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Author ordering in scientific research: evidence from scientists survey in the US and Japan[1]

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Abstract

This paper examines what drives author ordering in scientific research. We first discuss a theoretical framework for the choice between alphabetical ordering and relative-contribution-based ordering and develop hypotheses, focusing on the nature of research, in particular, the importance of collaboration in the context of incomplete contract, the measurement cost of contribution-based ordering and the role of a principal investigator (PI). Our empirical examinations, based on the new large scale original scientists' surveys in the US and Japan, show the supporting results. In particular, an alphabetical ordering is more likely to be used when the research is theoretical and has less empirical component and when the team size is large and not co-located. The variation of research method goes a long way in explaining the variation of the use of alphabetic ordering across fields (mathematics and economics vs. the others) as well as its variation within a field. We also find that PI or Co-PIs are more likely to exist when the project uses more resources as well as when the team is more heterogeneous. Finally, we confirm that author ordering sends two signals in contribution based ordering, the first author for the largest research contribution and the last author for the PI (or Co-PI).

Key words: alphabetical ordering; contribution; science; incomplete contract; help; principal investigator

JEL Code: O32; D23

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1. Introduction

Scientific research has become increasingly a team work (Stephan (2012) for a comprehensive review). As the share of multi-authored papers surges, it has become an important issue how the contribution of each author is recognized and how the recognition motivates researchers. In particular, their ordering could be an important instrument for recognizing contributions.

There are significant variations of name ordering across scientific disciplines and the reasons are still not yet well understood. In early contribution, Zuckerman (1968) studied name ordering of the papers in physics, chemistry and biology. It reports that the percentage of the papers with alphabetized (or lexicographic) name order varies significantly across three fields and it is the highest in physics. Furthermore, it points out that Nobel laureates are more likely to be the last authors than the first authors. It is also found that alphabetical (or lexicographic) ordering is more extensively used in economics than in natural science (Engers, Gans, Grant and King (1999) and Laband and Tollison (2000)). Laband and Tollison (2006) also show that the preponderance of non-alphabetized papers in agricultural economics, as compared to economics, within economics field.

There is no established view on when and why alphabetical ordering is used rather than contribution-based ordering. The question of why the author name ordering practices differ significantly across disciplines remain a major puzzle, as pointed out by Merton (1973) decades ago. However, we have at least three theories explaining the choice of alphabetical ordering. Engers, Gans, Grant and King (1999) propose a model based on ex-post Nash bargaining with no side payment, which can potentially explain the prevalence of alphabetical (or lexicographic) ordering in economics. In their model, alphabetical ordering is chosen with some positive probability ex-post to achieve Nash solution at the expense of ex-ante incentive for efficiency. It is even possible that alphabetical ordering appears as the market norm in the unique equilibrium. On the other hand, Laband and Tollison (2000) suggests that informal collaboration ("helping") is more important in economics than in biology, as shown by more "thanks" expressed in acknowledgements, and therefore a pay compression by alphabetical (or lexicographic) ordering is more used in economics to facilitate helping among authors. In this view, alphabetical ordering is chosen ex-ante for efficiency reason. Furthermore, Joseph, Laband, and Patil (2005) present a simulation result where we observe alphabetical ordering only when each of two authors performs very well. In this case, alphabetical ordering emerges ex-post even if they work hard to obtain priority in listings. Their model offers one potential explanation of why high-quality papers tend to have alphabetical ordering.

This paper aims at contributing to our understanding of the determinants of the author ordering in scientific research, based on novel survey data covering more than 4,000 US and Japanese science projects. We think that there are three major contributions of this paper. First, we find that the nature of research, in particular, the research method used goes a long way in explaining the variation of the use of alphabetic ordering across fields (mathematics and economics vs. the others) as well as its variation within a field. We argue that such result reflects the importance of collaboration in the context of incomplete contract, that is, an incomplete division of labor and the importance of unplanned help among the authors makes weak incentive more desirable. We point out the importance of "help" among the authors, but not social nature of research as pointed out by Laband and Tollison (2000).

Second, we show that the measurement cost of contribution based ordering is also a major reason for the choice of alphabetical ordering. While an individual incentive under alphabetical ordering declines sharply with the number of authors due to free-riding, the measurement cost saved by alphabetical ordering increases with the number of authors, as pointed out based on interviews by Zuckerman (1968). Such combination allows the possibility of a U shaped pattern between the incidence of alphabetical ordering and the team size. We also expect that collocated team will adopt more a contribution based ordering, controlling for the nature of research, due to lower measurement cost. We have corroborated this hypothesis.

