First version: September, 1997
Latest version: May 1998

First Author Conditions*

Abstract

This paper provides a theoretical explanation for the persistent use of alphabetical name-orderings on academic papers in economics. In a context where market participants are interested in evaluating the relative individual contribution of authors, it is an equilibrium for papers to use alphabetical ordering. Moreover, it is never an equilibrium for authors always to be listed in order of relative contribution. In fact, we show via an example that the alphabetical name-ordering norm may be the unique equilibrium, although, multiple equilibria are also possible. Finally, we characterize the welfare properties of the noncooperative equilibrium and show it to produce research of lower quality than is optimal and than would be achieved if co-authors were forced to use name-ordering to signal relative contribution.

Maxim Engers
Department of Economics
University of Virginia

Joshua S. Gans
Melbourne Business School
University of Melbourne

Simon Grant
Department of Economics
Australian National University

Stephen P. King
Department of Economics
University of Melbourne

*We wish to thank Jurgen Eichberger, Rohan Pitchford, John Quiggin and an anonymous referee for helpful comments. We would also like to thank Ray Over for references to the empirical literature on name ordering and Ross Milbourne for suggesting the title of this paper. All errors and omissions remain our responsibility.

1 Introduction

In co-authored work, the assignment of priority on published material can be a delicate matter. When the actual contribution of each author is not readily observable to outside interests (such as academic employers), priority may send an ordinal signal as to which author contributed more to the research. Moreover, authors themselves will be interested in sending such signals, if it is in their favor to do so.

A cursory glance at any economics journal, however, reveals a puzzle: authorship on the overwhelming majority of co-authored papers is ordered *lexicographically*, based on the alphabetical ordering of author's names. This pattern is illustrated in Table 1 for five major journals over the last two decades. Of co-authored papers in the sample, more than 85 percent had names listed alphabetically. Absent any clear correlation between name-order and research productivity, it appears that co-authors are jointly deciding not to use priority as a signal of contribution either directly or indirectly, say based on an ordering of seniority.[1]

Comparing this phenomenon with other disciplines, it appears that the further afield from economics, the less prevalent the use of a lexicographical ordering. In Table 2, we present ordering patterns in six other academic journals. While those closest to economics exhibit the same alphabetical convention, the *American Journal of Sociology* and others in the physical sciences exhibit orderings potentially unrelated to the spelling of the author's names. This suggests that the attribution norms in economics may differ from other disciplines.

Table 1: Ordering Patterns in Economics Journals, 1978 - 1997

Percent of Papers with Names Listed in Alphabetic Order by Number of Co-Authors

Journal	Multi-authored (%)	Two	Three	Four +	All
Journal of Political Economy	39.8	89.6	73.2	61.5	86.5
American Economic Review	43.7	90.1	63.1	57.7	86.3
Econometrica	42.2	88.0	85.6	100	87.6
Quarterly Journal of Economics	47.3	89.8	80.4	61.5	87.2
Review of Economic Studies	41.4	92.0	90.7	85.7	91.7

[1] The prevalence of multi-authored papers has been on the rise in the Post-War era. See Hudson (1996) for an illuminating documentation of this trend.

Table 2: Ordering Patterns in Other Academic Journals, 1978 - 1997

Percent of Papers with Names Listed in Alphabetic Order by Number of Co-Authors

Journal	Multi-Authored (%)	Two	Three	Four+	All
Journal of Finance	59.2	85.4	82.0	85.7	84.6
Journal of Economic History	23.3	83.8	62.5	n.a.	81.7
Yale Law Journal	13.1	83.6	100	n.a.	83.9
American Journal of Sociology	45.1	49.4	29.7	8.3	43.5
American Psychologist	40.8	53.3	18.7	13.3	39.3
Angewandte Chemie	38.9	64.3	41.4	13.1	52.6
New England Journal of Medicine	96.4	48.0	16.5	1.1	5.9

The comparative differences, while interesting, are not the main focus of this paper. We focus our attention on how a convention of lexicographic ordering may be self-sustaining. To this end, we construct a model that resolves the tension between the apparent convention of lexicographic ordering and the interests of parties in sending and receiving a more informative signal. In so doing, we demonstrate that lexicographic ordering is an equilibrium outcome of a game that involves bargaining among the co-authors under full information about their relative contributions, and the rational interpretation of signals by employers. Our result is not based on altruistic or cooperative explanations for the lexicographic ordering.[2] It occurs despite the fact that individual co-authors and (potential) employers care exclusively about the individual productivity of a researcher. Moreover, we show that the very existence of the possibility of a lexicographic ordering rules out the existence of an equilibrium in which name-ordering signals relative contribution, even though such an ordering may in principle be agreed upon by co-authors. Indeed, with some additional, quite intuitive restrictions, we can demonstrate that the lexicographic ordering equilibrium is unique. Finally, we compare different signalling outcomes and demonstrate that the total quality of research would increase if co-authors were compelled to use priority as a signal of relative contribution.

The intuition for our basic existence result is as follows. The key to understanding it lies in the nature of bargaining. Co-authors in economics can rarely bind themselves to

[2] One explanation for the use of the lexicographic order arises when co-authors have an on-going collaborative relationship with multiple outputs that involve varying relative contributions. Our model is based on a single collaborative output and is, therefore, independent of such explanations.

a specific ordering rule *ex ante*. While co-authors may agree on an ordering rule before commencing research, once relative contributions are known, co-authors can renegotiate this rule. Therefore, we model bargaining as taking place after the co-authors have information regarding the relative contribution to the paper. In such bargaining, the lexicographic and relative contribution orderings have two important characteristics: (i) when the lexicographic order is violated it is obvious to all; and (ii) this recognizability is asymmetric. Using a different ordering will be observable only if that order does not match the lexicographic one. Orders themselves have an ordinal (!) quality making them highly imperfect indicators of research input.

This second characteristic means that bargaining is an issue only when the author whose name is lower in the lexicographic ordering has actually contributed more to the article. In these circumstances, authors will bargain realizing that outsiders will draw an inference of contribution from the name order. If this 'market inference' is inconsistent with the bargained shares — in particular, if outsiders place too low a value on the contribution of authors who are not first under relative contribution ordering — then the only way to manipulate these perceptions is to use a lexicographic ordering. The authors agree to place more weight than outsiders expect on the lexicographic ordering as a means of compensating the author whose surname is first in the alphabet.

