \beta_0\gamma - hwe^{-\delta\alpha}$, and the second and third terms capture the effect of competition in quality standards for acceptance within and between journals, respectively.

Because the evaluation of all submitted manuscripts must be performed with the same review quality, the method to finance the chosen review quality could be based on their respective number of likely submissions within a research field and to then divide the cost among the journals. As such, in our model, we focus on a linear cost-sharing scheme, in which the total cost of providing review quality is split between the journals according to their manuscript arrival rates such that journal i is responsible for a cost share of

$$\phi(\lambda_i, \lambda_j) = \frac{1}{2} + \frac{t(\lambda_i - \lambda_j)}{2}, \text{ for } i, j \in \{1, 2\}, i \neq j, \text{ and } t \geq 0,$$

where t represents the cost-sharing factor, which measures the sensitivity of each journal's share of the total cost to its number of manuscripts received. In the case of $t = 0$, it corresponds to the situation in which the cost for providing a particular level of review quality is evenly split. A larger t implies that each journal's share increasingly depends on its actual number of submissions relative to the other journal.

We assume that each peer-reviewed journal first sets its own quality standard for accepting articles, and then both journals jointly decide on the level of review quality. The journal i's profit can be represented as

$$\Pi_i = P_i\lambda_i - \phi(\lambda_i, \lambda_j)C(\alpha) - \frac{\gamma}{w}$$

for $i = 1, 2$.

In order to identify the optimal solution, following (Yuan et al., 2019), we first find the level of review quality that maximizes the joint profit of the two peer-reviewed journals, $\Pi_1 + \Pi_2$, for a given pair (P_1, P_2). Using the optimal solution $\alpha(P_1, P_2)$, we then find the optimal standards for accepting articles. In the following proposition we characterize the equilibrium of this cooperative peer review scenario, using the superscript O to represent the journals' decisions and performance under this setting. In our model we assume that the two peer-reviewed journals are symmetric, and therefore, in equilibrium, the two academic journals must choose the same standards for accepting articles and review quality.

Proposition 2. *In the cooperative peer review scenario, each journal chooses a level of review quality α^O that uniquely satisfies*

$$2\delta hw[D(\alpha) + t(\beta_0 + 2\theta)C(\alpha)] - (2\beta_0 + \theta)c\alpha e^{\delta\alpha} = 0$$

at $\alpha = \alpha^O$, and its optimal standard for accepting articles is

$$p^O = P^O + \gamma, \text{ with } P^O = \frac{D(\alpha^O) + t(\beta_0 + 2\theta)C(\alpha^O)}{2\beta_0 + \theta}.$$

In the equilibrium of the cooperative peer review scenario, each journal's manuscript arrival rate, and utilization rate are

$$\lambda^O = \frac{(\beta_0 + \theta)D(\alpha^O) - t\beta_0(\beta_0 + 2\theta)C(\alpha^O)}{2\beta_0 + \theta}, \text{ and } \rho^O = 1 - \frac{1}{w\lambda^O + 1},$$

respectively. Furthermore, in equilibrium, the expected profit of each peer-reviewed journal is

$$\Pi^O = P^O\lambda^O - C(\alpha^O)/2 - \frac{\gamma}{w},$$

where each journal's optimal cost share in the common peer-review system is 1/2.

Proof: See Appendix C.

Recall from Corollary 1 that in the benchmark scenario of competition between peer-reviewed journals, we found that due to increased competition in standards between peer-reviewed journals (θ), both the optimal standard for accepting articles and the level of review quality decrease leading to lower profits. However, in the cooperative peer-review scenario, this result no longer holds, as demonstrated in the following mathematical result.

Proposition 3. *In the equilibrium of the cooperative peer-review scenario, a threshold $\hat{t}$ exists such that as the intensity of competition in standards for*

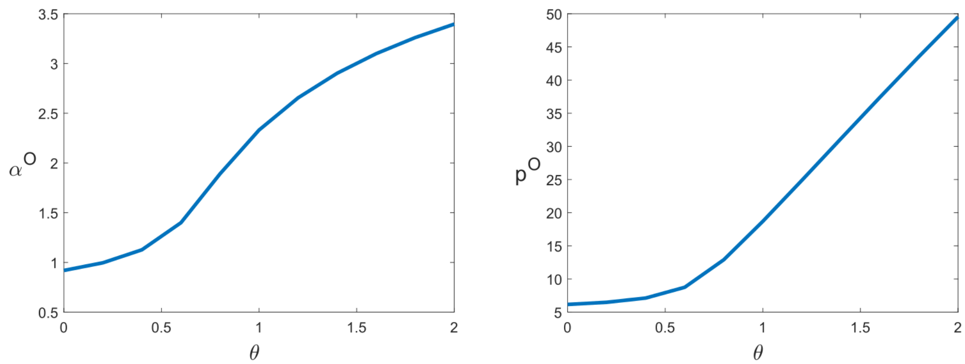

Figure 3: Under the cooperative peer-review setting, as competition becomes more intense (i.e., θ increases), both peer-reviewed journals respond by setting a higher quality standard for accepting articles (p^O) and increasing the level of review quality (α^O).

