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A theory of self-selection in a market with matching frictions: An application to delay in refereeing times in economics journals

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ABSTRACT

A matching market with imperfect information is studied. With imperfect information, it is shown that friction in a meeting process can facilitate self-selection and thus may improve the matching outcome. As an application, the effect of delay in refereeing time on publication outcome is analyzed in a publication process in economics journals. Though the delay causes efficiency loss by postponing the dissemination of new research, it will better sort the papers to each journal by their qualities by preventing mediocre papers from being submitted to a prestigious journal and published by luck. If an assortative outcome (good papers in prestigious journals and mediocre papers in less prestigious journals) is efficient, the delay may actually improve the publication outcome. Other matching market examples are also discussed.

1. Introduction

Assignment problems are environments in which applicants and positions need to be matched. The matching process involves each individual's search for the right partner. This process is composed of two steps: (i) applicants and recruiters meet, and (ii) they decide whether to make a match. The process is not without friction in either step.

First, a meeting chance is scarce. Application opportunities are not always available, and once an applicant fails to get a position, a certain amount of time elapses before the next opportunity arises. These frictions are ubiquitous. Most firms have a regular (usually annual) recruiting season, and if a worker fails to get a job during this period, he or she must wait until the next season. In economics journals, once a paper is submitted to one journal, it cannot be submitted to others until the acceptance decision is made. This friction delays the matching process and impairs efficiency.

Second, one may not be able to observe the potential partner's quality when a meeting occurs. When recruiters make recruiting decisions, they cannot perfectly observe the characteristics of applicants. Rather, recruiters use some available information to infer such characteristics. For example, universities admit students based on the various records they submit, but these records may be imperfect signals of their abilities. Academic journals make an acceptance decision largely based on the referees' evaluations, but these evaluations may not be perfect because (1) a referee may have a wrong impression about the paper and (2) a referee's idiosyncratic taste may affect the evaluation. Usually, in assignment problems as mentioned above, recruiters only observe the signals on the qualities of applicants, not the qualities themselves. The applicants may have better knowledge about their own qualities than the recruiters. This imperfect information may hinder the efficiency of the matching process. With imperfect observation, recruiters may end up with less desired applicants.

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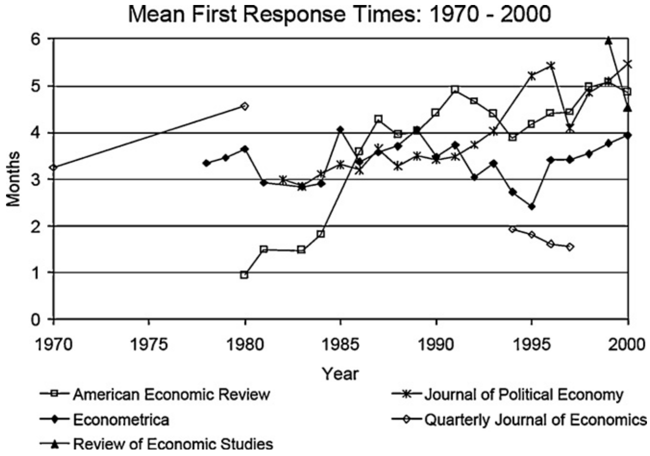

Fig. 1. Mean first response times at top journals [Source: Ellison, 2002a].

Many assignment problems have both frictional aspects. While many papers have addressed the effect of the scarce meeting opportunities (Burdett and Coles, 1997; Montgomery, 1991 among others), little attention has been paid to that of imperfect information. This paper considers an assignment problem taking both aspects into account and investigates how the two interact with each other.[1]

In particular, we are interested in the publishing practice in economics journals. As previously mentioned, the publishing procedure is a typical assignment problem which has the described features. Moreover, in the last four decades, there has been a significant change in this publishing practice: the slowdown of publishing process (Ellison, 2002a). Through the framework of an assignment problem considering both aspects of friction, we can analyze the effect of this delay on the publication outcome.

The slowdown of the publishing process is quite dramatic. It now takes 2 years on average for a paper from submission to acceptance while it took only 6–9 months thirty years ago, which means that friction at the meeting stage has increased. While the major part of the slowdown is attributed to more extensive revisions, the first response time (time between the initial submission and the first editorial decision; henceforth called FRT) has also increased. Fig. 1 shows the change of the mean FRTs of top journals. While some individual journals (Econometrica, QJE) maintain a similar FRT, it increased on average due to the sharp increase in AER and JPE. If we consider additional journals, the FRT increased from 1–2 months in the 1960s to 3–6 months in 2000 (Azar, 2007).

The delays in publication procedures are often seen as the cause of the problem since it delays the dissemination of new research. The delay in the FRT may not be a major part of the whole publishing process, but its contribution to the wider delay makes it an even bigger problem. While more extensive revisions and resulting delays may add value to the papers Laband (1990), delays in the FRT does not seem to give any value added.[2] Moreover, if we consider that a paper can be rejected several times before it is finally published, the FRT's delay effect is much more severe than it appears (Azar, 2004).

However, if we see the quality distribution of published papers in each journal (measured by the number of citations a paper enjoys), it seems that the publication outcome might have improved in the same period. Table 1 shows the frequency of citations which a typical paper of each journal enjoys in 1970, 1980, 1990, and 1998.[3] For comparison, the reported number is a normalized index so that the average of the top 5 journals is 1. We can see that the quality of papers published in the top journals increased relative to papers published in other journals. If we consider that publication of a paper in each journal is perceived as a preliminary evaluation of the paper's quality and a reader's decision whether to read the paper may depend on it, the concentration of high quality papers in top journals is positive in that the publication process sorted the papers very efficiently. This seeming improvement in the publication outcome is at odds with the prevalent concern about the cost of delays in the publication process.

[1] As discussed later, several papers investigated the imperfect information aspect of the matching process concurrently, but with different focuses.

[2] This delay seems even more wasteful if we consider that "Such a paper is delayed not because a referee is taking three months to decide on it but because it is sitting in a pile in his or her desk" (Franklin Fisher cited in Shepherd, 1995, recited from Azar, 2004).

[3] The impact of a typical paper in journal i in year t ($citeratio_{it}$) is calculated by

$$citeratio_{it} = \frac{\sum_{y=t-9}^{t} c(i, y, t)}{\hat{n}(i, t-9, t)}$$

where $c(i, y, t)$ is the number of times papers that appeared in journal i in year y were cited in year t and $\hat{n}(i, t-9, t)$ is an estimate of the total number of papers published in journal i between year $t-9$ and year t. See Ellison (2002a).

Table 1
Normalized citation ratios of journals [Source: Ellison, 2002a]

Journal	Value of *Nciteratio*			
	1970	1980	1990	1998
Top 5 General Interest Journals				
American Economic Review	1.01	1.02	0.73	0.64
Econometrica	0.86	0.95	1.71	1.00
Journal of Political Economy	0.81	1.69	1.11	1.23
Quarterly Journal of Economics	0.94	0.61	0.74	1.37
Review of Economic Studies	1.38	0.74	0.71	0.76
Next-tier General Interest Journals				
Economic Journal	0.65	0.78	0.49	0.33
International Economic Review	0.53	0.53	0.26	0.20
Review of Economics and Statistics	0.95	0.65	0.36	0.29
Average for Group	0.71	0.65	0.37	0.28
Top Field Journals in Major Fields				
Journal of Development Economics		0.28	0.30	0.16
Journal of Econometrics		0.49	0.53	0.36
Journal of Economic Theory	0.78	0.69	0.40	0.21
Journal of International Economics		0.35	0.38	0.26
Journal of Law and Economics	0.71	1.26	0.87	0.51
Journal of Monetary Economics		0.87	0.81	0.45
Journal of Public Economics		0.56	0.34	0.19
Journal of Urban Economics		0.61	0.28	0.24
RAND Journal of Economics		1.11	0.78	0.31
Average for Group	0.75	0.69	0.52	0.30
Some Other Economics Journals				
Canadian Journal of Economics	0.34	0.24	0.18	0.06
Economic Inquiry	0.26	0.44	0.29	0.15
Journal Applied Econometrics			0.32	0.26
Journal of Comparative Economics		0.38	0.24	0.16
Journal of Environmental Ec. & Man.		0.46	0.21	0.16
Journal of Mathematical Economics		0.42	0.28	0.10
Average for Group	0.30	0.39	0.25	0.15

In this paper, we show that the delay in the FRT (more friction in the meeting process) has both positive and negative effects on the publication outcome (assignment outcome). Therefore, we show that our assignment model with aforementioned frictions can accommodate both the prevalent concern about the cost of delay and the seeming improvement of the publication outcome reported in Table 1.

To see the effect of the delay in the FRT, we consider a static model with two different submission rules. One is that a paper can be submitted to all journals at the same time, and the other is that a paper can be submitted to only one journal. Under the former submission rule, we can say that the FRT is 0 (or there is no friction in the meeting process). Even if a paper is rejected, it can be immediately submitted to other journals without any time cost. Under the latter submission rule, on the contrary, we can say that the FRT is very long (or there is severe friction in the meeting process). Once a paper is rejected, it cannot be resubmitted to other journals.