Clearly, in equilibrium, the market inference about relative contributions must match both the actual contributions and the shares negotiated by the authors when the lexicographic and relative contribution orderings do not happen to coincide. But why does this process push players away from a relative contribution rule and towards a lexicographic ordering? Two additional factors lead to our strong results. First, we rely on the Nash cooperative bargaining solution for our results. This means that bargaining is not too biased towards the author who is first under a relative performance rule. As such bargaining leads to a more equitable share of the surplus than would be inferred by the market, the relative performance rule cannot be an equilibrium. Second, the market's inference, when it observes different alphabetical orderings, is asymmetric. A non-alphabetical name order sends a clear signal to the market that the author who is listed first has actually contributed more and should receive a greater proportion of the credit. On the other hand, conforming to the lexicographic ordering sends a mixed signal to the market that places some weight on the possibility that the first author in that instance might actually have contributed more. As a result, reversals harm authors whose name is earlier up in the alphabet; more than these authors would benefit from the lexicographic ordering. Therefore, authors whose name is early in the alphabet can only be compensated by the relatively weak inference associated with lexicographic ordering. To achieve any agreed sharing of the surplus from the published article, the authors must place a relatively greater weight on the lexicographic ordering than orderings that send a clearer signal. Of course, in response to this increased use of lexicographic rather than relative contribution ordering, outsiders will reduce their inference about the relative contribution of the first author when the lexicographic ordering is observed. The more authors rely on lexicographic ordering to compensate an author whose name is early in the alphabet, the less the market infers from this ordering. In the extreme, the combination of *ex post* bargaining and asymmetric inference from ordering rules may result in a lexicographic ordering norm.

While we know of no previous research on name-ordering in economics, it has received some attention in the broader scientific literature. That literature confirms our evidence that alphabetical ordering is more common in economics than in other disciplines. Zuckerman (1968) examined the difficulties in inferring relative contributions from name ordering. Indeed, she found that Nobel laureates were less likely to be listed first on scientific papers, often being listed last. Nonetheless, in chemistry, physics and biological sciences, alphabetical orderings occur more frequently than chance alone would dictate. Spiegel and Keith-Spiegel (1970) looked at name-ordering among psychologists and surveyed the attitudes of members of that profession. They found that attitudes were consistent with those stated in the *Ethical Standards of Psychologists* of the American Psychological Association (1970):

> Credit is assigned to those who have contributed to a publication, in proportion to their contribution, and only to these .... The experimenter or author who has made the major contribution to a publication is identified as the first listed. (quoted by Over and Smallman, 1973, p.161)

Indeed, when asked what should occur when contributions among collaborators were deemed to be equal, only 33% of respondents argued that an alphabetical ordering was appropriate with 60% opting for a coin toss. Over and Smallman (1970) note that alphabetical name-ordering is mandatory practice at some journals. Looking at one such journal, the *Journal of Physiology*, they found less collaborative publication by scientists in the lower (P-Z) part of the alphabet, than in other journals in the field. Finally, Over and Smallman (1973), in an examination of practices among psychologists, demonstrated that alphabetical name-orderings were more prevalent when more than two co-authors were involved. These studies argue that the use of alphabetical name-orderings is related to the lack of desire of collaborators to send a signal regarding relative contribution. In contrast, we argue that even when this motive is present there are strong market-based forces driving the prevalence of alphabetical name-orderings, especially when no other information is available.

The outline for the paper is as follows. In the next section, we construct the model which involves three stages: a research effort stage, followed by a complete information bargaining game between two co-authors over name-ordering, and finally the market's updating of its beliefs. Section 3 characterizes the full equilibrium of the game, while section 4 compares this with the first-best outcome. A final section concludes and offers thoughts regarding future research.

2 The Set-Up

We model the game between two co-authors Abigail and Ben labeled A and B, respectively. These researchers put effort into the production of a paper. The cost-of-effort function is the same for both authors and is given by $c(e_i)$, $c(0) = 0, c', c'' > 0, i = A, B$. Paper quality is random, with its distribution a function of the two effort choices. We assume that the relative contribution of author A to the paper's quality can be described by the random variable S_A. The total quality of the paper is given by the random variable V. Moreover, we assume that quality can be realized only through collaborative work: there is no method by which individual authors can appropriate parts of that value on their own. For any pair of effort choices $(\overline{e}_A, \overline{e}_B)$ in $\mathbb{R}_+ \times \mathbb{R}_+$ of authors A and B, we further assume that:

1. S_A is distributed with density on $[0, 1]$ with

$$\begin{aligned} \Pr[S_A > 1/2] &= q(\overline{e}_A, \overline{e}_B) \\ \mathrm{E}[S_A | S_A > 1/2] &= h(\overline{e}_A, \overline{e}_B) \\ \mathrm{E}[S_A | S_A < 1/2] &= 1 - h(\overline{e}_B, \overline{e}_A) \end{aligned}$$

   where $q(\overline{e}_A, \overline{e}_B) + q(\overline{e}_B, \overline{e}_A) = 1$, $q_1 > 0, h_1 > 0$ and $q_2 < 0, h_2 < 0$.

2. V is distributed with density on $\mathbb{R}_+$ and mean $\overline{V}(e_A, e_B)$ where $\overline{V}$ is a concave symmetric function with positive partial first derivatives.

3. V and S_A are independent.

The presence of uncertainty is important in generating a market signalling problem. The independence of V and S_A means that the market's (equilibrium) belief about S_A is not affected by the value of V that is observed by the market. This greatly simplifies the updating procedure of the market that we model below without any significant loss in generality.

We model the collaborative process of producing a jointly authored paper as a game in three stages. The first stage of this process entails the actual effort expended by the two authors to produce the joint paper. Although some degree of (mutual) monitoring may be possible by authors, we view the amount of effort committed by each author as essentially private knowledge for that author, or at the very least extremely difficult to verify to an outside observer. Hence we model this stage by the simultaneous choice of effort levels e_A and e_B by A and B, respectively.

The second stage loosely corresponds to the journal 'publication-pipeline' process. The transformation of the efforts expended by the two authors in the first stage into 'value-added' for the joint research project, is by its very nature an activity whose actual outcome is uncertain at the time the activity is undertaken. So although the paper has already been written at this stage, we assume the actual effort choices of the two co-authors cannot be determined by an inspection of the paper. It does not seem unreasonable to suppose, however, even if they are still uncertain about what the actual value their paper will command once published in the 'marketplace of ideas,' that the two authors can identify their relative contributions to this joint paper. So at the beginning of this stage we assume the two authors observe the realization of S_A which signals the relative contribution of author A to the project.