accepting articles between journals, θ, increases, each peer-reviewed journal chooses a higher level of review quality and a higher standard for accepting articles when the cost-sharing factor $t \geq \hat{t}$ with $\hat{t} = \frac{e^{\delta \alpha^O}}{2\delta h w \alpha^O}$.
Proof: See Appendix D.

Therefore, under the cooperative peer-review setting, this proposition finds the effect of higher competition in standards for accepting articles between journals (θ) on the optimal review quality and journal standard. This is illustrated in Fig 3. As competition becomes more intense (i.e., θ increases), both peer-reviewed journals respond by setting a higher quality standard for accepting articles and increasing the level of review quality (see Fig 3). This result is rather surprising, because one might expect the peer-reviewed journals to request a lower standard for acceptance as the competition level (θ) increases, as is the case under the benchmark scenario of competition between journals. Under the cooperative peer-review setting, increasing the quality standard for accepting articles (and the level of review quality) becomes a more lucrative option for both peer-reviewed journal.

4 Comparing the Benchmark scenario and the cooperative peer-review scenario

Now we will compare the Benchmark scenario of competition between journals and the cooperative peer-review setting to further analyze the impact of incorporating the peer-review cooperation in the academic publishing process. As seen in the following mathematical result, by sharing the cost of providing a common peer-review system, the two academic journals can achieve a higher review quality, which allows them to request a higher standard for accepting articles without compromising on the manuscript arrival rate. However, a threshold cost-sharing factor exists above which the benefit from cooperative peer review disappears. Note that this formal result is based on a setting in which both peer-reviewed journals share the same review-duration standards.

Proposition 4. *All else being equal, the equilibrium standard for acceptance and review quality under cooperative review are always higher than under competition:*

$$p^O \geq p^C, \text{ and, } \alpha^O \geq \alpha^C.$$

Furthermore, a threshold cost-sharing factor t^c exists below which the journal's profit under the cooperative peer-review setting is greater than under the competition setting:

$$\Pi^O > \Pi^C \text{ when the cost-sharing factor is } 0 \leq t < t^c.$$

Proof: See Appendix E.

Therefore, the cost-sharing scheme in cooperative peer review helps the academic journals offer a higher review quality in the manuscript evaluation process than they would otherwise be able to achieve individually. However, in the pursuit of fairness in cost sharing, and thus increasing the cost-sharing factor t above a threshold, the benefit from peer-review cooperation may be eliminated, such that neither journal benefits from a common peer review system. The implication is that in designing a cost-sharing scheme for cooperative peer review, the journals need to carefully weigh a fairness-efficiency trade-off, (see Yuan et al. (2019) for further details). A key insight from the previous mathematical results is that if the cost-sharing factor is properly specified, cooperative peer review can benefit the competing academic journals and help increase their profit levels (see Fig 4), their standards for

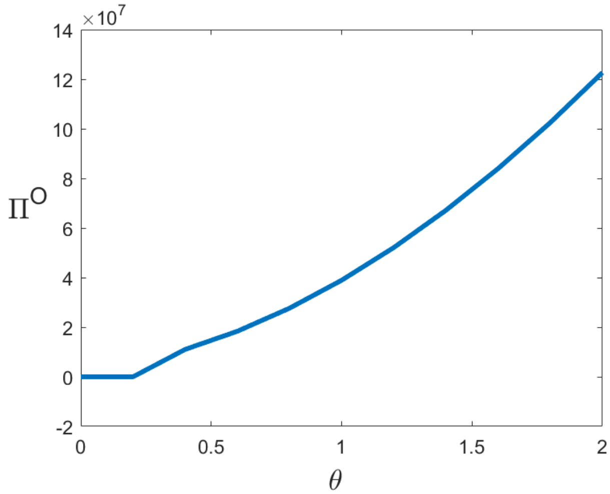

Figure 4: As θ increases, cooperative peer review can benefit the competing academic journals and help increase their profit (Π^O).

accepting articles, and their review quality (see Fig 3). This result formally establishes the benefit of cooperative peer-review.