Third, we show how the choice of the governance form in the research team interacts with the choice of name ordering. Having a PI or co-PIs who manage the project including monitoring each member's progress is associated with the relative-contribution-based ordering even after controlling for factors affecting the two. PI has an incentive to measure members' contributions fairly because he typically is assumed to be the last author (thus has less conflicts of interest with other members) and presumably cares his reputation as a PI. The rest of the paper is organized as follow. Section 2 provides theoretical background and hypotheses. Section 3 explains data. Section 4 and 5 explains the estimation models and results. Section 6 concludes.

2. Theoretical Background

While a number of factors are likely to affect the types of author ordering (See Figure 1), we focus here on the nature of research, the role of Principal Investigator (PI) and the measurement cost.

2.1 Nature of research- importance of collaboration in the context of incomplete contract in research-

First, the nature of research determines the importance of the incompleteness of the initial "contract" (i.e. agreement) on what should be done and how the tasks should be allocated and the importance of unplanned mutual help along the course of conducting research. When the research project seeks unknown and uncodified fundamental concepts and mechanisms, efforts should cover numerous trials and explorations of new ideas. Then, it would be impossible to define the division of labor ex-ante among the researchers, and getting new idea, different perspectives and feedbacks from the coauthors would become very important. Furthermore, verifying these efforts, many of which may not be embodied in the final research output, can be very difficult and costly. In such sciences, alphabetical ordering is likely to be efficient because team pay system with equal sharing will encourage "helping" behaviors, while ordering based on relative contributions hinder such cooperation, as analyzed in Lazear (1989) and Itoh (1992).[2] In contrast, when the key concepts are codified and the methodology is well established, the research project will be focused on exploiting existing idea and defining the division of labor ex-ante is easy. In this case, contribution-based ordering could be optimal due to the shift in the tradeoff between cooperative and competitive efforts, because the value of unmeasured helping is rather limited.

The importance of unplanned and unobservable collaborations from co-authors can be highlighted in a comparison between pure theoretical researches vs. empirical researches. In pure theoretical researches where the exploration of new perspectives and mechanisms is valuable, unplanned "helps" one member offers to the other co-authors could lead to path-breaking results but the assessment of such contribution could be very different across co-authors because of redundancies (i.e. one already had suggested idea), cryptomnesia (i.e. reappearance of once-forgotten memory of suggested idea as if it were one's own idea), and simple forgetting. Another aspect of abstract theoretical research is that they involve numerous trials most of which end up in failures and are hard to describe in an explicitly codified manner. This is different from empirical and experimental researches where failed trials are shared among team members in the form of computer data log files or laboratory notes. If one's contribution was conducting many trials which all turned out to be failures but not necessarily reported to other co-authors, it is not clear how much recognition should be given to him/her even though crossing out failure cases is necessary process in science. Given

[2] Itoh (1992) further implies that encouraging teamwork through alphabetical ordering is even more desirable if help from a co-author is complementary with one's own efforts.

that assessments of one's contribution are not perfectly correlated among co-authors, compressed pay embodied in alphabetical ordering is likely to be optimal (MacLeod 2003). When there is clear division of labor (and thus helping each other is not so frequent or indispensable) and investigating numerous ideas and approaches are less necessary, co-authors are more likely to have equal assessment of each other's contribution.

2.2. Principal investigator (PI) as an organizer and monitor

The principal investigator (PI) organizes activities in the research team and monitors each member's work and progress as well as defines and implements the attribution rule for the authors.[3] The existence of a PI enables the exploitation of the scale and scope in research and therefore the formation of a large team. It could also change the relative efficiency of the alphabetical and contribution-based ordering completely—more likely to expand the scope of relative contribution based ordering—for the following reasons:

First, the PI has a strong incentive to monitor co-authors by frequently checking the progress and asking them to record results in experiment notebooks because of the credit given to him as the PI. The PI also arranges for meetings and workshops to facilitate collaborations among the team members. These roles indicate that he may observe, at least partially, the full dimension of the efforts and the outputs of the team members. Therefore, the PI may be able to use relative contributions based ordering more effectively–encourage competition without harming cooperation among the team members.

Second, the PI typically has a control of essential assets for the project such as facility, equipment, and scarce materials used in experiments. Therefore, he/she has the much stronger bargaining power than other co-authors. This means that he can design an incentive contract and may make a leave-it-or-take-it offer to other co-authors. Furthermore, since he works on multiple projects with many authors, he also has a strong incentive to accumulate reputational capital as depicted in the literature of multimarket reputation (Kreps and Wilson 1982, Milgrom and Roberts 1982). Therefore, the PI has capacity to commit to pre-determined author ordering policy to avoid the inefficiency as analyzed by Engers, Gans, Grant and King (1999), where the actual contributions may end up with almost equal share, even if contribution based ordering

[3] The principal investigator is often the person who put forward a successful research proposal for financial resources for the project, develops a research execution plan, recruits the team members and manages the project in staffing and budgeting.

is more efficient. This effect also tends to expand the scope of relative contribution based ordering in some cases[4].