Knowing their respective contributions, although uncertain about what the total quality of the project will be, the two authors bargain over the attribution rule for the paper in this submission stage. Although nothing in our framework precludes the possibility of authors deciding on the attribution rule in the first stage, before they have committed to their respective efforts for this joint project, nothing prevents them from renegotiating the attribution rule once they have learnt the size of their relative contributions. As we have not explicitly modeled a commitment device for the first stage, we believe it is appropriate to consider the decision about attribution rules as being decided in the later stage.[3]

Formally, the attribution rule is a mapping from relative contributions into the order space: that is, $\beta : [0,1] \to \{(A,B),(B,A)\}$. To make things simple suppose that co-authors bargain over only two 'pure' attribution rules:

(1) **The Lexicographic Ordering (LO)**, with $\beta(s) = (A,B)$ for all s in $[0,1]$; and

(2) **Relative Contribution Ordering (RC)**, with $\beta(s) = (B,A)$ if s in $[0,1/2)$ and $\beta(s) = (A,B)$ if s in $[1/2,1]$.[4]

We allow for the 'outcome' of the bargaining procedure to be a probability mixture of these two attribution rules where p in $[0,1]$ denotes the probability that **LO** is chosen. Without explicitly modelling the bargaining protocol we shall assume that the outcome corresponds to Nash's (1950) well-known co-operative solution for bargaining problems.[5] After the resolution of the probability mixing (if any) for the bargaining outcome, the order of the authors for the paper is determined by the chosen attribution rule.

In the final stage, the value (or equivalently, quality) of the project V is revealed to the market along with the order of authors. The market (say, consisting of potential and/or

[3] In the next section we show there exists an equilibrium of our game in which only alphabetical name-orderings are used. Notice that this is observationally equivalent to a regime where authors precommit to the use of alphabetical name-orderings in stage 1. The significance of our result is that such an outcome can be sustained in a *non-cooperative* framework eschewing the need for an extraneous commitment device.

[4] We have chosen this specification for simplicity only. As explained below, it is the symmetry of the bargaining solution when orderings do not coincide that plays an important role in our analysis. We could easily have chosen bargaining rules that mapped any realization of S_A into a probability that one ordering rule is used.

[5] Our results would be unaffected if the Kalai-Smorodinsky (1975) or egalitarian bargaining solution concepts were employed instead.

current employers) assigns weights α and $1-\alpha$ so that the payoffs to A and B are $\pi_A = \alpha V - c(e_A)$ and $\pi_B = (1-\alpha)V - c(e_B)$ respectively. The weights represent the market's beliefs regarding the relative productivity of each co-author, conditional on the market's observation of the ordering on the paper and prior beliefs regarding the ordering rule being used by the co-authors and their effort choices.

Summarizing the above we have:

1. Co-authors A and B simultaneously choose effort levels.

2. S_A is revealed to authors who then 'bargain' over the attribution rule.

   If the Lexicographic Ordering (**LO**) is chosen or $S_A \geq 1/2$,
   then the order of co-authors is (A, B),
   otherwise the order of co-authors is (B, A)

3. V and the order of authors are revealed to the market. The market attributes α of V to A (and the remainder to B) where α is the market's 'best' guess of A's relative contribution given the publicly available information and the market's equilibrium beliefs about the other variables.

To economize on notation, we denote the alphabetical ordering (A, B) by $(+)$ and the reverse alphabetical ordering (B, A) by $(-)$.

2.1 Stage 3: The Market's Weight Assignment Problem

As we shall see in the next subsection, the two co-authors are indifferent as to which attribution rule is used if both attribution rules lead to the same ordering. This occurs in the event $S_A \geq 1/2$ in which case the ordering of co-authors is $(+)$. In the complementary event (that is, when $S_A < 1/2$) the ordering depends upon the outcome of the bargaining. The order can either be $(+)$ if **LO** is agreed upon, or $(-)$ if **RC** is used. Hence from the market's perspective, for a given set of its beliefs about the effort choices of the co-authors $\left(e_A^M, e_B^M\right)$, the ordering $(+)$ is less informative about A's relatively greater contribution to the quality of the paper than is the ordering $(-)$ about B's. If we let p^M denote the market's prior belief that **LO** is chosen in the event that A's contribution is actually less than B's (that is, in the event $S_A < 1/2$) and $q^M = q(e_A^M, e_B^M)$, the state space can usefully be divided into four mutually exclusive and exhaustive events.

Event	Probability
$S_A < 1/2$ and $(+)$	$\left(1-q^M\right)p^M$
$S_A \geq 1/2$ and $(+)$	q^M
$S_A < 1/2$ and $(-)$	$\left(1-q^M\right)\left(1-p^M\right)$
$S_A \geq 1/2$ and $(-)$	0

Thus, the market's posterior belief that A's relative contribution is less than B's despite an observation of the ordering $(+)$ is given by

$$\Pr\left[S_A < 1/2 \middle| (+)\right] = \frac{\left(1-q^M\right)p^M}{q^M + \left(1-q^M\right)p^M}$$

Hence, the weight placed on co-author A given the observation of $(+)$ is:

$$\begin{aligned} \alpha\left[(+)\right] &= \Pr\left[S_A < 1/2 | (+)\right]\mathrm{E}\left[S_A | S_A < 1/2\right] + \Pr\left[S_A > 1/2 | (+)\right]\mathrm{E}\left[S_A | S_A > 1/2\right] \\ &= \frac{\left(1-q^M\right)p^M}{q^M + \left(1-q^M\right)p^M}\left(1-h\left(e_B^M, e_A^M\right)\right) + \frac{q^M}{q^M + \left(1-q^M\right)p^M}h\left(e_A^M, e_B^M\right) \qquad (1) \end{aligned}$$

In contrast, from the observation of the ordering $(-)$ the market knows with certainty that the **RC** rule was used and hence the weight placed on co-author A is:

$$\begin{aligned} \alpha\left[(-)\right] &= \mathrm{E}\left[S_A | S_A < 1/2\right] \\ &= \left(1-h\left(e_B^M, e_A^M\right)\right) \qquad (2) \end{aligned}$$

The asymmetric nature of market beliefs indicates the importance of the lexicographic assumption as opposed to an ordering which sent no signal per se. That is, when A contributes relatively more than B, the market cannot distinguish which ordering was actually used. Thus, so long as the market places some probability on the event that the **RC** ordering is used, the name-ordering of A before B, sends a partial signal with some weight placed on the event that S_A was in fact greater than $1/2$. We discuss the implications of the existence of a perfectly uninformative signalling device in Section 3 below.