To gain an overall sense of the improvement achieved through cooperative peer review over the Benchmark scenario of competition between journals, we conducted a computational simulation where the review-duration standard $w \in (0.2, 0.7)$, and $\delta \in (0.3, 0.9)$. Recall that as δ increases, the review quality becomes more effective in reducing authors' disutility from long review duration. In this computational simulation, $B = 10$, $\gamma = 1$, $\beta_0 = 1$, $c = 10$, $\theta = 0.5$ and $h = 5$.

As Figures 5, 6, and 7 illustrate, our computational simulation shows that the cooperative peer review setting is better compared to the competition setting between journals in three important dimensions of the peer review process: (i) review quality; (ii) quality standards for accepting articles; and (iii) journal profit.

Fig 5 illustrates the gain in review quality of cooperative peer review relative to competition ($\alpha^O - \alpha^C$) under different values of δ and w. This figure shows that the gain in review quality is higher when authors are highly sensitive to long review durations (as w increases) and review quality is effective in alleviating authors' disutility from a long review duration.

Fig 6 illustrates the gain in quality standards for acceptance of cooper-

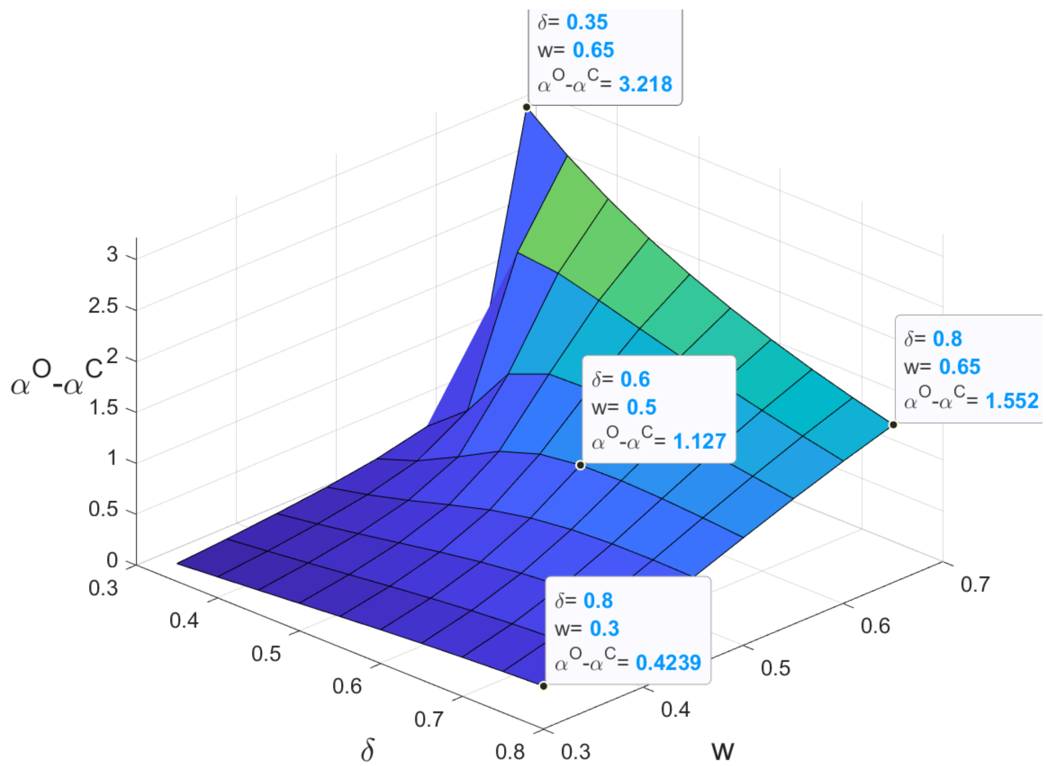

Figure 5: Gain in review quality of cooperative peer review relative to competition ($\alpha^O - \alpha^C$) under different values of δ and w.