Thirdly, the PI can minimize the conflict of interests by avoiding direct competition with his co-authors. In fact, PI often becomes the last author, while the other authors are ordered according to the relative contributions. Then, PI has a little incentive to "steal" the credit from the other team members.

To summarize, the existence of the PI reduces the cost of measuring the individual performance and enforcing the ordering of the authors according to the relative contributions, while the incentive problem for the PI can be solved by providing him the last position in author ordering.

2.3 Cost of monitoring and evaluations

One disadvantage of contribution based ordering is the cost of monitoring and evaluating individual contributions—necessary for the determination of relative contributions—including the cost of haggling and conflicts. Such transaction cost is absent for alphabetical ordering. This consideration suggests that alphabetical ordering is chosen if the number of author size is very large and the potential risk of conflict is large.

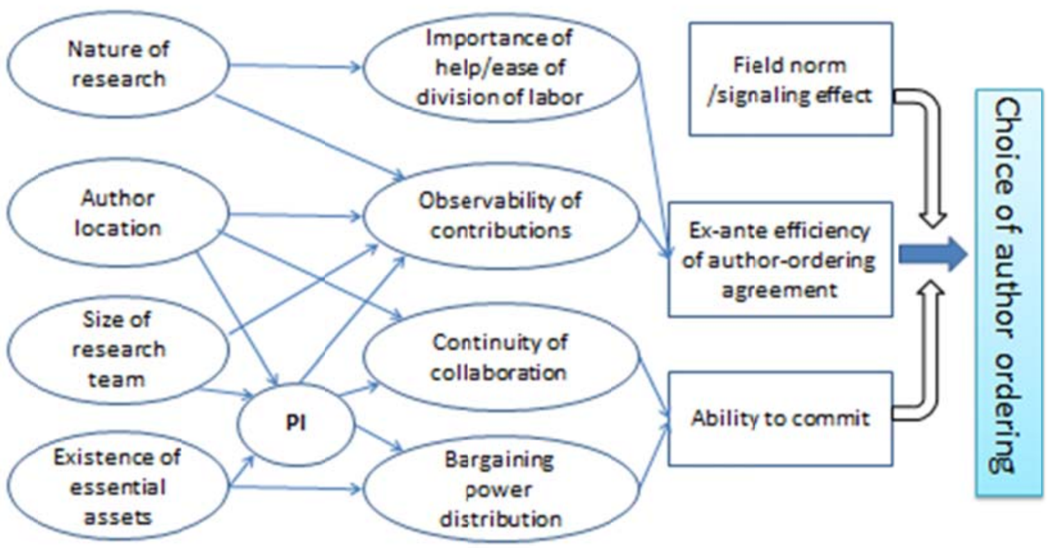
Similarly, author location could affect author ordering through its impacts on the observability of co-author contributions. If all authors work in the same institution, there will be more frequent communications, more interactions, and higher expectation of long-term collaboration. Therefore, relative contributions are more likely to be jointly observed and the efforts to make fair assessment of each other's contribution will be high.[5] This makers ordering based on relative contributions more

[4] The commitment power of the PI also can also expand the scope of alphabetical ordering. Co-authors may feel it unfair to rank them using differences especially when the market gives them very different credits based on the order, so that the alphabetical ordering may become ex-post infeasible. The existence of PI may be able to prevent such renegotiation.

[5] Note that author location could have a countervailing effect when efforts are observable but not verifiable. If all authors work in the same institution, implicit agreements are more likely to be honored because any deviation may be easily punished. This means that if members agree to choose alphabetical ordering from the efficiency reason, they are more likely to commit to it. It is also likely that members become more lenient toward a colleague who did not contribute to the project from the expectation that he will contribute to the next project if they share the expectation of repeated collaboration. These factors make alphabetical ordering more likely. We examine this

likely.

Figure 1. Factors affecting author-ordering



(Figure 1)

2.4. Field norm

Another factor that we believe is important is field norm. If most research teams in the field choose alphabetical ordering, choosing relative contribution based ordering will have a stronger signaling effect, which in turn discourages teams from choosing the latter unless the inequality in contributions is large enough. Similarly, if a majority of co-author teams in the field choose relative contribution based ordering, its signaling effect becomes weaker, encouraging many more to choose the ordering to avoid the biased nature of alphabetical ordering. Proving the existence of field norm and its

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possibility in our analysis.

empirical assessment is difficult because it only reinforces the influence of other factors. Therefore, we do not examine any hypothesis involving the role of field norm.