2.2 Stage 2: Bargaining over the Attribution Rule.

Given the realization of S_A, the co-author's effort choices $(\bar{e}_A, \bar{e}_B)$, the market's beliefs about the co-authors' effort choices $\left(e_A^M, e_B^M\right)$ and the market's ex ante belief that the co-authors will choose the **LO** rule when $S_A < 1/2$, (p^M), the (gross of effort costs) expected payoffs are:

A) with the **LO** rule:

$$\begin{aligned}
R_A^+ &= \alpha\left[(+)\right]\overline{V}\left(\overline{e}_A,\overline{e}_B\right) \\
&\equiv \left[\frac{\left(1-q^M\right)p^M\left(1-h\left(e_B^M,e_A^M\right)\right)}{q^M+\left(1-q^M\right)p^M}+\frac{q^M h\left(e_A^M,e_B^M\right)}{q^M+\left(1-q^M\right)p^M}\right]\overline{V}\left(\overline{e}_A,\overline{e}_B\right) \\
R_B^+ &= \left(1-\alpha\left[(+)\right]\right)\overline{V}\left(\overline{e}_A,\overline{e}_B\right) \\
&\equiv \left[\frac{\left(1-q^M\right)p^M h\left(e_B^M,e_A^M\right)}{q^M+\left(1-q^M\right)p^M}+\frac{q^M\left(1-h\left(e_A^M,e_B^M\right)\right)}{q^M+\left(1-q^M\right)p^M}\right]\overline{V}\left(\overline{e}_A,\overline{e}_B\right)
\end{aligned}$$

B) with the **RC** rule and $S_A > 1/2$ payoffs are the same as in **A)**

C) with the **RC** rule and $S_A < 1/2$

$$\begin{aligned}
R_A^- &= \alpha\left[(-)\right]\overline{V}\left(\overline{e}_A,\overline{e}_B\right) \\
&\equiv \left(1-h\left(e_B^M,e_A^M\right)\right)\overline{V}\left(\overline{e}_A,\overline{e}_B\right) \\
R_B^- &= \left(1-\alpha\left[(-)\right]\right)\overline{V}\left(\overline{e}_A,\overline{e}_B\right) \\
&\equiv h\left(e_B^M,e_A^M\right)\overline{V}\left(\overline{e}_A,\overline{e}_B\right)
\end{aligned}$$

Obviously when $S_A > 1/2$, the two attribution rules are in agreement about the order and there is nothing to bargain over. However, when $S_A < 1/2$, $\left(R_A^+ - R_A^-\right)\left(R_B^+ - R_B^-\right) < 0$, that is, there is a conflict between each player's most preferred rule. We consider the well-known Nash bargaining 'solution' to the bargaining problem. This solution is given by the probability that the **LO** rule is used that solves the following program:

$$\text{Max}_{p\in[0,1]}\ \left(pR_A^+ + (1-p)\,R_A^-\right)\left(pR_B^+ + (1-p)\,R_B^-\right)$$

The first-order condition for an interior maximum is

$$\left(R_A^+ - R_A^-\right)\left(p^*R_B^+ + (1-p^*)\,R_B^-\right) = \left(R_B^- - R_B^+\right)\left(p^*R_A^+ + (1-p^*)\,R_A^-\right)$$

Now since,

$$\begin{aligned}
\left(R_A^+ - R_A^-\right) &= \left(R_B^- - R_B^+\right) \\
&= \frac{q^M}{q^M+\left(1-q^M\right)p^M}\left(h\left(e_A^M,e_B^M\right)+h\left(e_B^M,e_A^M\right)-1\right)\overline{V}\left(\overline{e}_A,\overline{e}_B\right)
\end{aligned}$$

it follows that:

$$p^*R_A^+ + (1-p^*)\,R_A^- = p^*R_B^+ + (1-p^*)\,R_B^- = \frac{1}{2}\overline{V}\left(\overline{e}_A,\overline{e}_B\right) \tag{3}$$

That is,

$$p^*\alpha\left[(+)\right] + (1-p^*)\,\alpha\left[(-)\right] = \frac{1}{2}$$

Hence,

$$p^* = \min\left\{1, \frac{1/2 - \alpha\left[(-)\right]}{\alpha\left[(+)\right] - \alpha\left[(-)\right]}\right\} \tag{4}$$
$$= \min\left\{1, \frac{\left(h\left(e_B^M, e_A^M\right) - 1/2\right)\left(q^M + \left(1 - q^M\right)p^M\right)}{\left(h\left(e_A^M, e_B^M\right) + h\left(e_B^M, e_A^M\right) - 1\right)q^M}\right\}$$

where $p^* > 0$ because $\alpha\left[(-)\right] < 1/2$.

The equality of the post-bargaining gross payoffs follows from the fact that the Pareto frontier is linear with slope -1 and intersects the forty-five degree line (see Figure 1 below). As $R_A^- < \bar{V}/2 \leq R_B^+$ it follows from the geometry of the Nash bargaining solution that $p^* > 0$ and indeed this is confirmed by the expression for p^* above. Thus, even if the market placed no weight on the probability that the **LO** rule is used, that is, $p^M = 0$, the researchers themselves would agree to that ordering some of the time there was an actual name-ordering conflict, that is, when the two ordering rules yielded different name orders. The reason for this is that the ordering $(-)$ causes a much larger loss for A than the gain for B. To compensate A for this, some weight must be placed on the use of the **LO** rule. We demonstrate below that this property implies that there is no equilibrium in the full game that involves $p^* = 0$.

2.3 Stage 1: Co-authors' effort choices

Given A's belief $\bar{e}_B$ about B's effort choice, and her beliefs about the market's expectations, her choice of effort problem can be expressed as:

$$\max_{e_A} \pi_A(e_A, \bar{e}_B, e_A^M, e_B^M, p^M)$$
$$\text{where } \pi_A(.) = \left[q\left(e_A, \bar{e}_B\right) + \left(1 - q\left(e_A, \bar{e}_B\right)\right)p^*\right]R_A^+ + \left(1 - q\left(e_A, \bar{e}_B\right)\right)\left(1 - p^*\right)R_A^- - c\left(e_A\right)$$
$$\text{and } p^* \text{ is given by the expression } (4).$$

similarly given B's belief $\bar{e}_A$ for A's effort choice, his choice of effort problem is

$$\max_{e_B} \pi_B(e_B, \bar{e}_A, e_A^M, e_B^M, p^M)$$
$$\text{where } \pi_B(.) = \left[q\left(\bar{e}_A, e_B\right) + \left(1 - q\left(\bar{e}_A, e_B\right)\right)p^*\right]R_B^+ + \left(1 - q\left(\bar{e}_A, e_B\right)\right)\left(1 - p^*\right)R_B^- - c\left(e_B\right)$$
$$\text{and } p^* \text{ is given by the expression } (4).$$

3 Equilibrium of the Full Game

An equilibrium for the full game requires that given the market's expectations about the use of the **LO** rule, and the market's expectation about the effort choices of the co-authors, each co-author finds it optimal to choose the effort choice that the market and her co-author expects. Furthermore, the market's expectation about the probability the authors will use the **LO** rule in the 'bargaining over the attribution rule' stage equals the probability that results from their bargaining. Formally,

Definition 1 *$(e_A^*, e_B^*, e_A^M, e_B^M, p^M, p^*)$ is an equilibrium of the full game if:*

(a) $e_A^M = e_A^* \in \arg\max_{e_A} \pi_A(e_A, e_B^*, e_A^M, e_B^M\ p^M, p^*)$;

(b) $e_B^M = e_B^* \in \arg\max_{e_B} \pi_B(e_B, e_A^*, e_A^M, e_B^M\ p^M, p^*)$;

(c) $p^M = p^*$ where p^* is given by the expression (4).