As previously mentioned, the delay in the FRT is harmful since it delays the publication process especially for rejected papers. This concern is also evident in our model. When the submission opportunity is not limited, a high caliber paper can be published in some journals even if it is rejected by a prestigious journal. When the submission opportunity is limited, however, once the same caliber paper is rejected in a prestigious journal, it cannot be published in any other journal. This will cause the deterioration of the published papers' average quality. The prevalent concern about the cost of the delay is confirmed.

However, in the model we can also see the positive impact of a longer FRT, which has not usually been noticed. When the submission opportunity is not limited, a mediocre quality paper will be submitted to a prestigious journal and can be accepted with some luck. When the submission opportunity is limited, however, a mediocre quality paper would not be submitted to a prestigious journal since the cost is too high if it is rejected. Papers will be submitted to journals after the chances of being accepted are carefully weighed. Therefore, papers are well sorted in their qualities according to the prestige levels of journals, with superior quality papers being published in top journals.

Note that the model accommodates the empirical facts reported in Table 1. As is argued, the papers' average quality in top journals improves while the average quality of all published papers deteriorates when the submission opportunity is limited. Thus, in the quality distribution of published papers, the quality of papers published in top journals relative to that of papers published in other journals increases as there is more of a delay in the FRT.

Based on the above argument, this paper shows that the delay in the FRT may actually improve the publication outcome. Whether the delay in the FRT improves the efficiency of the publication process is dependent on the complementarity between the papers' qualities and the journals' prestige. That is, if we believe that an assortative matching (good quality papers published in prestigious journal and mediocre quality papers in less prestigious journals) is better than a mixed matching, the gains from the well-sorted publication will dominate the cost of the deterioration of the published papers' average quality.

Though we use the context of publishing practice in the model description and analysis, the argument of this paper can generally be applied to other assignment problems. Our model tells us that in a market with private information, the frictions in the meeting process can facilitate self-selection. Other assignment problems will be discussed later with the perspective of this paper's argument.

The paper proceeds as follows. Section 1.1 will briefly discuss related literature. Basic intuition for the main result will be obtained by a simple example in Section 2. Section 3 will introduce the full model and Section 4 will analyze the equilibrium. The outcomes of different submission rules will be compared and thus the efficiency effect of the delay is analyzed in Section 5. Section 6 will conclude by discussing more applications.

1.1. Related literature

The assignment (matching) problem is an old subject in economics. Much of the literature are interested in the stability of the centralized matching mechanism, which originated from Gale and Sharpley (1962). The classic paper about the decentralized matching problem, which is this paper's subject, is Becker (1973). With complementarity of partners' traits in the production function, the efficient assignment is positively assortative. Becker shows that in a frictionless environment this efficient outcome is achieved.

In the decentralized matching problem, friction in the meeting process is introduced in two ways. First, a meeting is randomly made and its chance is scarce (called 'search friction'). For example, Burdett and Coles (1997) deal with this problem in a marriage market context and show that matching is made based on class partition. Second, a meeting is directed but its chance is limited. Montgomery (1991) studies a labor market with two identical firms and two identical workers, in which the firms post the wage and the workers apply to one firm. In this environment, there only exists a mixed strategy equilibrium. Workers' independent mixing implies the possibility that one firm attracts two workers while the other firm attracts none. This is called 'matching friction' or 'coordination friction.' This paper deals with the second type of friction.

All the literature mentioned above, however, do not deal with the informational problem that potential partner's traits are imperfectly observed. This paper integrates this informational problem in an assignment problem. This informational problem has only very recently been addressed. Chakraborty et al. (2009) deals with a similar environment, but is interested in the stability of a centralized matching mechanism.[4] Chade (2006) introduces private information to the framework of Burdett and Coles (1997) rather than that of Montgomery (1991).[5] The most closely related paper is Chade et al. (2009). Using college admission as a context, however, they are interested in the matching outcome when there exists a fixed application cost rather than a comparison between different submission (application) rules. Their interest lies in more traditional and theoretical questions in this line of literature; whether the positive assortative matching is preserved when an informational problem is added. This paper focuses instead on an efficiency comparison of different submission rules.

Specifically, we use the publishing practice as a major application.[6] The delay in turn-around times in economics publishing process has long been recognized. Yohe (1980) and Trivedi (1993) tried to correctly recognize how serious the existing situation was based on the presumption that a publication delay causes problems. Ellison (2002a) did not only recognize the situation but also tried to investigate the cause of the tendency of prolonged delays. Ellison focused on the more extensive revision as a major part of the delay, and investigated several candidate causes which were suggested through discussions with other economists. He concluded that the change in academic environments cannot fully explain the delay, and suggested that the change in social norms might be the cause. In a subsequent paper (Ellison, 2002b), he suggested a model which can explain the delay as a tendency. This paper, unlike Ellison, focuses on the delay in the FRT and investigates the effects of the delay, not the cause of it. The beneficial effect of the delay in publishing practice was discussed by Azar (2004, 2007) and Leslie (2005), but their main interest was the reduced refereeing burden resulting from the reduced submission rather than sorting benefit, which is the main interest of this paper.

2. Motivating example

In this section, we will see a simple example illustrating the main point of the paper. In the model description and analysis including this section, we will use academic journals' publishing practices as a context.

[4] Chakraborty et al. argues that the existence of stable matching mechanism may not generally exist, but exists when the preferences are identical and information on the matching outcome is restricted.

[5] Chade shows that the main characteristic of an optimal search strategy is preserved. That is, each agent sets a reservation signal and that the optimal reservation signal is increasing in agent's trait.

[6] There are other papers studying various aspects of publishing practice other than delay in turn-around times. Among others, McCabe and Snyder (2005) deals with open access practice and Ellison (2007) studies the tendency that top economists published their papers in other outlets than peer-reviewed journals. Here we concentrate on the papers concerning the delay in turn-around times.

There are unit mass of papers and two journals, J_1 and J_2. Papers are different in their qualities with two quality levels, q_H and $q_L(q_H > q_L)$ and the papers of each quality have the same mass, (1/2). Each journal publishes (1/4) mass of papers, and they have different levels in regards to reputation so that everyone prefers publishing a paper at J_1. Specifically, if a paper is published at the journal $J_1(J_2)$, the author will get $V_1(V_2)$ utility, and $V_1 > V_2$. Each journal prefers publishing the better quality paper. Though the author of a paper knows its quality, the journal cannot observe each paper's quality q, but only a signal s. This signal is binary, $s \in \{s_H, s_L\}$, each representing high and low signals. The distribution of the signal satisfies:

$$Pr(s_i|q_i) = p > \frac{1}{2} \text{ for } i = H, L$$

That is, a high quality paper is more likely to show a high signal while a low quality paper is more likely to show a low signal. The signal observed by each journal is assumed to be the same.[7]

To evaluate the publication outcome, we should have an efficiency standard. We assume that it is socially efficient to have an assortative outcome, in which better quality papers are published in more prestigious journals. As is argued in Section 1, publication of a paper in each journal is a preliminary evaluation of the paper and affects the readers' decision whether to read it. Therefore, it would be better to publish a better paper in a more prestigious journal. Specifically, each journal's publication outcome has an output defined by $r_j q$ where q is the quality of a paper and r_j is a journal specific coefficient, and r_j is larger for more prestigious journal ($r_1 > r_2$).

I will consider two possible submission rules to capture the effect of the delay in publication process. One is that a paper can be submitted to all journals at once, and the other is that a paper is submitted to only one journal.

2.1. Submission to both journals

All papers will be submitted to both journals. Since multiple submission is possible, the author of a paper may decide in which journal to publish his paper if accepted by both journals. A paper is published when it is accepted by the journal and the author decides to publish it in that journal.

Journals will accept the paper to fulfill the required mass of publication. Since the authors prefer publishing a paper in J_1 to in J_2, they will only publish their papers in J_2 when rejected by J_1. Note that a journals' acceptance decision is based on the commonly observed signal. Therefore, the top (1/4) mass in the distribution of this commonly observed signal will be published in J_1 while the next top (1/4) mass will be published in J_2. Since the mass of papers with signal s_H is (1/2), a randomly chosen half will be published in J_1. Those papers showing s_H which failed in being accepted by J_1, will be published in J_2. As a result, all papers with s_H will be randomly assigned either to J_1 or to J_2.

The expected quality of the published papers in both journals will be the same, and is the expected quality of papers with signal s_H.[8]

$$E(q|J_1) = E(q|J_2) = pq_H + (1 - p)q_L$$

2.2. Submission to only one journal

In this case, authors will determine which journal to submit their papers to. We will construct an equilibrium in which the papers of quality q_H are submitted to J_1 while those of quality q_L to J_2. Each journal will accept the paper with a higher signal.