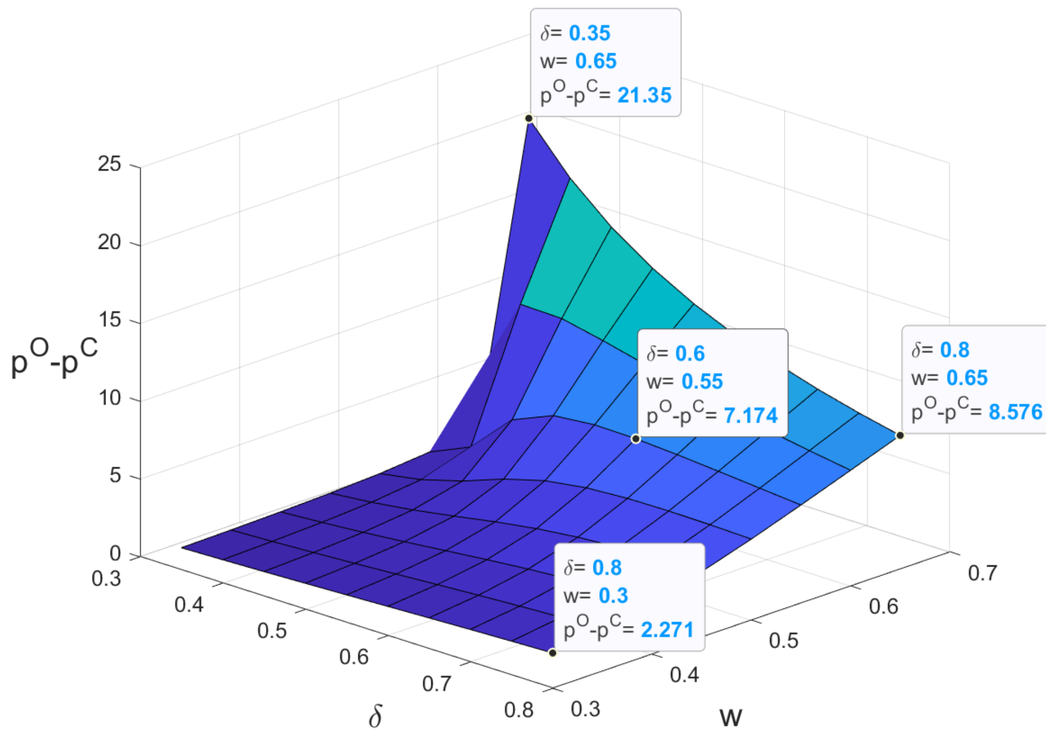

Figure 6: Gain in standards for accepting articles of cooperative peer review relative to competition ($p^O - p^C$) under different values of δ and w.

ative peer review relative to competition ($p^O - p^C$) under different values of δ and w. Again, this figure shows that the gain in quality standards for accepting articles is higher when authors are highly sensitive to long review duration (as w increases) and review quality is relatively effective in alleviating authors' disutility from a long review duration.

Finally, Fig 7 illustrates the gain in journal profit of cooperative peer review relative to competition ($\Pi^O - \Pi^C$) under different values of δ and w. In this case, the figure shows that cooperative peer review relative to competition between journals is the most lucrative when authors are relatively sensitive to review duration and review quality is effective to some extent in alleviating authors' disutility from a time-consuming peer review.

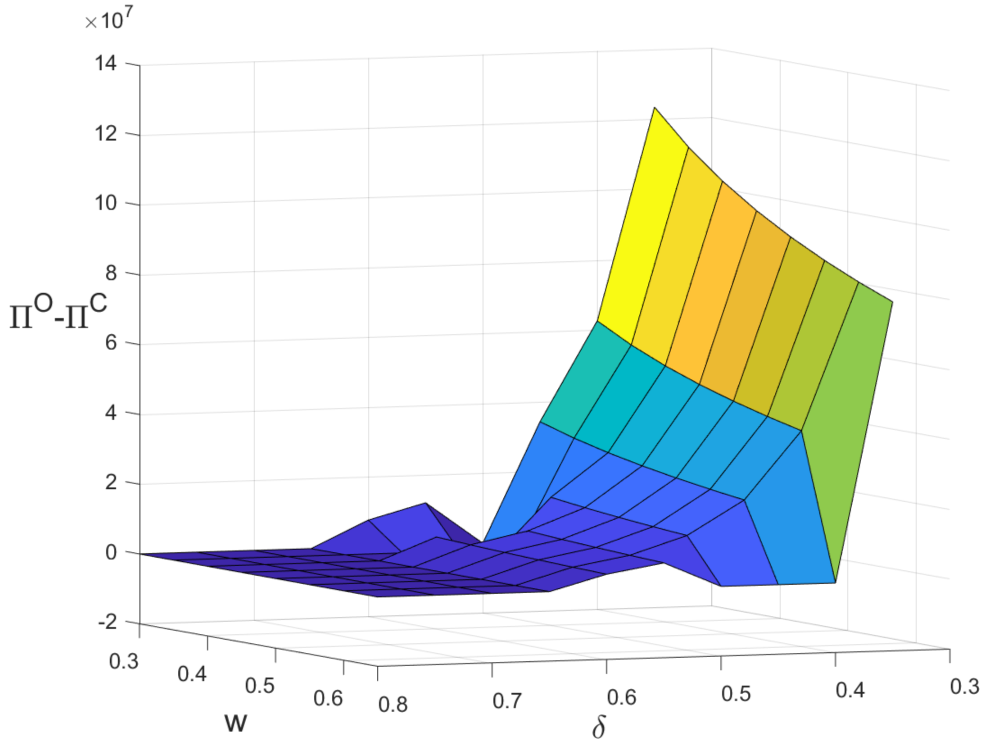

Figure 7: Gain in journal profit of cooperative peer review relative to competition ($\Pi^O - \Pi^C$) under different values of δ and w.