Our central result is that a market expectation that only the **LO** rule will be employed in conjunction with exclusive use of the **LO** rule as a result of the co-authors' bargaining, can be sustained in an equilibrium of the full game.

Proposition 1 *$p^* = 1$ (the **LO Norm**) may be sustained in an equilibrium of the full game in which the authors engage in (Nash) bargaining over the ordering of authors. Moreover, in this equilibrium both authors make the same effort choice e^{LO} characterized by*

$$\frac{\overline{V}_1\left(e^{LO}, e^{LO}\right)}{2} = c'\left(e^{LO}\right)$$

Proof. Suppose the market believes that only **LO** will be used, that is, $p^M = 1$ and that both co-authors will choose the same effort choice e^{LO} . If the **LO** rule is actually used by the co-authors in stage two, then in stage three, *whatever* the surplus that is actually created, the outcome is the symmetric outcome where both co-authors receive half of the realized total surplus, since

$$\alpha\left[(+)\right] = \frac{1/2 \times 1}{1/2 + 1/2 \times 1}\left(1 - h\left(e^{LO}, e^{LO}\right)\right) + \frac{1/2}{1/2 + 1/2 \times 1} h\left(e^{LO}, e^{LO}\right) = \frac{1}{2}$$

If the **RC** rule is used, however, then in the event $s_A < 1/2$, the share going to A, $\alpha\left[(-)\right] = 1 - h\left(e, e\right)$, is less than a half. Hence this simply means transferring utility from A to B. Given the symmetric nature of the Nash bargaining solution, this entails that **LO** is chosen with probability one. That is, $p^* = 1 (= p^M)$, is the outcome of the bargaining in stage two.

Finally, given the expectation as to what will happen in stages 2 and 3, in stage 1, A's maximization problem collapses to

$$\max_{e_A} \frac{\overline{V}_1\left(e_A, \overline{e}_B\right)}{2} - c\left(e_A\right)$$

where $\overline{e}_B$ is A's expectation of the level of effort that B will choose. An analogous expression represents B's stage 1 maximization problem and it is immediate that the symmetric solution entails an effort choice of e^{LO} by both co-authors. ■

This result demonstrates that the use of the **LO** rule to send no signal about relative contribution is a noncooperative equilibrium of the full game. Figure 1 provides a graphical illustration of the result. Recall that with $\alpha[(+)] = 1/2$, $R_A^+ = R_B^+ = \overline{V}/2$, hence the point (R_A^+, R_B^+) lies on the forty-five degree line. Recall also that $(R_A^+ - R_A^-) = (R_B^- - R_B^+)$, hence the point (R_A^-, R_B^-) lies to the northwest of (R_A^+, R_B^+) and the line connecting them has slope -1. If this line is extended in both directions to intersect with both axes, it is obvious from the geometry that the point on that extended line for which the product of payoffs is maximized is the point (R_A^+, R_B^+). That would be the Nash solution if all points along the extended line were available, and by Nash's assumption of Independence of Irrelevant Alternatives, it remains the solution if only convex combinations of (R_A^+, R_B^+) and (R_A^-, R_B^-) are feasible. Therefore the convex combination (or 'probability mixture') that places weight $p^* = 1$ on the point (R_A^+, R_B^+) yields the Nash outcome for the 'bargaining over attribution rule' stage.[6]

It is very difficult either to characterize other equilibria or to show that the **LO norm** equilibrium is unique, given the general structure of the game. In particular, notice that the strategic interactions between A and B in their effort choice subgame are possibly quite complex and can potentially exhibit strategic complementarity, substitutability, neither, and multiple interior equilibria. What can be readily shown, however, is that a pure **RC** rule equilibrium does not exist.

Proposition 2 *There do not exist market beliefs that can sustain $p^* = 0$ as an equilibrium outcome of the full game.*

Proof. In the previous section, we demonstrated that even if $p^M = 0$, $p^* > 0$. That is, in negotiations, the parties agree to some positive probability that the **LO** rule is used. Rational market expectations requires that market beliefs regarding **LO** rule usage equal actual usage in equilibrium. Therefore, market beliefs concerning the exclusive use of the **RC** rule are unsustainable. ∎

3.1 Uniqueness

Uniqueness of the **LO Norm** can be shown to hold if we refine the model further by making some simplifying functional form assumptions. In particular, let us remove all direct strategic interactions between the two co-authors in their effort choice subgame and leave only those determined by market interactions. Given an effort choice $\overline{e}_i$ by individual i $(i = A, B)$, suppose that i's contribution to the total quality of the paper is given by the random variable

[6] Note that this equilibrium is "stable" in the following sense: for market beliefs, p^M, close to 1, p^* exceeds p^M. Hence, the equilibrium correspondence that $p^* = p^M$ cuts the 45 degree line from above at $p^* = 1$. This can be see by differentiating (4) with respect to p^M holding effort choices and other beliefs constant (as one can do because of the continuity and convexity assumptions). It can be easily demonstrated that this partial derivative is (strictly) less than 1.

V_i which has a gamma distribution with parameters $\bar{e}_i$ and 1.[7] Suppose further that V_A and V_B are independently distributed. Finally, assume that $c(e) = e^2/2$. These assumptions are consistent with but stronger than our earlier conditions for V and S_A

Under these additional restrictions we can show the following.

Proposition 3 *$p^* = 1$ (the **LO Norm**) is the unique equilibrium of the modified full game. Moreover both authors make the same effort choice e^{LO} equal to $1/2$.*

Proof. Under the assumption of a gamma distribution for V_i and the independence of V_A and V_B, it is easy to see that $V = V_A + V_B$ is also distributed gamma with parameters $(\bar{e}_A + \bar{e}_B)$ and 1 (and so, in particular $\overline{V}(e_A, e_B) = \bar{e}_A + \bar{e}_B$) and $S_A = V_A / (V_A + V_B)$ is distributed beta with parameters $\bar{e}_A$ and $\bar{e}_B$ (and so, in particular $q(\bar{e}_A, \bar{e}_B) = \bar{e}_A / (\bar{e}_A + \bar{e}_B)$).[8] Moreover, V and S_A are independent consistent with our earlier assumptions. We show existence first and then turn to uniqueness.