Among the papers submitted to J_1, $(1/2)p$ mass will show signal s_H which is more than the publication capacity (1/4). Therefore, papers with a high signal will be randomly accepted by J_1. The probability of a paper with signal s_H being accepted is $(1/4/p/2) = (1/2p)$. Among the papers submitted to J_2, $(1/2)(1 - p)$ will have signal s_H which is less than the capacity (1/4). Papers with signal s_L will also be accepted with probability $((1/4) - (1/2)(1 - p)/(1/2)p) = (2p - 1/2p)$.

This conjecture is an equilibrium if the authors of q_H (q_L) papers choose to submit to J_1 (J_2) given the journals' acceptance standard. This decision is based on the expected utility of submission which is calculated given the probability of publication. For example, if a paper of quality q_H is submitted to J_1, it is published when it shows signal s_H and is then selected with probability $(1/2p)$. Therefore, its publication probability is $p * (1/2p) = (1/2)$. If it is submitted to J_2, it is published if it shows signal s_H, or it shows signal s_L but is selected with probability $(2p - 1/2p)$. Its publication probability is $p + (1 - p)(2p - 1/2p)$. The author of q_H paper will submit his paper to J_1 if:

$$\frac{1}{2}V_1 \geq \{p + (1 - p)\frac{2p - 1}{2p}\}V_2.$$

[7] It is more likely that the evaluations of the same paper are different between journals. However, we assume that they are the same so that different submission rules give the same amount of information on the whole. If there are different signals on the same paper, the additional submission opportunity will give more information about the quality of a paper. When there is no refereeing cost, the additional chance of submission will always be beneficial.

[8] The same average quality of the published papers in two journals is the artifact of discrete signal structure of this example, which is designed for simplicity. As is in the main model later, the more prestigious a journal is, the better the average quality of the published papers.

The same kind of reasoning can be applied to an author's decision of q_L paper. He chooses to submit his paper to J_2 if:

$$(1-p)\frac{1}{2p}V_1 \leq \frac{1}{2}V_2.$$

Manipulating these two inequalities gives:

$$\frac{3p-1}{p} \leq \frac{V_1}{V_2} \leq \frac{p}{1-p}. \tag{1}$$

In summary, if Eq. (1) is satisfied, it is an equilibrium that q_H papers are submitted to J_1 and q_L papers are submitted to J_2. In this equilibrium, the quality of published papers in each journal will be:

$$E(q|J_1) = q_H$$
$$E(q|J_2) = q_L$$

2.3. Comparison of two submission rules

If a paper can be submitted to both journals concurrently, it can have a second chance at being published even if it is not accepted by the more prestigious journal. This second chance will increase the good quality paper's publication probability. If a paper can be submitted to only one journal, however, a good quality paper is not published at all (or published very late after the long delay) if not accepted by the prestigious journal. Hence the average quality of the published papers will decrease if the chance of submission is limited.

$$\frac{1}{2}q_H + \frac{1}{2}q_L < pq_H + (1-p)q_L$$

However, the average quality of published papers in the more prestigious journal is higher when a paper is submitted to only one journal. When a paper can be submitted to both journals, a lower quality paper will be submitted to the more prestigious journal and may be accepted by chance. However, if the opportunity for submission is limited, papers will be self-selected in the submission decision based on the difference of their publication possibility in each journal. Low quality papers would not be submitted to the prestigious journal because of a low probability of publication. Therefore, the average quality of papers published in the prestigious journal will increase while that of papers in the mediocre journal will decrease.

$$q_H > pq_H + (1-p)q_L > q_L$$

Conceptually, an assignment of papers to each journal can be thought of as a two-step process involving selection and allocation. First, the papers to be published are selected. Second, selected papers will be allocated to each journal. If the submission opportunity is limited, the selected papers' average quality will be lower (loss in selection efficiency), but high quality papers will be published in the prestigious journal (gain in allocative efficiency). As the assortative assignment outcome is more important in its evaluation, the gain in allocative efficiency can dominate the loss in selection efficiency. In this example, the publication outcome will be better when a paper is submitted to only one journal than if submitted to both journals on condition that:

$$\frac{r_1}{r_2} \geq \frac{p}{1-p}.$$

The condition says separate competition yields a better outcome if the importance of assortative assignment outcome $((r_1/r_2))$ is large enough. As signal is more accurate (p gets larger), the gain in allocative efficiency by self-selection gets smaller and the above condition is less likely to be satisfied.

3. Model

Now we introduce the general model and confirm that the idea of the above example can be extended to the more general setting.

3.1. Papers (Authors)

There are a unit mass of papers. Papers have different qualities q. This quality is known only to the author. Papers' qualities are continuously distributed over $[\underline{q}, \bar{q}]$ with distribution function $F(q)$ and density function $f(q)$. Since a paper or its author can be fully identified by the paper's quality q, we hereafter use q to denote either a paper of quality q or its author depending on the context.

3.2. Journals

There are n journals $\{J_1, J_2, \cdots, J_n\}$, each of which has a publication space p_j respectively. We assume that the mass of papers is always larger than the available space, i.e. $\sum_{j=1}^{n} p_j < 1$. That is, some papers cannot be published in the end, and there always exists competition for publication.

3.3. Preference

Authors have a common preference over these journals. That is, the prestige hierarchy of journals is commonly perceived. We assume journals are ordered according to this common preference and $J_j > J_{j'}$ if $j < j'$. Specifically, an author gets utility V_j when his paper is published in J_j and $V_j > V_{j'}$ if $j < j'$. This value can be interpreted as the prestige carried by each journal. In this paper, we assume this value is exogenously given and cannot be controlled in the short term. Journals also have a common preference over papers, and prefer to publish higher quality papers.

3.4. Information

While a paper's quality is known to the author, it is not perfectly observed in the journal's editorial decision process. A publication decision is made based on the observed signal s. Referee evaluations and the editor's impression of the paper will work as a signal. A signal is continuously distributed in [0,1] conditioned on a paper's quality with density and distribution function, $g(s|q)$ and $G(s|q)$. I assume that $G(s|q)$ is continuous in q. This signal is informative about the quality of papers as in the following assumption.

Assumption 1. The conditional signal distribution has common support [0,1] and satisfies the monotone likelihood ratio property (MLRP).

$$\frac{g(s|q_i)}{g(s|q_{i'})} \text{is non-decreasing in } s \text{ if} q_i > q_{i'}$$

Assumption 1 means that the higher the observed signal, the more likely it is from the high quality paper. We assume the observed signal for all journals are the same.[9] If this signal is independently drawn, which is more likely to be a case, the detail of the following analysis will change, although the main point of the paper will remain the same.

3.5. Submission rules

We consider two submission rules. One allows a paper to be submitted to only one journal. The other has no restriction on submissions. To put it differently, under the former rule, the marginal cost of submitting a paper to one more journal is infinity while it is 0 under the latter. As mentioned in Section 1, these two submission rules are polar cases of variant delay in the FRT.[10]

3.6. Efficiency evaluation

To evaluate the publication outcome, we assume the output function $h(r, q)$. This output function is a function of journals' traits r and papers' quality q. A journal has a better trait as its prestige improves, that is, $r_j > r_{j'}$ if $j < j'$. If a paper of quality q is published in a journal with trait r, it will have an output $h(r, q)$ and a journal's output can be thought of as the integration of $h(r, q)$ for all the published papers. The sum of all journals' output will be the criterion by which the assignment outcome is evaluated. As in the motivating example in Section 2, the distribution of r in journals represents how an assortative matching is important in the efficiency evaluation. I assume the output function $h(r, q)$ satisfies:

$$h_1 > 0, h_2 > 0, h_{12} \geq 0.$$

[9] As mentioned in footnote 4, we made this assumption to ensure a fair comparison of the two submission rules.
[10] By analyzing the effect of the delay in a static setting, we ignore one aspect of the cost caused by a longer delay, which is the publication delay of accepted papers.

3.7. Time line

The time line of the model is as follows.

1. Papers will be submitted to journals. If papers can be submitted to only one journal, authors should decide where to submit their papers. If there is no limit on submissions, papers will be submitted to all journals.
2. Editors will make publication decisions.
3. If a paper is accepted by multiple journals, the author will decide where to publish it.

4. Equilibrium

4.1. Pooled competition: submission to multiple journals

The editors of each journal want to publish the highest quality papers possible. From Assumption 1, a higher signal means, on average, higher quality. Therefore, the optimal publication decision should be a cut-off rule. That is, if the papers' signals are higher than the cut-off, they will be accepted for publication. If a paper is accepted in multiple journals, the author will choose the most prestigious journal among them. Editors will decide the cut-off to fulfill the publication space considering some of the accepted papers would be published in more prestigious journals.

Given the distribution of papers' qualities and conditional signal distribution, we can think of the ex ante distribution of papers' signals. By abusing the notation, let's denote the signal distribution by distribution function $G(s)$.

$$G(s) = \int_{\underline{q}}^{\bar{q}} G(s|q)dF(q)$$

By the law of large numbers (we have a continuum of papers), this ex ante distribution coincides with the realized distribution. Editorial decisions are based on the realized signal.