5 Conclusion

Our paper contributes to the literature on peer review theory by being the first to examine cooperative peer review in a research field, in addition to developing a novel model for review quality and standards for accepting articles in the academic publishing process. In a cooperative scenario, peer-reviewed journals would share a submission management system, a reviewer database, a reviewer selection process, recommended standards for reporting reviews, a review quality instrument, and a model for reviewer compensation. However, the final decision on what to publish in each journal would rest with the journal's editor. In our model, we assumed authors' satisfaction is influenced by the duration and quality of the peer review process.

Using game theory to describe how peer review agents behave, we developed a parsimonious model of cooperative peer review in a research field. Therefore, our paper is an example of peer review theory applied to the exploration of cooperative peer review. In peer review theory, a set of strategies for the peer review agents is an equilibrium if each represents a best response to the other strategies. The equilibria of these games can predict how actual populations of journals, authors and reviewers would behave when confronted with situations analogous to the peer-review game being studied.

By comparing the case of cooperative peer review with a benchmark of competition between peer-reviewed journals, we demonstrated that a scholarly journal could achieve higher profitability by sharing a common peer review system with a symmetric peer-reviewed journal. This symmetry refers to the fact that, in equilibrium, both journals would share the same standards. Our results show that as much as cooperation in peer review facilitates resource sharing in the research field, it heightens competition in quality standards for accepting articles within each journal. Furthermore, as the intensity of competition in standards for acceptance between journals increases, surprisingly, the academic journals may opt to request higher quality standards for accepting articles, albeit while providing a higher review quality.

Rather than providing an exhaustive analysis of cooperation, this paper is the first step toward understanding cooperative peer review in a research field where multiple academic journals offer to publish research and share a common scientific interest. Our work can be extended in a number of directions. For instance, in practice, cooperative peer review may occur among more than two academic journals in the same field. Another direction for future research would be to examine the case with asymmetric journals.

We expect our key insights to hold, but the asymmetry itself may lead to interesting implications in scholarly communication. Lastly, our key findings, especially those relevant to the cooperative setting, may be tested in the research field.

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Appendix

A Proof of Proposition 1.

In order to prove our results we will follow the same approach as Yuan et al. (2019). Given peer-reviewed journal j's standard for accepting articles P_j and review quality α_j, peer-reviewed journal i maximizes its profit Π_i through P_i and α_i. Therefore, using the first-order conditions, the optimal review quality α_i satisfies

$$\frac{\partial \Pi_i}{\partial \alpha_i} = P_i \delta h w e^{-\delta \alpha_i} - c\alpha_i = 0,$$

and the optimal standard for acceptance P_i satisfies

$$\frac{\partial \Pi_i}{\partial P_i} = D(\alpha_i) - 2\beta P_i + \theta P_j = 0.$$

In a similar way by using the first-order conditions we can derive the optimal review quality α_j and the optimal quality standard P_j for journal j, given journal i's standard for accepting articles P_i and review quality α_i. Therefore, the equilibrium standard for accepting articles and review quality can be obtained from the following system of equations:

$$\begin{aligned}
P_i \delta h w e^{-\delta\alpha_i} - c\alpha_i &= 0 \\
P_j \delta h w e^{-\delta\alpha_j} - c\alpha_j &= 0 \\
D(\alpha_i) - 2\beta P_i + \theta P_j &= 0 \\
D(\alpha_j) - 2\beta P_j + \theta P_i &= 0
\end{aligned}$$

where we can first solve the equilibrium standard for acceptance as a function of α_i and α_j

$$P_i = \frac{2\beta D(\alpha_i) + \theta D(\alpha_j)}{4\beta^2 - \theta^2}$$

and then obtain the best-response function of review quality α_i in terms of α_j

$$G(\alpha_i, \alpha_j) = (2\beta D(\alpha_i) + \theta D(\alpha_j))\delta h w - (4\beta^2 - \theta^2)c\alpha_i e^{\delta\alpha_i} = 0.$$

Because $G(\alpha_i, \alpha_j)$ is a concave function in α_i given $\alpha_j \geq 0$, and $G(0, \alpha_j) > 0$, it follows that a unique α^C exists as the best response of review quality α_i in terms of α_j, such that

$$G(\alpha^C, \alpha_j) = 0$$

and

$$\frac{\partial G(\alpha^C, \alpha_j)}{\partial \alpha_i} = 2\beta(hw)^2\delta^2 e^{-\delta\alpha_i} - (4\beta^2 - \theta^2)(ce^{\delta\alpha_i} + c\delta\alpha_i e^{\delta\alpha_i})|_{\alpha_i = \alpha^C} < 0.$$