Observe that the first order conditions for the respective co-authors' stage 1 maximization problems may be expressed as

$$\begin{aligned}
\left[\frac{e_B}{e_A + e_B} + \frac{e_A}{e_A + e_B}\right]\left[\alpha\left[(+)\right] - \frac{1}{2}\right] + \frac{1}{2} &= e_A \Longrightarrow e_A = \alpha\left[(+)\right] \\
\left[\frac{e_A}{e_A + e_B} - \frac{e_A}{e_A + e_B}\right]\left[\alpha\left[(+)\right] - \frac{1}{2}\right] + \frac{1}{2} &= e_B \Longrightarrow e_B = \frac{1}{2}
\end{aligned}$$

Imposing $p^M = p^*$, substituting $e_B = 1/2$ and rearranging (4) we obtain

$$p^*(e_A) = \frac{(2h(1/2, e_A) - 1)\, q^*(e_A)}{(2h(1/2, e_A) - 1)\, q^*(e_A) + h(e_A, 1/2) - h(1/2, e_A)} \tag{5}$$

where $q^*(e_A) \equiv q(e_A, 1/2)$. Substituting $\alpha[(+)] = e_A$ and solving (1) for p^* we also obtain

$$p^*(e_A) = \frac{q^*(e_A)\,(h(e_A, 1/2) - e_A)}{(1 - q^*(e_A))\,(h(1/2, e_A) + e_A - 1)} \tag{6}$$

It is straightforward to see that the RHSs of (5) and (6) both equal 1 for $e_A = 1/2$. This proves existence.

A sufficient condition for uniqueness would be to rule out situations in which $p^* < p^M$. Rearranging (4), this is true if $\left(1 - q^M\right)/q^M < \mathrm{E}\left[S_A | S_A > 1/2\right]$ which is never true for $q^M < 2/3$. This condition is always satisfied as

[7] The probability density function for V_i is then

$$f(v) = \frac{1}{\Gamma(\bar{e}_i)} v^{\bar{e}_i - 1} \exp(-v), \; 0 < v < \infty$$

[8] That is, the probability density function for S_A is

$$f(s) = \frac{\Gamma(\bar{e}_A + \bar{e}_B)}{\Gamma(\bar{e}_A)\Gamma(\bar{e}_B)} s^{\bar{e}_A - 1}(1 - s)^{\bar{e}_B - 1}, \; 0 < s < 1$$

$$q^M = \frac{e_A}{e_A + e_B} = \frac{\alpha[(+)]}{\alpha[(+)] + \frac{1}{2}} \leq \frac{2}{3}$$

where the last inequality follows from the fact that $\alpha[(+)] \leq 1$. ■.

3.2 Multiple Equilibria

In general an equilibrium in which *only* the **LO Norm** is employed need not be the unique equilibrium of the full game. As we add strategic interactions between A and B beyond those that are generated by market relationships, it is possible that there also exist equilibria in which both the **RC** and **LO Norms** are employed. Those equilibria result in the alphabetical name-ordering being used more likely than not, but *not* being used with certainty. This is consistent with observations of occasional violations of the alphabetic name-ordering convention in economics journals. What is interesting, however, is that a comparison of the first order conditions characterizing the optimum effort choices for the respective co-authors' stage 1 programs in cases where $p^* = p^M < 1$, implies that $e_A^* \geq e_B^*$. Therefore, in such an equilibrium where there is a non-zero probability that the **RC Norm** may be employed, observations of an alphabetical name-ordering are consistent with market beliefs ascribing a greater relative contribution from the author with a name earlier in the alphabet.

These points may be illustrated by means of the following example. To simplify the calculation and characterization of an equilibrium of the full game, suppose that each co-author's effort choice is limited to one of three possible levels: L(ow), M(edium) or H(igh). The (common) cost of effort function, $c(e)$ is

e	L	M	H
$c(e)$	16	78	152

.

For any pair of effort levels by the two co-authors, the expected total value of the project, $\overline{V}(e_A, e_B)$, is given by:

$$\overline{V}(e_A, e_B)$$

		e_B		
		L	M	H
	L	256	384	512
e_A	M	384	512	640
	H	512	640	768

.

Notice that although effort choice is discrete, the relationship between an increase in effort by an author, and the associated increase in that author's cost and the increase in the expected value of the project, is similar to the functional specification used in the previous subsection. In particular, we have that the increment to the expected value of the project for a single increment in the effort level of one author (holding the other author's effort level constant) is always 128, but that the increase in effort cost is greater going from M to H, than it is going from L to M.

To complete the description of the situation we require for any feasible pair of effort levels by the two co-authors, the probability that co-author's A's contribution will be greater than B's (i.e. $\Pr[S_A > 1/2]$), and the expected contribution of A, given her contribution is greater than B's (i.e. $\mathrm{E}[S_A|S_A > 1/2]$). These quantities can be derived from the following two tabulations of the values of the functions $q(e_i, e_j)$ and $h(e_i, e_j)$.

$q(e_i, e_j)$

e_i \ e_j	L	M	H
L	$1/2$	$3/8$	$1/4$
M	$5/8$	$1/2$	$3/8$
H	$3/4$	$5/8$	$1/2$

$h(e_i, e_j)$

e_i \ e_j	L	M	H
L	$23/32$	$45/64$	$11/16$
M	$47/64$	$23/32$	$45/64$
H	$3/4$	$47/64$	$23/32$

Recall given A exerts effort level e_A and B exerts effort level e_B, then $\Pr[S_A > 1/2] = q(e_A, e_B)$, $\mathrm{E}[S_A|S_A > 1/2] = h(e_A, e_B)$ and $\mathrm{E}[S_A|S_A < 1/2] =$ 1-$h(e_B, e_A)$

In addition to the **LO Norm** (symmetric) equilibrium which we know exists from Proposition 1 there is also an equilibrium in which for bargaining situations where co-author B's contribution to the total value of the project is greater than A's, the market expects it is equally likely that the co-authors will use the **RC** or **LO norms**.

Proposition 4 *Both (1)* $(e_A^*, e_B^*,\ e_A^M, e_B^M, p^M, p^*) = (M, M, M, M, 1, 1)$ *and (2)* $(e_A^*, e_B^*, e_A^M, e_B^M, p^M, p^*) = (H, L, H, L, 1/2, 1/2)$ *are equilibria of the full game.*

Proof. (1) From the proof of Proposition 1 we have $p^* = 1\left(= p^M\right)$ as required, and $\alpha[(+)] = 1/2$. So A's expected payoff following her effort choice for this putative equilibrium collapses to $\overline{V}(M, M)/2 - c(M) = 178$. By deviating and playing L, her expected payoff is $\overline{V}(L, M)/2 - c(L) = 176$. And, by deviating and playing H, her expected payoff is $\overline{V}(H, M)/2 - c(H) = 168$. Since B's payoffs from deviating are the same as those just calculated for A, it follows that neither has an incentive to deviate from the strategy specified in the putative equilibrium. $\square$