For J_1, all accepted papers will be published. To fill the publication space, J_1 should set the cut-off c_1 so that the mass of papers with higher signal than c_1 is exactly p_1, that is $1 - G(c_1) = p_1$. When J_2 set its cut-off c_2, it is taken into consideration that all papers with a signal higher than c_1 will be published in J_1, and the cut-off c_2 will be determined so that the mass of papers with signals between c_1 and c_2 is exactly p_2, that is $G(c_1) - G(c_2) = p_2$. The same is true for all other journals.

As a result, the matching outcome is decided by the distribution of papers' signals which I call a process of 'a pooled competition.' A profile of the cutoff $\{c_j^p\}_{j=1}^n$ (superscript p denotes pooled competition) will characterize the outcome. If a paper's signal s is between c_{j-1}^p and c_j^p, it will be published in journal J_j. Therefore, the mass of papers with signal higher than c_j^p is equal to the sum of publication spaces of journals from J_1 to J_j, and the profile of cutoffs satisfies:

$$1 - G(c_j^p) = \sum_{k=1}^{j} p_k \text{ for } j = 1, \cdots, n. \tag{2}$$

Since the matching outcome is determined by (2), the publication output of each journal H_j^p can be calculated based on it. The mass of papers with quality q published in J_j is the mass of papers with quality q and signal s between c_j^p and c_{j-1}^p, and this is $f(q)[G(c_{j-1}^p|q) - G(c_j^p|q)]$. For those papers, the outcome is $h(r_{j,}q)$. The publication outcome of journal J_j is obtained by integrating it by all quality levels.

$$H_j^p = \int_{\underline{q}}^{\bar{q}} h(r_{j,}q)[G(c_{j-1}^p|q) - G(c_j^p|q)]dF(q)$$

The total output H^p will be the sum of them.

$$H^p = \sum_{j=1}^{n} \overset{p}{\underset{j}{H}}$$

4.2. Separate competition: submission to one journal

When papers can be submitted to only one journal, authors should make their choice by comparing the expected payoffs. The expected payoff is dependent on the papers' probability of getting accepted in each journal, which is determined by a journal's publication decision. Since the editor's optimal decision is to set the cutoff signal once the pool of submitted papers are given, each journal's publication decision is, in turn, dependent on the authors' submission choices. Therefore, in equilibrium, authors' submission decisions are optimal given the journals' cutoff signals and journals' cutoff signals are set to fill the publication space given the authors' submission decisions.

If a profile of submission decisions is given, each journal will have a distribution of signals from submitted papers and the cutoff is then determined to fill the publication space. Since the competitions for each journal's publication are separated by submission decisions, I call this separate competition. Authors' submission decisions can be denoted as a partition $\{Q_j\}_{j=1}^n$ where Q_j is the set of papers which are submitted to journal J_j. Then, for journal J_j, the cutoff c_j^s (superscript s denotes separate competition) is determined so that the mass of papers in Q_j which show a higher signal than the cutoff c_j^s is exactly the publication space p_j.

$$\int_{Q_j} [1 - G(c_j^s|q)]dF(q) = p_j \tag{3}$$

Note that c_j^s does not exist to satisfy (3) if the mass of papers in Q_j is less than the publication space p_j. In this case, all submitted papers will be accepted and the cutoff is 0, the minimum signal level.

Authors will submit their papers to a journal which gives the highest expected utility. Given the cutoff profile $\{c_j^n\}_{j=1}^n$ of all journals, authors can calculate the expected utility of submissions to each journal. If paper q is submitted to journal J_j, the expected utility is $V_j[1 - G(c_j^s|q)]$. Therefore, Q_j should be a set of papers whose expected utility is maximized when submitted to J_j.

$$Q_j = \{q|j \in \arg\max_{j'} V_{j'}[1 - G(c_{j'}^s|q)]\} \tag{4}$$

In equilibrium, authors' submission choices and the publication decisions of each journal should be consistent. Therefore, an equilibrium can be summarized in a partition $\{Q_j\}_{j=1}^n$ which represents submission choices and a profile of cutoff signals $\{c_j^s\}_{j=1}^n$ which represents publication decisions.

Definition 1. An equilibrium of a separate competition (submissions to only one journal) is a pair $(\{Q_j\}_{j=1}^n, \{c_j^s\}_{j=1}^n)$ satisfying (3) and (4).

Now, we characterize an equilibrium. Let us start with a profile of cutoff signals. The first thing to note is that a paper will have more difficulty being published in the preferred journal. That is, the cutoff should be higher in a preferred journal in equilibrium. If the cutoff signal of a less preferred journal is higher than that of a preferred journal, authors will never submit their papers to the less preferred journal. Since there will be no submission to this less preferred journal, the cutoff of this journal should be 0 and cannot be higher than that of a preferred journal. Therefore, in equilibrium, cutoff signals should be in order of the prestige of journals.

In the above argument, we cannot exclude that there are less submitted papers than the publication space for some journals in equilibrium. Then all the papers submitted to that journal will be accepted and the cutoff signal is 0. However, since the cutoff signals are in order of the prestige of journals, those journals which have 0 cutoff signals will be concentrated on the lower end of prestige hierarchy. That is, if one journal has 0 cutoff signal, all journals which have a lower prestige will also have 0 as their cutoff. If two journals have 0 cutoff (that is, all submitted papers are accepted), every author will prefer to submit his paper to the more prestigious one of the two. Therefore, among two journals with 0 cutoff, only the preferred journal may have a positive mass of submitted papers.

Lemma 1. *In equilibrium, the publication standard is higher for a preferred journal, and thus the ex ante probability of acceptance is lower when a paper is submitted to the preferred journal. That is,* $c_j^s \geq c_{j'}^s$ if $j' > j$. *Equality holds only when there is no competition for space in both journals*, i.e. $c_j^s = c_{j'}^s = 0$. *In this case, there will be no submitted papers in the less preferred journal.*

From here on, we will consider a case in which there are more submitted papers than available publication space in every journal. This will hold in equilibrium if the sum of all journals' publication spaces is sufficiently low. Then Lemma 1 is restated as $c_j^s > c_{j'}^s$ if $j' > j$ (weak inequality is replaced with strong inequality).

Given the cutoff signals in order, we now move to the authors' submission decisions. We consider the relationship between preference orderings of authors q and q' (q has a better quality paper than q', $q > q'$) over two journals J_j and $J_{j'}$ (J_j is more preferred to $J_{j'}$, $j' > j$). From Lemma 1, we know that the cutoff of J_j is higher than that of $J_{j'}$ ($c_j^s > c_{j'}^s$). Given these cutoffs, authors will form a preference ordering over submissions of their papers to different journals.

Suppose that an author with low quality paper q' prefers submitting his paper to J_j rather than $J_{j'}$.

$$V_j[1 - G(c_j^s|q')] \geq V_{j'}[1 - G(c_{j'}^s|q')] \tag{5}$$

The question is whether an author with high quality paper q also prefers submitting his paper to J_j. Obviously, a high quality paper will have a higher probability of being accepted in both journals than a low quality paper. Therefore, the answer to the question is related to which probability increases relatively more. If we rewrite (5), then:

$$\frac{V_j}{V_{j'}} \geq \frac{1 - G(c_{j'}^s|q')}{1 - G(c_j^s|q')} \tag{6}$$

The left hand side of (6) is the prestige ratio of two journals. This is common for all authors. The right hand side is the ratio of probability of the paper being accepted in each journal. If this expression is lower for high quality paper q, then author q will also prefer submitting his paper to J_j. The right hand side is lower for a high quality paper if the probability of being accepted in more prestigious journal J_j increases relatively more than that in less prestigious journal $J_{j'}$. This turns out to be true with assumption 1. That is, if the signal distribution satisfies monotone likelihood ratio property, the probability of getting a higher signal increases more rapidly as the quality of a paper increases. Therefore, if an author prefers submitting his paper to the more prestigious of the two journals, this will be the case for all authors with higher quality papers.

Lemma 2. *With Monotone Likelihood Ratio Property of signal* (Assumption 1), *for any two journals J_j and $J_{j'}$ such that J_j is more prestigious than $J_{j'}$ or $j' > j$, if author q' prefers submitting his paper to the more prestigious journal J_j, then any author q with a higher quality paper* ($q > q'$) *also prefers submitting his paper to J_j.*

Proof. It is sufficient to show that the right hand side of (6) is decreasing as the quality of the paper increases. That is, we want to show $(1 - G(c^s_{j'}|q)/1 - G(c^s_j|q)) \leq (1 - G(c^s_{j'}|q')/1 - G(c^s_j|q'))$ if $q > q'$ and $c^s_j > c^s_{j'}$ by Lemma 1. By MLRP,

$$g(s|q)g(s'|q') \geq g(s|q')g(s'|q) \text{ if } q > q' \text{ and } s > s'. \tag{7}$$

Integrating both sides of (7) over s from s' to 1 gives the familiar monotone hazard rate condition:

$$\frac{g(s'|q)}{g(s'|q')} \leq \frac{1 - G(s'|q)}{1 - G(s'|q')}.$$

Integrating both sides of (7) over s' from s' to s by abusing notation gives

$$\frac{g(s|q)}{g(s|q')} \geq \frac{G(s|q) - G(s'|q)}{G(s|q') - G(s'|q')}.$$

Combining the above two inequalities,

$$\frac{G(s|q) - G(s'|q)}{1 - G(s|q)} \leq \frac{G(s|q') - G(s'|q')}{1 - G(s|q')} \text{ if } q > q' \text{ and } s > s'. \tag{8}$$

We get what we want to show by adding 1 to both sides. □

We now consider two adjacent journals in prestige hierarchy, J_j and J_{j+1}. What is shown in Lemma 2 is that there exists a cutoff quality $\tilde{q}_j$ such that all authors with papers of higher quality than $\tilde{q}_j$ prefer submitting their papers to J_j and those with papers of lower quality than $\tilde{q}_j$ prefer submitting papers to J_{j+1}. There are $n - 1$ pairs of these adjacent journals and we can define a list of cutoff qualities $\{\tilde{q}_j\}_{j=1}^{n-1}$ in the same manner.