In our model we assume that the two peer-reviewed journals are symmetric, and therefore, in equilibrium, the two academic journals must choose the same review quality and standard for accepting articles, i.e., α^C and P^C, respectively. Hence we get the equilibrium condition

$$G(\alpha^C, \alpha^C) = 0$$

which is simplified as

$$\delta h w D(\alpha^C) - (2\beta_0 + \theta)c\alpha^C e^{\delta\alpha^C} = 0,$$

and

$$P^C = \frac{D(\alpha^C)}{2\beta_0 + \theta},$$

where $D(\alpha^C) = A - hwe^{-\delta\alpha^C}$. Therefore, in the equilibrium of the benchmark scenario, each journal's manuscript arrival rate is

$$\lambda^C = D(\alpha^C) - \beta P^C + \theta P^C = \beta P^C = (\beta_0 + \theta)\frac{D(\alpha^C)}{2\beta_0 + \theta},$$

and each journal's utilization rate and expected profit can be calculated as

$$\rho^C = 1 - \frac{1}{w\lambda^C + 1}, \text{ and } \Pi^C = P^C\lambda^C - C(\alpha^C) - \frac{\gamma}{w}.$$

B Proof of Corollary 1.

It is here that we must prove that α^C and P^C are decreasing in θ. In order to prove our results we will follow the same approach as Yuan et al. (2019). We have previously shown in Appendix A that the equilibrium review quality α^C satisfies

$$G(\alpha^C, \alpha^C) = 0$$

with G being a concave function in α, and $G(0, 0) > 0$. Therefore, it follows that

$$G'_\alpha = (\partial G(\alpha, \alpha)/\partial\alpha)|_{\alpha=\alpha^C} < 0,$$

and

$$G'_\theta = (\partial G(\alpha, \alpha)/\partial\theta)|_{\alpha=\alpha^C} = -c\alpha^C e^{\delta\alpha^C} < 0,$$

and we get that

$$\frac{\partial\alpha^C}{\partial\theta} = -\frac{G'_\theta}{G'_\alpha} = \frac{c\alpha^C e^{\delta\alpha^C}}{\delta^2(hw)^2 e^{-\delta\alpha^C} - (2\beta_0 + \theta)ce^{\delta\alpha^C}(1 + \delta\alpha^C)} < 0$$

holding β_0 fixed. Because $\frac{\partial\alpha^C}{\partial\theta} < 0$, we have that the optimal review quality α^C is decreasing in θ, and thus, it follows that the equilibrium standard for accepting papers P^C is also decreasing in θ.

Furthermore, in equilibrium, each journal's profit is calculated as

$$\Pi^C = P^C\lambda^C - C(\alpha^C) - \frac{\gamma}{w} = P^C(D(\alpha^C) - \beta_0 P^C) - C(\alpha^C) - \frac{\gamma}{w},$$

which gives the first-order condition with respect to θ as

$$\frac{\partial\Pi^C}{\partial\theta} = \frac{\partial P^C}{\partial\theta}(D(\alpha^C) - \beta_0 P^C) + P^C\left(\delta hwe^{-\delta\alpha^C}\frac{\partial\alpha^C}{\partial\theta} - \beta_0\frac{\partial P^C}{\partial\theta}\right) - c\alpha^C\frac{\partial\alpha^C}{\partial\theta}$$

which is simplified as

$$\frac{\partial \Pi^C}{\partial \theta} = \frac{\partial P^C}{\partial \theta}(D(\alpha^C) - 2\beta_0 P^C) \leq 0$$

because $\frac{\partial P^C}{\partial \theta} < 0$ and $D(\alpha^C) - 2\beta_0 P^C = \frac{\theta P^C}{2\beta_0 + \theta} \geq 0$.

C Proof of Proposition 2.