(2) For the putative equilibrium profile $(H, L, H, L, 1/2, 1/2)$, we have $\Pr[S_A > 1/2] = 3/4$, $\mathrm{E}[S_A|S_A > 1/2] = 3/4$ and $\mathrm{E}[S_A|S_A < 1/2] = 5/16$. Hence $\alpha[(+)] = 11/16$ and $\alpha[(-)] = 5/16$ follow from (1) and (2) respectively. Substituting this into (4), we have $p^* = (1/2 - 5/16)/(11/16 - 5/16) = 1/2 = p^M$, as is required for the consistency between the market's expectation of the use of the **LO Norm** and its actual use by the two co-authors. In this putative equilibrium, A's (expected) payoff is

$$\begin{aligned} & \left(\Pr[(+)]\,\alpha[(+)] + (1 - \Pr[(+)])\,\alpha[(-)]\right)\overline{V}(H, L) - c(H) \\ = & \left(\frac{7}{8} \times \frac{11}{16} + \frac{1}{8} \times \frac{5}{16}\right) 512 - 152 = 176. \end{aligned}$$

By deviating and playing L, yields an expected payoff of only

$$\left(\frac{3}{4} \times \frac{11}{16} + \frac{1}{4} \times \frac{5}{16}\right) 256 - 16 = 136.$$

And, if she deviates and plays M her expected payoff falls to

$$\left(\frac{13}{16} \times \frac{11}{16} + \frac{3}{16} \times \frac{5}{16}\right) 384 - 78 = 159.$$

B's expected payoff in this putative equilibrium is

$$\left(\frac{7}{8} \times \frac{5}{16} + \frac{1}{8} \times \frac{11}{16}\right) 512 - 16 = 168.$$

If he instead plays M, his expected payoff falls to

$$\left(\frac{13}{16} \times \frac{5}{16} + \frac{3}{16} \times \frac{11}{16}\right) 640 - 78 = 167.$$

And, finally, if he plays H instead, his expected payoff is reduced to

$$\left(\frac{3}{4} \times \frac{5}{16} + \frac{1}{4} \times \frac{11}{16}\right) 768 - 152 = 160.$$

Thus we have established that neither A nor B has an incentive to deviate from the strategy specified in the putative equilibrium. $\blacksquare$

This example demonstrates that the symmetry of the bargaining outcome does not, of itself, rule out an equilibrium in which the **RC** rule is used, at least some of the time.

4 Welfare Implications

The purpose of this section is to examine the welfare properties of the **LO Norm** characterized in the previous sections. So as to simplify exposition we will continue to maintain our functional form assumptions introduced in section 3.1. However, our qualitative results carry over to the more general case.

We conduct our welfare analysis in two ways. First, we demonstrate that overall research quality in the **LO Norm** is lower than the first best. Second, we demonstrate that imposing restrictions on the use of the lexicographic ordering (although it is an issue as to how this could be enforced) would result in an improvement in research quality.

4.1 Joint maximization — The 'first-best'

The first best involves choosing research efforts to maximize total research quality less effort costs without regard to distributional issues.

$$\max_{e_A, e_B} \overline{V}\left(e_A, e_B\right) - c\left(e_A\right) - c\left(e_B\right)$$

This has a unique symmetric solution $\overline{e}_A = \overline{e}_B = e^{FB}$, characterized by

$$\overline{V}_1\left(e^{FB}, e^{FB}\right) = c'\left(e^{FB}\right)$$

Under our functional form assumptions joint surplus maximization effort choices are $e_A^{FB} = e_B^{FB} = 1$. Therefore, the first best research quality exceeds that of the **LO Norm**. The reason for this is that individual effort has a positive spillover on the other author's payoff through the improvement in research quality. This spillover is not taken into account when there is a large market weight on the **LO Norm** possibility. Hence, there is underprovision of effort akin to any model of privately provided public goods.

4.2 Committing to an RC Norm.

Suppose that it were possible to prohibit the use of the **LO** rule. This would mean that the **RC** rule was used with certainty and hence, that $p^* = p^M = 0$. Under this restriction, the co-author's stage 1 effort choice problems can be expressed as:

$$\max_{e_A} \left[1 - h\left(e_B^M, e_A^M\right) + \left(h\left(e_A^M, e_B^M\right) + h\left(e_B^M, e_A^M\right) - 1\right) q\left(e_A, \overline{e}_B\right)\right] \overline{V}\left(e_A, \overline{e}_B\right) - c\left(e_A\right)$$
$$\max_{e_B} \left[h\left(e_B^M, e_A^M\right) - \left(h\left(e_A^M, e_B^M\right) + h\left(e_B^M, e_A^M\right) - 1\right) q\left(\overline{e}_A, e_B\right)\right] \overline{V}\left(\overline{e}_A, e_B\right) - c\left(e_B\right)$$

The first order equilibrium conditions are:

$$\begin{aligned} & \left[1 - h\left(\overline{e}_B, \overline{e}_A\right) + \left(h\left(\overline{e}_A, \overline{e}_B\right) + h\left(\overline{e}_B, \overline{e}_A\right) - 1\right) q\left(\overline{e}_A, \overline{e}_B\right)\right] \overline{V}_1\left(\overline{e}_A, \overline{e}_B\right) \\ + \quad & \left(h\left(\overline{e}_A, \overline{e}_B\right) + h\left(\overline{e}_B, \overline{e}_A\right) - 1\right) q_1\left(\overline{e}_A, \overline{e}_B\right) \overline{V}\left(\overline{e}_A, \overline{e}_B\right) = c'\left(\overline{e}_A\right) \end{aligned}$$

$$\begin{aligned} & \left[h\left(\overline{e}_B, \overline{e}_A\right) - \left(h\left(\overline{e}_A, \overline{e}_B\right) + h\left(\overline{e}_B, \overline{e}_A\right) - 1\right) q\left(\overline{e}_A, \overline{e}_B\right)\right] \overline{V}_2\left(\overline{e}_A, \overline{e}_B\right) \\ - \quad & \left(h\left(\overline{e}_A, \overline{e}_B\right) + h\left(\overline{e}_B, \overline{e}_A\right) - 1\right) q_2\left(\overline{e}_A, \overline{e}_B\right) \overline{V}\left(\overline{e}_A, \overline{e}_B\right) = c'\left(\overline{e}_B\right) \end{aligned}$$

which also has a unique solution $\overline{e}_A = \overline{e}_B = e^{CO}$, characterized by

$$\frac{\overline{V}_1\left(e^{CO}, e^{CO}\right)}{2} + q_1\left(e^{CO}, e^{CO}\right)\left[2h\left(e^{CO}, e^{CO}\right) - 1\right] \overline{V}\left(e^{CO}, e^{CO}\right) = c'\left(e^{CO}\right)$$

Under our functional form assumptions, the equilibrium effort choices for the **RC Norm** case that would arise are also symmetric $e_A^{CO} = e_B^{CO} = e^{CO}$ with

$$\begin{aligned} e^{CO} &= h\left(e^{CO}, e^{CO}\right) \\ \text{where } h\left(e,e\right) &= \frac{\int_{\frac{1}{2}}^{1} s^{e}\left(1-s\right)^{e-1} ds}{\int_{\frac{1}{2}}^{1} s^{e-1}\left(1-s\right)^{e-1} ds} \\ \text{Hence, } e^{CO} &\approx 0 \cdot 775 \end{aligned}$$

Observe that this involves an improvement in research quality over the level achieved when the **LO Norm** is permitted. The reason for this is that, while the public good aspect of each author's effort choices still militate against high effort, there is a racing aspect as well. Because an **RC** rule will be used with certainty, if one author reduces their effort by a small amount, this causes an even greater reduction in their payoff. This creates an additional incentive to exert effort. Hence, effort levels are higher when authors can commit to the **RC** rule.