Note that this list of cutoff qualities may not provide sufficient information for authors' submission decisions. Suppose, for example, we have three journals J_1, J_2, and J_3. We can define $\tilde{q}_1$ and $\tilde{q}_2$ in the same way. Suppose that $\tilde{q}_1 < \tilde{q}_2$. Consider author q such that $\tilde{q}_1 < q < \tilde{q}_2$. Author q prefers submitting his paper to J_1 or to J_3 than to J_2. However, in order to know author q's submission decision, we should decide which journal is preferred between J_1 and J_3, which requires the information about another cutoff quality between J_1 and J_3.

This problem occurs since $\tilde{q}_1 < \tilde{q}_2$. However, this is not possible in equilibrium. If this were to be the case, all authors would submit their papers either to J_1 or to J_3 and there would be no submission to J_2. The cutoff signal in J_2 should be 0. By Lemma 1, the cutoff signal in J_3 should be also 0 and all authors prefer submitting their papers to J_2 than to J_3, which means $\tilde{q}_2 = \underline{q}$. This contradicts $\tilde{q}_1 < \tilde{q}_2$. The same argument can be applied to the general model with n journals and an aforedefined list of cutoff qualities will summarize the authors' submission decisions.

Lemma 3. *In equilibrium, if author q prefers submitting to J_j than to J_{j+1}, then the preference would likewise be in submitting to J_j than to any journals with a lower prestige than J_{j+1}. Thus cutoff qualities $\{\tilde{q}_j\}_{j=1}^{n-1}$ are ordered, that is, $\tilde{q}_j > \tilde{q}_{j+1}$ for all $j = 1, \cdots, n-2$.*

From Lemma 3, we know that the only possible equilibrium configuration is stratification (i.e. papers submitted to more prestigious journals have a better quality than those submitted to less prestigious journals) and an ordered list of cutoff qualities $\{\tilde{q}_j\}_{j=1}^{n-1}$ will summarize the submission decisions. An author with a paper of quality $q \in [\tilde{q}_j, \tilde{q}_{j-1})$ will submit to journal J_j and pools of submitted papers in different journals are stratified in their qualities.

For expositional convenience, I define $\tilde{q}_0 = \bar{q}$ and $\tilde{q}_n = \underline{q}$ and write the list of cutoff qualities as $\{\tilde{q}_j\}_{j=0}^{n}$. The partition $\{Q_j\}_{j=1}^{n}$ which represents the authors' submission choices in equilibrium definition can be substituted by this ordered list of cutoff qualities $\{\tilde{q}_j\}_{j=0}^{n}$, and $Q_j = [\tilde{q}_j, \tilde{q}_{j-1})$. We can rewrite the equilibrium definition using $\{\tilde{q}_j\}_{j=0}^{n}$.

Corollary 1. *The pair of profiles* $(\{\tilde{q}_j\}_{j=0}^{n}, \{c^s_j\}_{j=1}^{n})$ *is an equilibrium if*

$$\int_{\tilde{q}_j}^{\tilde{q}_{j-1}} [1 - G(c^s_j|q)]dF(q) = p_j \text{ for } j = 1, \ldots, n \tag{9}$$

and

$$V_j[1 - G(c_j^s|\tilde{q}_j)] = V_{j+1}[1 - G(c_{j+1}^s|\tilde{q}_j)] \text{ for } j = 1, \ldots, n-1 \tag{10}$$

In each journal J_j, the pool of submitted papers is $[\tilde{q}_j, \tilde{q}_{j-1})$. The cutoff signal for publication decision will be determined to fill the publication space by (9). Given the profile of cutoff signals in each journal, the author with a paper of the cutoff quality is indifferent between two adjacent journals in his submission decision as shown in (10). By utilizing this alternative definition of equilibrium, we can show there exists a unique equilibrium.[11]

Lemma 4. (*Existence and Uniqueness*) *There exists a unique equilibrium* $(\{\tilde{q}_j\}_{j=0}^n, \{c_j^s\}_{j=1}^n)$ *in the submission game.*

Proof. The existence can be proved using the fixed point argument. The proof is in Appendix A. Here we prove uniqueness. Suppose there exists two distinct equilibria $(\{\tilde{q}_j\}_{j=0}^n, \{c_j^s\}_{j=1}^n)$ and $(\{\tilde{q}'_j\}_{j=0}^n, \{c_j^{s'}\}_{j=1}^n)$. Let k be the smallest j such that $c_j^s \neq c_j^{s'}$. If $k > 1$, (9) leads to $\{\tilde{q}_j\}_{j=0}^{k-1} = \{\tilde{q}'_j\}_{j=0}^{k-1}$ since $\{c_j^s\}_{j=1}^{k-1} = \{c_j^{s'}\}_{j=1}^{k-1}$. However, since $c_k^s \neq c_k^{s'}$, (10) shows that $\tilde{q}_{k-1} \neq \tilde{q}'_{k-1}$, which is a contradiction. If $k = 1$, suppose $c_1^s > c_1^{s'}$ without loss of generality. Then $\tilde{q}_1 < \tilde{q}'_1$ due to (9). In turn, (10) guarantees $c_2^s > c_2^{s'}$. Again with (9), $\tilde{q}_2 < \tilde{q}'_2$ and so on. This process will lead to $\tilde{q}_{n-1} < \tilde{q}'_{n-1}$ and $c_n^s > c_n^{s'}$ which contradicts (9) when $j = n$. □

The output of each journal H_j^s (superscript s denotes separate competition) can be calculated.

$$H_j^s = \int_{\tilde{q}_j}^{\tilde{q}_{j-1}} h(r_j, q)[1 - G(c_j^s|q)]dF(q)$$

And total output H^s will be the sum, $\sum_{j=1}^n H_j^s$.

5. Comparison of two submission rules

Now we can compare the outcomes of two submission rules. Given the traits of journals, the total output of each outcome is solely dependent on the quality distribution of published papers. Thus we will concentrate on the comparison of quality distributions under two submission rules.

As mentioned before, we can conceptually decompose the publication procedure into two steps. We should first select the papers to be published regardless of the journal in which they are published. Then we can decide where to publish these selected papers. We will call these two steps selection and allocation respectively, and compare the quality distributions following each step.

First, a separate competition had inefficiency in a selection step. In a separate competition, high quality papers are submitted to high prestige journals and some of them must be rejected.[12] These high quality papers can not be published elsewhere once they are rejected, contrary to a pooled competition in which they can be published in low prestige journals. Instead of these high quality papers, low quality papers will fill more publication space. As a result, the quality distribution of all published papers will deteriorate in a separate competition.

Proposition 1. *The quality distribution of all published papers in a pooled competition first order stochastically dominates(FOSD) the quality distribution in a separate competition.*

Proof. In Appendix A □

The deterioration of published papers' qualities in a separate competition shows the cost of a longer FRT. If FRT is longer, a high quality paper which is rejected in a very prestigious journal will not be published for a long time.

In an allocation step, a separate competition will provide better sorting than a pooled competition. Papers will be self-selected in the submission stage. Therefore, allocation is fully stratified among the selected papers, i.e. a paper's quality in a higher prestige journal cannot be lower than a paper's quality in a lower prestige journal. In a pooled competition, on the contrary, allocation is more mixed, in that the qualities of published papers in each journal are more widely spread than in a separate competition. We can say that the allocation is more assortative in a separate competition than in a pooled competition.