Again, in order to prove our results we will follow the same approach as Yuan et al. (2019). Given the quality standards for accepting articles for the two peer-reviewed journals, P_i and P_j, under cooperative peer review, in equilibrium, the optimal review quality $\alpha^O = \alpha(P_i, P_j)$ is such that it maximizes the joint profit of the two academic journals

$$\max_{\alpha} \pi(\alpha, P_i, P_j) = P_i(D(\alpha) - \beta P_i + \theta P_j) + P_j(D(\alpha) - \beta P_j + \theta P_i) - C(\alpha) - 2\frac{\gamma}{w}$$

and thus, it follows that α^O satisfies the first-order condition with respect to α

$$(\partial \pi / \partial \alpha)|_{\alpha = \alpha^O} = (P_i + P_j) hw\delta e^{-\delta \alpha^O} - c\alpha^O = 0,$$

where α^O is increasing in P_i and P_j. This is so because the respective partial derivative in terms of P_i and P_j satisfies

$$\frac{\partial \alpha^O}{\partial P_i} = \frac{\partial \alpha^O}{\partial P_j} = \frac{hw\delta e^{-\delta \alpha^O}}{(P_i + P_j) hw\delta^2 e^{-\delta \alpha^O} + c} > 0.$$

Given journal j's quality standard for accepting articles P_j, in equilibrium, we have that the optimal standard of journal i is obtained through the corresponding profit-maximizing problem

$$\begin{aligned} \max_{P_i} \pi(P_i, P_j) = \quad & P_i(D(\alpha^O) - \beta P_i + \theta P_j) - \phi(\lambda_i, \lambda_j) C(\alpha^O) - \tfrac{\gamma}{w} \\ \text{subject to} \quad & (P_i + P_j) hw\delta e^{-\delta \alpha^O} - c\alpha^O = 0, \\ & \lambda_i = D(\alpha^O) - \beta P_i + \theta P_j, \\ & \lambda_j = D(\alpha^O) - \beta P_j + \theta P_i. \end{aligned}$$

where the peer-review cost-sharing function $\phi(\lambda_i, \lambda_j)$ can be simplified as

$$\phi(\lambda_i, \lambda_j) = 1/2 + t(\beta + \theta)(P_j - P_i)$$

by substituting λ_i and λ_j. Therefore, the optimal standard for accepting articles P_i^* in terms of P_j satisfies the first-order condition

$$D(\alpha(P_i^*, P_j)) - 2\beta P_i^* + \theta P_j + P_i^* hw\delta e^{-\delta\alpha(P_i^*,P_j)} \frac{\partial\alpha(P_i^*,P_j)}{\partial P_i} + \\ t(\beta+\theta)C(\alpha(P_i^*, P_j)) - \phi(\lambda_i, \lambda_j)c\alpha(P_i^*, P_j)\frac{\partial\alpha(P_i^*,P_j)}{\partial P_i} = 0.$$

In a similar way by using the first-order condition we can derive the optimal quality standard P_j^* for journal j, given journal i's standard for accepting articles P_i

$$D(\alpha(P_i, P_j^*)) - 2\beta P_j^* + \theta P_i + P_j^* hw\delta e^{-\delta\alpha(P_i,P_j^*)} \frac{\partial\alpha(P_i,P_j^*)}{\partial P_j} + \\ t(\beta+\theta)C(\alpha(P_i, P_j^*)) - \phi(\lambda_j, \lambda_i)c\alpha(P_i, P_j^*)\frac{\partial\alpha(P_i,P_j^*)}{\partial P_j} = 0.$$

In our model we assume that the two peer-reviewed journals are symmetric, and therefore, in equilibrium, the two academic journals must choose the same standard for accepting articles, i.e., P^O. Hence we get the equilibrium condition by adding up the above equations for P_i^* and P_j^*

$$D(\alpha(P^O, P^O)) - (2\beta_0 + \theta)P^O + t(\beta_0 + 2\theta)C(\alpha(P^O, P^O)) = 0$$

with $2P^O hw\delta e^{-\delta\alpha^O} = c\alpha^O$, which implies the following conditions relative to the equilibrium standard for accepting articles P^O and the equilibrium review quality $\alpha^O = \alpha(P^O, P^O)$

$$2hw\delta(D(\alpha^O) + t(\beta_0 + 2\theta)C(\alpha^O)) - (2\beta_0 + \theta)c\alpha^O e^{\delta\alpha^O} = 0,$$

and

$$P^O = \frac{D(\alpha^O) + t(\beta_0 + 2\theta)C(\alpha^O)}{2\beta_0 + \theta}.$$

Therefore, in the equilibrium of the cooperative scenario, each journal's manuscript arrival rate is

$$\lambda^O = \frac{\beta D(\alpha^O) - t(\beta^2 - \theta^2)C(\alpha^O)}{2\beta - \theta},$$

and each journal's utilization rate and expected profit can be calculated as

$$\rho^O = 1 - \frac{1}{w\lambda^O + 1}, \text{ and } \Pi^O = P^O\lambda^O - \frac{1}{2}C(\alpha^O) - \frac{\gamma}{w}.$$

D Proof of Proposition 3.