4.3 Efficiency of Non-LO Norm Equilibria

At first blush the previous analysis suggests that any equilibrium that involves some use of the **RC** rule might improve efficiency. However, looking to our example in section 3.2, we can easily see that this is not the case.

In that example, notice that ex ante expected surplus is maximized when both exert high effort. That is,

$$\begin{aligned} \overline{V}\left(H,H\right) - 2c(H) &= 464 \\ \overline{V}\left(H,M\right) - c(H) - c(M) &= 410 \\ \overline{V}\left(M,M\right) - 2c(M) &= 356 \\ \overline{V}\left(H,L\right) - c(H) - c(L) &= 344 \end{aligned}$$

The symmetric equilibrium outcome resulting from employing the **LO Norm** is clearly inefficient. But in this particular example, it more efficient than the asymmetric equilibrium outcome (with effort choices of H and L) that generate a project with the same expected value but at greater cost of effort.

4.4 A No-Signalling Option

Part of the difficulty with the **LO** rule is its asymmetric nature. Its possibility makes it difficult for A to send the market a clear signal if she has contributed more to the article. Note, however, that the authors would not agree to use the **RC** rule even when the alternative is simply to send no signal. For instance, a no-signal option could involve a distinctive color. While bargaining would then be relevant for any realization of S_A its ex post nature requires a solution that splits the joint surplus. The no-signalling option would allow the market to set $\alpha = \frac{1}{2}$, and could always implement an equal division of the surplus. Hence, it would be favored by the co-authors in ex post bargaining with probability 1. The result would be an equilibrium that mimicked the **LO Norm**.

In reality, such a no-signalling device is difficult to imagine. Our methods of citation analysis are necessarily alphabetically based and it has been shown that this can lead to a reduction in attribution to second authors and beyond. They get lost in the et al. (Merton, 1973).

5 Conclusions and Future Directions

The model presented in this paper represents a first step towards analyzing collaborative interactions in scientific work. It demonstrates that, under certain conditions, an alphabetical name-ordering will exist as a norm in a non-cooperative game with self-interested agents. In so doing, it indicates the directions that might be pursued to explain the more interesting empirical anomaly of differing patterns across disciplines. An understanding of this would be helpful in understanding both the sociology of science (Merton, 1973) and the economics of production in teams. Our earlier tabulations indicate the wealth of empirical research that could be pursued on this topic: from the relationship between attribution and team size to the existence of alternative signals of relative contribution apart from name-ordering.

To this end, on a theoretical level, our model potentially can be enriched in several ways. First, the present model has the outside options of both co-authors as zero. This lies at the heart of the strong equity drive in bargaining. While this assumption might accurately characterize collaborative efforts in economics, it is less likely to hold in other disciplines. For instance, in experimental research, priority is often assigned to the laboratory head. That individual can potentially appropriate most of the value of a project if others were to leave. To see how this might alter our model, suppose that one author can appropriate the entire value without the other. Suppose that such power resides with A (it can receive the entire value without B). Then the order will be alphabetical (regardless of market beliefs). On the other hand, if B can appropriate all value on its own, then the ordering will be reversed.[9] Thus, if one author, and only one author, can appropriate the entire value, the order itself is uninformative about anything except who had the strong outside option.

It would be interesting to explore situations in which outside options summed to less

[9] In this case there is the equivalent of an *ex ante* commitment device — B can simply seize the research if not placed first.

than total value and situations in which the relative value of outside options was correlated with relative contribution. It is likely that the types of equilibria possible will be enriched and have to be refined by use of reasonable restrictions on market beliefs in order to derive empirically relevant results. Nonetheless, it is probable that such considerations will reduce the intensity of forces driving a pure **LO Norm** and lead to a situation where the choice between the **LO** and **RC** norms is randomized in equilibrium. This is more consistent with observed evidence and would be necessary in order to analyze cross-disciplinary effects.

A second path modelling could take is suggested by Tables 1 and 2: that the greater the number of collaborators, the less likely is it that an **LO** rule will be chosen. Of course, the causation might run in the opposite direction (as suggested by Over and Smallman, 1970); that is, when market beliefs place high probability on the **LO** rule being used, the incentives for additional researchers to become part of the projects may be diminished. Therefore, by considering a model with an endogenous number of authors we can consider whether team size has an effect on name-ordering. Moreover, one could probably come to a better understanding about how signalling possibilities affect incentives to engage in collaborative projects.

Finally, our model does not have any observable heterogeneity among authors. If other properties such as seniority, eminence or task-related specialization could be observed by the market, then other possible inferences could be drawn from name-ordering. The apparent lack of use of an alphabetical ordering in sociology and the physical sciences should not necessarily indicate a superior efficiency in collaborative ventures. It may be that some other no-signalling norm prevails.

In a broader sense, this paper suggests that team and individual signalling problems can have an important influence on effort incentives. The implications of this for contract theory and the economics of organization remains an open area for future research.

References

Hudson, J. (1996), "Trends in Multi-Authored Papers in Economics," *Journal of Economic Perspectives*, 10 (3), pp.153-158.

Kalai, E. and M. Smorodinsky (1975), "Other Solutions to Nash's Bargaining Problem", *Econometrica*, 43, 513-518.

Merton, R.K. (1973), *The Sociology of Science: Theoretical and Empirical Investigations*, University of Chicago Press: Chicago.

Nash, J.F. (1950): "The Bargaining Problem," *Econometrica,* 18, 155–162.

Over, R. and S. Smallman (1970), "Citation Idiosyncracies," *Nature*, 228, p.1357.

Over, R. and S. Smallman (1973), "Maintenance of Individual Visibility in Publication of Collaborative Research by Psychologists," *American Psychologist*, 28 (February), pp.161-166.

Spiegel, D. and P. Keith-Speigel (1970), "Assignment of Publication Credits: Ethics and Practices of Psychologists," *American Psychologist*, 25, pp.738-747.

Zuckerman, H.A. (1968), "Patterns of Name-ordering among Authors of Scientific Papers: A Study of Social Symbolism and its Ambiguity," *American Journal of Sociology*, 74 (November), pp.276-291.

Figure 1: Figure 1