Specifically, the quality distribution of published papers in the most preferred journal J_1 will improve in a separate competition. While some low quality papers will be published in J_1 in a pooled competition, they will not be submitted in

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[11] The cutoff qualities can be defined as above since $G(s|q)$ is continuous in q. Otherwise, $\tilde{q}_j$ can be defined as:

$$\tilde{q}_j = \min\{q|V_j[1 - G(c_j^s|q)] \geq V_{j+1}[1 - G(c_{j+1}^s|q)]\}$$

[12] This is because there should be more submitted papers than publication spaces in high prestige journals in equilibrium. This will be true even when the total publication space is the same as the mass of papers. This is sometimes called "matching friciton" or "coordination friction" in the matching literature.

the first place and thus not be published in a separate competition. Therefore, better quality papers will fill the publication space instead. Likewise, the quality distribution of published papers in the least preferred journal will deteriorate in a separate competition.[13]

Proposition 2. *The quality distribution of published papers in the most preferred journal J_1 in a separate competition first order stochastically dominates (FOSD) that in a pooled competition. The reverse is true in the quality distribution of the least preferred journal J_n.*

Proof. In Appendix A □

Since output improves with higher quality, the improvement in quality distribution will result in improved output. Therefore, Proposition 2 implies that output will improve in the most preferred journal while it will deteriorate in the least preferred journal in a separate competition.

$$H_1^p < H_1^s$$
$$H_n^p > H_n^s$$

Note that the average quality of published papers of the top journal is higher in a separate competition while that of all published papers is lower than in a pooled competition. Therefore, the quality ratio of published papers of the top journal to all journals is higher in a separate competition than in a pooled competition. This implication is consistent with the empirical facts reported in Table 1 considering that there has been a significant increase in the FRT during this period.

For all journals other than J_1 and J_n, the comparison of published papers' quality distribution under two submission rules is not definite. In a journal J_j ($j \neq 1$ or n), the support of quality distribution in a separate competition is $[\tilde{q}_j, \tilde{q}_{j-1})$, while it is $[\underline{q}, \bar{q}]$ in a pooled competition. That is, there are both higher quality papers and lower quality papers published in a pooled competition than in a separate competition. Thus there cannot be any first order stochastic dominance relationship for these journals. Even if we compare the average quality of published papers, it is hard to find regularity in the comparison. The comparison depends on the quality distribution $F(q)$, the signal distribution $G(s|q)$, and the journal's prestige $\{V_j\}_{j=1}^n$ in a complicated way. Moreover, equilibrium characterization in a separate competition is very minimal. For any pair of profiles $(\{\tilde{q}_j\}_{j=0}^n, \{c_j^s\}_{j=1}^n)$ which satisfy $\tilde{q}_j > \tilde{q}_{j+1}$ and $c_j^s > c_{j+1}^s$ for all j, we can find a set of parameters $(\{p_j\}, \{V_j\})$ to make it an equilibrium given the quality distribution $F(q)$ and signal distribution $G(s|q)$. In particular, it is possible that the average quality of published papers in higher prestige journals gets worse while that in lower prestige journals gets better under a separate competition than under a pooled competition. This possibility is confirmed in the following example.

Example 1. *There are four types of paper qualities $q_1 > q_2 > q_3 > q_4$. The mass of papers with each quality level is $(1/4)$. There are four signals $s_1 > s_2 > s_3 > s_4$. The conditional distribution of signal on each quality level is given in the following table.*

	s_1	s_2	s_3	s_4
q_1	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{8}$
q_2	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{6}$	$\frac{1}{6}$
q_3	$\frac{1}{6}$	$\frac{1}{6}$	$\frac{1}{3}$	$\frac{1}{3}$
q_4	0	$\frac{1}{5}$	$\frac{2}{5}$	$\frac{2}{5}$

There are four journals $\{J_j\}_{j=1}^4$ which give utility of V_j to authors once their papers are published in that journal. Each journal's publication space is $(1/8)$. We know the comparison result of the quality distribution in the top and bottom journals between two submission rules and thus concentrate on the comparison of the published papers' average qualities in J_2 and J_3.

In a pooled competition, papers with signal s_1 will be published in J_1 or J_2 since their mass is exactly $(1/4)$. Journal J_3 will get papers with signal s_2 whose mass is $(19/80)(> (1/8))$.

In a separate competition, we can construct an equilibrium in which each type of paper is submitted to each journal. That is, q_1 papers are submitted to J_1, q_2 papers are submitted to J_2, and so on. Then we can calculate each journal's cutoff signal. In J_1, papers with s_1 will be accepted. In J_2, papers with s_2 will also be accepted with probability $(1/2)$ in addition to those with s_1. In J_3, papers with s_3 will be accepted with probability $(1/2)$ in addition to those with s_1 and s_2. In J_4, papers with s_3 will be accepted with probability $(3/4)$. For this to be an equilibrium, the profile of the submission decision is each author's optimal choice. That is, q_1 authors prefer submitting papers to J_1 than to J_2 while q_2 authors prefer submitting papers to J_2 rather than to J_1. For q_1 authors, this condition is true if $(1/2)V_1 \geq ((1/2)+(1/4)(1/2))V_2$. For q_2 authors, this condition is true if $(1/3)V_1 \leq (1/2)V_2$. Therefore, this condition will be satisfied if $(5/4) \leq (V_1/V_2) \leq (3/2)$. We can repeat the same argument and obtain a similar condition for (V_2/V_3) and (V_3/V_4). We can find a prestige value $\{V_j\}_{j=1}^4$ to satisfy all these conditions and make the proposed profile of submission decisions an equilibrium.

Our main focus is the comparison of the average qualities of the published papers in J_2 and J_3. Let's assume that $q_1 = 10$, $q_2 = 9$, $q_3 = 8$, and $q_4 = 1$. The average qualities of the published papers in J_2 and J_3 in the separate competition are q_2 and q_3 respectively.

[13] In the proof, we explicitly write down the distribution functions of each journal under different submission rules and show that the difference of them has a definite sign using the fact the cutoff signals of both journals are lower in a separate comeptition than in a pooled competition.

In the pooled competition, on the other hand, these are the average qualities of the papers with signal s_1 and s_2 respectively. Therefore, the average qualities of the published papers in J_2 and J_3 under different submission rules are as follows.

	separate competition	pooled competition
J_2	9	$9\frac{1}{3}$
J_3	8	$7\frac{23}{57}$

In J_2, the average quality is higher under a pooled competition than a separate competition while the reverse is true in J_3.

Though the equilibrium characterization under separate competition is very minimal, it is certain that the average qualities of published papers are higher in a separate competition than in a pooled competition for some top portion of journals. Gain in allocative efficiency causes the published papers' higher average qualities in top portion of journals in a separate competition.

Before analyzing the further comparison, we note that efficiency in selection and better sorting in allocation is in a trade-off relationship. If there is to be self-selection in the submission stage, authors who submit their papers to a high prestige journal should have the risk of not getting their papers published at all, and thus there must be some efficiency loss in selection to have better sorting in allocation. If not, authors with low quality papers cannot be prevented from submitting their papers to a high prestige journal.

However, once a submission opportunity is limited (that is, a delay in the publication process is given), change in the prestige hierarchy can reduce the efficiency loss in selection without damaging the better sorting in allocation. A competition for a limited space in a high prestige journal will be more severe if the prestige of the journal gets relatively higher. If a journal's prestige is much higher than other journals, more papers will be submitted to this journal even with a low probability of being accepted and cause more efficiency loss in selection. Moreover, additionally submitted papers to a prestigious journal have relatively lower qualities. This will decrease the quality of papers published in a prestigious journal. As the difference in journals' prestige widens, there will be more loss in the selection efficiency.

Let us define a prestige ratio of adjacent journals, v_j, as follows:

$$v_j = \frac{V_j}{V_{j+1}} \text{ for } j = 1, \cdots, n-1$$

The overall prestige distribution can be summarized by the vector $\mathbf{v} = (v_j)_{j=1}^{n-1}$, which can simply be called a prestige ratio. A prestige ratio $\mathbf{v}'$ is less than $\mathbf{v}$ if $v'_j \leq v_j$ for all j and $v'_j < v_j$ for some j and it is denoted by $\mathbf{v}' < \mathbf{v}$. As this prestige ratio gets smaller, smaller mass of papers will be submitted to the high prestige journals. Authors do not want to run the risk for the relatively small prestige difference. Since authors' submissions are still stratified by their papers' qualities, relatively low quality papers would not be submitted in high prestige journals. Even though the mass of submitted papers is smaller, their average quality is higher. Thus, the quality of published papers also increases. For low prestige journals, relatively high quality papers, which would have previously been submitted to high prestige journals, will be submitted and the quality of published papers will also improve. As a result, less of a difference in prestige will improve the output of all journals.[14] In summary, while a prestige difference is needed to have a self-selection in the submission stage, its size should be small to prevent over-competition for high prestige journals.

Proposition 3. *In a separate competition, if the prestige ratio is less,* i.e. $\mathbf{v}' < \mathbf{v}$, *the output of all journals will increase,* $H_j^{s'} > H_j^s$ *for all j.*

Proof. In Appendix A □

Since less of a difference in prestige will improve the publication outcome in a separate competition without affecting the outcome in a pooled competition, the change will favor a separate competition in the comparison. The outcome of a separate competition is likely to be better than that of a pooled competition as there is less of a difference in prestige.