In order to prove our results we again follow the same approach as Yuan et al. (2019). From Proposition 2, we have that, in the cooperative peer review scenario, each journal chooses a level of review quality α^O that uniquely satisfies

$$2\delta hw[D(\alpha) + t(\beta_0 + 2\theta)C(\alpha)] - (2\beta_0 + \theta)c\alpha e^{\delta\alpha} = 0$$

at $\alpha = \alpha^O$. Here, for ease of exposition, we define

$$V(\alpha) = 2\delta hw[D(\alpha) + t(\beta_0 + 2\theta)C(\alpha)] - (2\beta_0 + \theta)c\alpha e^{\delta\alpha}.$$

The derivative of $V(\alpha)$ with respect to θ is

$$\frac{\partial V(\alpha)}{\partial\theta} = 4\delta hwtC(\alpha) - c\alpha e^{\delta\alpha}.$$

It is here that we must prove that α^0 and P^0 are increasing in θ, when the cost-sharing factor $t \geq \hat{t}$ with $\hat{t} = \frac{e^{\delta\alpha^O}}{2\delta hw\alpha^O}$. Thus, we have that

$$\begin{aligned}
\frac{\partial\alpha^O}{\partial\theta} &= -\left.\frac{\partial V(\alpha)/\partial\theta}{\partial V(\alpha)/\partial\alpha}\right|_{\alpha=\alpha^O} \\
&= -\left.\frac{4\delta hwtC(\alpha) - c\alpha e^{\delta\alpha}}{2\delta hw[\delta hwe^{-\delta\alpha} + t(\beta_0+2\theta)c\alpha] - (2\beta_0+\theta)(ce^{\delta\alpha} + c\alpha\delta e^{\delta\alpha})}\right|_{\alpha=\alpha^O}.
\end{aligned}$$

Because $\left.\frac{\partial V(\alpha)}{\partial\alpha}\right|_{\alpha=\alpha^O} \leq 0$, if $4\delta hwtC(\alpha^O) - c\alpha^O e^{\delta\alpha^O} \geq 0$, then

$$\frac{\partial\alpha^O}{\partial\theta} \geq 0,$$

and therefore, it follows that α^0 is increasing in θ.

Furthermore, because

$$P^O = \frac{c\alpha^O e^{\delta\alpha^O}}{2\delta hw},$$

it follows that

$$\frac{\partial P^O}{\partial\theta} = \frac{ce^{\delta\alpha^O} + c\alpha^O\delta e^{\delta\alpha^O}}{2\delta hw} \cdot \frac{\partial\alpha^O}{\partial\theta} \geq 0,$$

and we obtain that P^0 is increasing in θ.

E Proof of Proposition 4.

Under competition between the peer-reviewed journals, in equilibrium, each journal chooses a level of review quality α^C that uniquely satisfies

$$G(\alpha^C) = \delta hw(A - hwe^{-\delta\alpha^C}) - (2\beta_0 + \theta)c\alpha^C e^{\delta\alpha^C} = 0.$$

However, under cooperative peer review, each journal chooses in equilibrium a level of review quality α^O that uniquely satisfies

$$V(\alpha^O) = 2\delta hw[A - hwe^{-\delta\alpha^O} + t(\beta_0 + 2\theta)C(\alpha^O)] - (2\beta_0 + \theta)c\alpha^O e^{\delta\alpha^O} = 0.$$

Therefore, for any cost-sharing factor $t > 0$, it follows that

$$G(0) < V(0),$$

and for any $\alpha \geq 0$, we have

$$G(\alpha) < V(\alpha), \text{ and, } G'(\alpha) < V'(\alpha)$$

which indicates that

$$\alpha^C \leq \alpha^O.$$

Hence, because

$$P^O = \frac{D(\alpha^O) + t(\beta_0 + 2\theta)C(\alpha^O)}{2\beta_0 + \theta}, \text{ and, } P^C = \frac{D(\alpha^C)}{2\beta_0 + \theta}, \text{ with, } \alpha^C \leq \alpha^O,$$

it also follows that

$$P^C \leq P^O.$$

Based on Proposition 4 in (Yuan et al., 2019), we show that a t^c exists as given in the proposition. If $t = 0$, that is, each journal splits the review-quality cost equally, then the cooperative peer-review scenario is equivalent to the Benchmark scenario in which each journal's review cost is only $\frac{C(\alpha)}{2}$, given α. Thus, each journal's profit under cooperative peer review with $t = 0$ is always larger than in competition. From Proposition 4 in (Yuan et al., 2019), because the equilibrium profit under cooperative peer review Π^O decreases in $t > t^*$, a threshold t^c exists such that if $0 \leq t < t^c$, $\Pi^O > \Pi^C$, whereas if $t \geq t^c$, it follows that $\Pi^O \leq \Pi^C$.