We now come back to the comparison of outcomes under two submission rules given a fixed prestige ratio. In the above it is shown that we will have better sorting while there is efficiency loss in selection when the submission opportunity is limited. If there is no complementarity in output between papers' qualities q and the journal's trait r, there is no advantage in having more assortative matching and a pooled competition will always have a better outcome than a separate competition.

If complementarity exists and the gain in allocation efficiency is large enough to overcome the loss in selection efficiency, a separate competition has better outcome than a pooled competition. This gain in allocation efficiency comes in the form of better output in high prestige journals. If the traits of these high prestige journals become higher, the assortativeness of publication outcome becomes more important in efficiency evaluation. Thus the gain in allocation efficiency will increase, and a separate competition is welfare improving compared with a pooled competition.

[14] In the proof, we show that the equilibrium cut-off qualities increase if the prestige ratio gets smaller. This increase will improve the qualities of the submitted papers to all journals.

Proposition 4. *If there is no complementarity between papers' qualities and a journal's trait*, i.e. $h_{12} = 0$, *the total output of a pooled competition is always higher than that of a separate competition. If* $h_{12} > 0$ *and* $h_{22} = 0$, *there exists* $\tilde{j}$ *and* $\bar{r}(\tilde{j})$ *such that a separate competition will have a better outcome than a pooled competition if* $r_j > \bar{r}(\tilde{j})$ *for all* $j > \tilde{j}$,.

Proof. In Appendix A □

6. Conclusion

This paper deals with an assignment problem with matching frictions and private information. As a typical example of a market with these features, we examine a publishing practice of economics journals. The model's implication is consistent with the empirical pattern reported in Ellison (2002a). In contrast to the prevalent belief that the delay causes a problem, this paper shows that such delay can have a beneficial effect by facilitating self-selection in authors' submission decisions. If the assortativeness of matching is a very important factor in evaluating a publication outcome, the delay in FRT can actually be efficiency improving. Therefore, we may have to be more cautious about the common assertion that the delay should be reduced.

The main message of this paper is that matching friction in the assignment market can facilitate self-selection. This message can be applied to a wide range of assignment markets.

For example, in countries such as Japan and Korea, there exists a centralized recruitment process for middle ranked public servants. A test is given to all applicants and recruitment is based on the test score. The new recruits will be assigned to each ministry or department according to their preference. However, the prestige hierarchy of government positions is well known and all recruits have similar preferences. Therefore, the test score is a key factor which determines the assignment. That is, a recruit with a higher score will be assigned to a more prestigious ministry or department. We can think of an alternative recruitment process, in which the recruitment process is carried out by each ministry or department. By having the exam on the same day, applicants can apply to only one ministry. If the test score is a noisy signal of an applicant's ability and the applicants have better information about their own abilities, the outcome of these two systems coincide with those of a pooled and a separate competition analyzed in this paper. In the former system, the applicants apply to all ministries and the assignment is based on the test score, which is a realized signal of ability. In the latter system, applicants apply to only one ministry and the assignment is based on this application decision and the realized signal. We can also use the argument of this paper for the comparison of these two systems. If we care about the average ability of recruits irrespective of the ministry in which they are working, the former system will provide a better recruitment. If we think more prestigious ministry positions are more important and assigning better recruits to these positions is emphasized, the latter system will serve the purpose.

In another example, university admission problems can occur in some countries where admission is highly dependent on centralized test results. Student applications to universities can be done before this centralized test is taken or after test results are pronounced. If universities' rankings are commonly known and coincides with students' preferences, whether the application decision is made before or after the test will incur the similar difference as between a pooled and a separate competition. If students must decide where to apply before the test, students' decisions are the same as submission decisions in a separate competition. Thus the outcome is also that of a separate competition. If students make an application decision after test results are realized, they will know the score distribution and their scores' ranking. They will apply to a university which will accept them considering the score distribution. Therefore, the assignment outcome is made based on the score distribution just as in a pooled competition. The argument of this paper can also be applied to the comparison of these two systems.

We will conclude this paper by pointing out a possible direction of extension. This paper adds a private information component to the traditional matching markets which were widely discussed. In this paper, the utility one gets from a match is exogenously given. In a labor market, however, firms can post the wage before workers make an application decision. I hope that this framework can be extended to such a transferable utility case and that new implications will be obtained.

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Appendix A.

Proof of Lemma 4. I will define set CQ and CS as follows:

$$CQ = \{(q_1, \cdots, q_{n-1}) \in [\underline{q}, \bar{q}]^{n-1} | q_i \geq q_{i+1}, i = 1, \cdots, n-2\}$$
$$CS = \{(c_1, \cdots, c_n) \in [0, 1]^n | c_i \geq c_{i+1}, i = 1, \cdots, n-1\}$$

Set CQ is the set of all possible cutoff qualities which represents authors' submission decisions. Set CS is the set of all possible cutoff signals which represents journals' publication decisions. A pair of vectors $(\mathbf{q}, \mathbf{c})$ is a typical element of the set $CQ \times CS$.

I also define a function $\varphi : CQ \times CS \to CQ \times CS$ such that

$$\varphi(\mathbf{q}, \mathbf{c}) = (\varphi_1^q, \cdots, \varphi_{n-1}^q, \varphi_1^c, \cdots, \varphi_n^c)$$

where

$$\varphi_1^q = \begin{cases} \underline{q} & \text{if } V_i[1 - G(c_i|q)] > V_{i+1}[1 - G(c_{i+1}|q)] \text{ for all } q \in [\underline{q}, \bar{q}] \\ \bar{q} & \text{if } V_i[1 - G(c_i|q)] < V_{i+1}[1 - G(c_{i+1}|q)] \text{ for all } q \in [\underline{q}, \bar{q}] \\ q_i^* \text{ s.t. } V_i[1 - G(c_i|q_i^*)] = V_{i+1}[1 - G(c_{i+1}|q_i^*)] & \text{otherwise} \end{cases}$$

For $i \neq 1$

$$\varphi_i^q = \begin{cases} \underline{q} & \text{if } V_i[1 - G(c_i|q)] > V_{i+1}[1 - G(c_{i+1}|q)] \text{ for all } q \in [\underline{q}, \bar{q}] \\ q_i^* \text{ s.t. } V_i[1 - G(c_i|q_i^*)] = V_{i+1}[1 - G(c_{i+1}|q_i^*)] & \text{if } q_i^* \leq \varphi_{i-1}^q \\ \varphi_{i-1}^q & \text{otherwise} \end{cases}$$

$$\varphi_1^c = \begin{cases} 0 & \text{if } \int_{q_1}^{\bar{q}} dF(q) < p_1 \\ c_1^* \text{ s.t. } \int_{q_1}^{\bar{q}} [1 - G(c_1^*|q)]dF(q) = p_1 & \text{otherwise} \end{cases}$$

For $i \neq 1$

$$\varphi_i^c = \begin{cases} 0 & \text{if } \int_{q_i}^{q_{i-1}} dF(q) < p_i \\ c_i^* \text{ s.t. } \int_{q_i}^{q_{i-1}} [1 - G(c_i^*|q)]dF(q) = p_i & \text{if } c_i^* \leq \varphi_{i-1}^c \\ \varphi_{i-1}^c & \text{otherwise} \end{cases}$$

The function φ is defined in a sequential manner. That is, φ_1^q is first defined and then φ_2^q and so on. Basically, the function φ will find a new profile of authors' submission decisions φ^q given the journals' publication decisions and a new profile of journals' publication decisions φ^c given the authors' submission decisions. The equilibrium is the fixed point of the function φ.

Note that the set $CQ \times CS$ is compact and the function φ is continuous. By Brauer's fixed point theorem, there exists a fixed point of that function, which is an equilibrium. □

Proof of Proposition 1. Let $\phi^s(q)$ and $\phi^p(q)$ be the distribution functions for all published papers' qualities under a separate and a pooled competition respectively. Then

$$\phi^s(q) = \frac{1}{\sum p_j} \left[\int_{\underline{q}}^{\tilde{q}_{n-1}} [1 - G(c_n^s|t)]dF(t) + \cdots + \int_{\tilde{q}_j}^{q} [1 - G(c_j^s|t)]dF(t) \right] \text{ if } \tilde{q}_j \leq q < \tilde{q}_{j-1}$$

$$\phi^p(q) = \frac{1}{\sum p_j} \int_{\underline{q}}^{q} [1 - G(c_n^p|t)]dF(t)$$

Note that $c_1^s > c_n^p > c_n^s$. Since $c_j^s > c_{j+1}^s$, there exists j' such that $c_j^s > c_n^p$ for all $j \geq j'$ and $c_j^s \leq c_n^p$ for all $j < j'$. Using this, simple algebra will easily show that $\phi^s(q) - \phi^p(q) \geq 0$ for $q < \tilde{q}_{j'-1}$ and that $\bar{\phi}^p(q) - \bar{\phi}^s(q) \geq 0$ for $q \geq \tilde{q}_{j'-1}$. □

Proof of Proposition 2. Let ϕ_j^s and ϕ_j^p be the distribution functions of published papers' qualities in a Journal J_j under a separate and a pooled competition respectively, and $\bar{\phi} = 1 - \phi$. Then

$$\phi_1^s(q) = \begin{cases} 0 & \text{if } q < \tilde{q}_1 \\ \frac{1}{p_1} \int_{\tilde{q}_1}^{q} [1 - G(c_1^s|t)]dF(t) & \text{otherwise} \end{cases}$$

$$\phi_1^p(q) = \frac{1}{p_1} \int_{\underline{q}}^{q} [1 - G(c_1^p|t)]dF(t)$$

Note that $c_1^p > c_1^s$ since $\int_{\tilde{q}_1}^{\bar{q}}[1-G(c_1^s|t)]dF(t) = \int_{\underline{q}}^{\bar{q}}[1-G(c_1^p|t)]dF(t) = p_1$. We define $\bar{\phi}_j = 1-\phi_j$.

$$\bar{\phi}_1^s(q) = \begin{cases} 1 & \text{if } q < \tilde{q}_1 \\ \dfrac{1}{p_1}\displaystyle\int_q^{\bar{q}}[1-G(c_1^s|t)]dF(t) & \text{otherwise} \end{cases}$$

$$\bar{\phi}_1^p(q) = \frac{1}{p_1}\int_q^{\bar{q}}[1-G(c_1^p|t)]dF(t)$$

Using $c_1^p > c_1^s$, it can be easily shown that $\bar{\phi}_1^s(q) - \bar{\phi}_1^p(q) \geq 0$ for all q.
Similarly,

$$\phi_n^s(q) = \begin{cases} \dfrac{1}{p_n}\displaystyle\int_{\underline{q}}^{q}[1-G(c_n^s|t)]dF(t) & \text{if } q < \tilde{q}_{n-1} \\ 1 & \text{otherwise} \end{cases}$$

$$\phi_n^p(q) = \frac{1}{p_n}\int_{\underline{q}}^{q}[G(c_{n-1}^p|t) - G(c_n^p|t)]dF(t)$$

Note that $c_n^p > c_n^s$ since $\int_{\underline{q}}^{\bar{q}}[1-G(c_n^s|t)]dF(t) > \sum_{j=1}^{n} p_j = \int_{\underline{q}}^{\bar{q}}[1-G(c_n^p|t)]dF(t)$. Using this, simple algebra will show that $\phi_n^s(q) - \phi_n^p(q) \geq 0$ for all q. □

Proof of Proposition 3. We will consider the case only one v_j is different. That is, $\mathbf{v} = (v_j)_{j=1}^{n-1}$, $\mathbf{v}' = (v_1, v_2, \cdots, v_j', \cdots, v_{n-1})$ and $v_k' < v_k$. The proposition can be obtained through the sequence of this comparison.

We will show $\tilde{q}_j' > \tilde{q}_j$ for all j. Then the quality distributions of published paper in all journals with $\mathbf{v}'$ will first order stochastically dominates those with $\mathbf{v}$ and the proposition will follow.

Consider $\tilde{q}_{n-1}'$ and $\tilde{q}_{n-1}$. Suppose $\tilde{q}_{n-1}' \leq \tilde{q}_{n-1}$. Then $c_n^{s'} \leq c_n^s$ because of (9). This will lead to $c_{n-1}^{s'} \leq c_{n-1}^s$ due to (10). Again, because of (9), $\tilde{q}_{n-2}' \leq \tilde{q}_{n-2}$. This process will go on until $c_{k+1}^{s'} \leq c_{k+1}^s$ and $\tilde{q}_k' \leq \tilde{q}_k$. Since $v_k' < v_k$, $c_k^{s'} < c_k^s$ by (10). By the same process, we will reach $\tilde{q}_1' < \tilde{q}_1$ and $c_1^{s'} < c_1^s$, which contradict each other by (9). Therefore, $\tilde{q}_{n-1}' > \tilde{q}_{n-1}$.

Since $\tilde{q}_{n-1}' > \tilde{q}_{n-1}$, $c_n^{s'} > c_n^s$ by (9). This will lead to $c_{n-1}^{s'} > c_{n-1}^s$ due to (10). By (9), $\tilde{q}_{n-2}' > \tilde{q}_{n-2}$. This process will go on until $c_{k+1}^{s'} > c_{k+1}^s$ and $\tilde{q}_k' > \tilde{q}_k$. Until now, we showed that $\tilde{q}_j' > \tilde{q}_j$ for $j \geq k$.

Since $v_k' < v_k$, it can be either $c_k^{s'} \geq c_k^s$ or $c_k^{s'} < c_k^s$. If $c_k^{s'} \geq c_k^s$, then $\tilde{q}_{k-1}' > \tilde{q}_{k-1}$ by (9). The above process will go on until $\tilde{q}_1' > \tilde{q}_1$ and $c_1^{s'} \geq c_1^s$ which contradict each other by (9). Therefore, $c_k^{s'} < c_k^s$.

Again, it can be either $\tilde{q}_{k-1}' > \tilde{q}_{k-1}$ or $\tilde{q}_{k-1}' \leq \tilde{q}_{k-1}$. If $\tilde{q}_{k-1}' \leq \tilde{q}_{k-1}$, $c_{k-1}^{s'} < c_{k-1}^s$ by (9). This will lead to $\tilde{q}_{k-2}' \leq \tilde{q}_{k-2}$ and so on until $\tilde{q}_1' \leq \tilde{q}_1$ and $c_1^{s'} < c_1^s$, which is a contradiction. Therefore $\tilde{q}_{k-1}' > \tilde{q}_{k-1}$.

Now, $c_k^{s'} < c_k^s$ and $\tilde{q}_{k-1}' > \tilde{q}_{k-1}$. It can be either $c_{k-1}^{s'} \geq c_{k-1}^s$ or $c_{k-1}^{s'} < c_{k-1}$. If $c_{k-1}^{s'} \geq c_{k-1}^s$, $\tilde{q}_{k-2}' > \tilde{q}_{k-2}$ by (9). This will lead to $c_{k-2}^{s'} > c_{k-2}^s$ by (10), and $\tilde{q}_{k-3}' > \tilde{q}_{k-3}$ by (9). This will go on until $\tilde{q}_1' > \tilde{q}_1$ and $c_1^{s'} \geq c_1^s$, which is a contradiction. Therefore, $c_{k-1}^{s'} < c_{k-1}^s$.

From the above argument, we showed that $\tilde{q}_i' > \tilde{q}_i$ and $c_i^{s'} < c_i^s$ will lead to $\tilde{q}_{i-1}' > \tilde{q}_{i-1}$, and that $c_i^{s'} < c_i^s$ and $\tilde{q}_{i-1}' > \tilde{q}_{i-1}$ will lead to $c_{i-1}^{s'} < c_{i-1}^s$. Adding the repetition of this argument to the fact that $c_k^{s'} < c_k^s$ and $\tilde{q}_{k-1}' > \tilde{q}_{k-1}$ will conclude that $\tilde{q}_j' > \tilde{q}_j$ for $j < k$. Therefore all the cutoff qualities will increase with the less prestige ratio, which is the desired result. □

Proof of Proposition 4. First, we prove that a pooled competition has a better output than a separate competition if $h_{12} = 0$. Define the difference of a journal's output from that of the lowest prestige journal $k(q, r)$.

$$k(r, q) = h(r, q) - h(r_n, q)$$

If $h_{12} = 0$, $k(r, q)$ is not dependent on q, and by abusing the notation we can write $k(r, q) = k(r)$.

The total output under each system is the sum of $k(r)$ and output when all journals have a trait r_n. That is,

$$H^s = \sum p_j \int_{\underline{q}}^{\bar{q}} h(r_n, q)d\phi^s(q) + \sum_{j=1}^{n} k(r_j)p_j$$

$$H^p = \sum p_j \int_{\underline{q}}^{\bar{q}} h(r_n, q)d\phi^p(q) + \sum_{j=1}^{n} k(r_j)p_j$$

where $\tilde{q}_0 = \bar{q}$, $\tilde{q}_n = \underline{q}$, and $c_0^p = 1$ as in the main text. The second term is the same and the difference of output is the same as the difference in the first term. Because of the first order stochastic dominance result of Proposition 1, $H^s < H^p$.

Now, we prove that a separate competition can have a better outcome than a pooled competition if $h_{12} > 0$. From the argument of the main text, we know there exists $\bar{j}$ such that for all journals $j \geq \bar{j}$, the average quality of the published papers is higher under a separate competition than under a pooled competition. For those journals, the difference of output is

$$\frac{H_j^s - H_j^p}{p_j} = \int_{\underline{q}}^{\bar{q}} h(r_j, q) d\phi_j^s(q) - \int_{\underline{q}}^{\bar{q}} h(r_j, q) d\phi_j^p(q).$$

Since $h_{22} = 0$, this difference is not dependent on the quality distribution of the published papers except for the average. If $h_{12} > 0$, it is easy to show $(d(H_j^s - H_j^p)/dr_j) > 0$. That is, as the trait level r_j increases, this output difference will be larger. This difference can cover the loss from other journals if r_j is large enough. □

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