2.5 Hypotheses

Given these theoretical grounds, we test the following hypotheses with respect to the choice of alphabetical ordering.

First, nature of research, in particular, the incompleteness of co-authorship agreement—frequent encounter to unforeseen contingencies—and the importance of unplanned help (collaborations) required in such contingencies significantly raise the benefit of weak or no relative performance based incentive. We expect that contract incompleteness and importance of help are high in theoretical research and in the research pursuing fundamental understanding. It is difficult to define ex-ante division of labor for a theoretical research because parallel exploration is often desirable and spontaneous help (collaborations) is indispensable. In contrast, ex-ante division of labor is relatively easier in empirical research and in the research pursuing a specific real world problem, given that the target is more clearly specified.

Hypothesis 1 (Effects of nature of research):
Theoretical research tends to adopt an alphabetical ordering, while an empirical research tends to adopt a contribution based ordering. Similarly, a research pursuing a fundamental understanding tends to adopt an alphabetical ordering, while that pursuing a solution to a specific real world problem tends to adopt a contribution based ordering.

Second, the measurement cost of contribution-based ordering increases with the number of authors, and it is also high when the authors are not collocated. At the same time, the number of authors also affects the incentive provided under alphabetical ordering, which declines sharply with the number of authors due to free-riding (*i.e.* 1/N problem), while the incentive effect of contribution-based ordering, at least for the first author, does not decline as sharply with the number of authors.

Hypothesis 2 (Effects of size of research team): The relationship between the size of project team and the choice of author ordering is likely to be non-linear and can exhibit the U-shape with respect to the probability of alphabetical ordering—a small and a very large teams are more likely to adopt alphabetical ordering.

Assuming that the nature of the research project is controlled, collocation of the authors would reduce the measurement cost of a contribution-based ordering, so that the collocated team would use more contribution-based ordering and the team whose authors are not collocated will use alphabetical ordering.

Hypothesis 3 (Effects of author location): When all authors are not affiliated with the same institution, the ordering is more likely to be alphabetical, since the measurement cost of using contribution-based ordering is high.

There are two distinct roles of PI: one for project design and resource mobilization and the other for project management. For the first role (i.e. project design and funding), there are economies of scale and large-scale mobilization of resources (large team size, use of external research materials etc.) requires someone specializing in organizing the activities—thus, PIs are likely to exist. In addition, when relative contribution based ordering is effective, a monitor is necessary. Thus, the nature of research and team composition that make alphabetical ordering more likely as stated in the above hypotheses will make PI less likely to exist. At the same time, the exogenous reason for the existence of PI such the resource mobilization reason may make alphabetical ordering less likely to be adopted, since a monitor is more likely to exist. For an example, large budget indicates that the research requires some physical assets or scarce resources. They make PIs more likely to exist and, since PIs have incentives and capability to monitor team members, the ordering based on relative contributions is more likely to be adopted.

Hypothesis 4 (Size of resource mobilization, the existence of PI and its effects): Projects that have large budget and mobilize the other large resources are more likely to have PIs, which in turn make alphabetical ordering less likely. In addition, the factors which make alphabetical ordering less likely as stated in the above hypotheses 1 and 3 (research nature and co-location) will make PI more likely to exist. The existence of PI in turn facilities the use of contribution based ordering.

PIs also enjoy separate recognitions as the last author and are motivated to accumulate reputational capital for fair evaluations and commitment.

Hypothesis 5 (Two types of signals from contribution based author ordering): The author ordering in the case of non-alphabetical ordering sends the two important signals: one for signaling the relative contributions of researchers and the other for signaling the contribution in terms of initiating and managing the research project.

3. Data sources and descriptive statistics

3.1 Data sources and the distribution of the ordering types

We use the Hitotsubashi Univ-NISTEP-Georgia Tech scientists' survey in Japan and the US (see "Knowledge creation process in science: Key comparative findings from the Hitotsubashi-NISTEP-Georgia Tech scientists' survey in Japan and the US" (jointly with Igami, Walsh and Ijichi)[6]. This collected 2,100 responses in Japan and 2,300 responses in the US (the response rate was 27% in Japan and 26% in the US), with one third of the population from top 1% highly cited papers (referred to by H papers), and the rest of the paper referred to by N papers. The survey covers comprehensively the project characteristics which produced such paper: motivations of the research projects, knowledge sources that inspired the project, uncertainty in the knowledge creation process, research competition, composition of the research team, sources of funds and research outputs, e.g., research papers, students, patents, etc. It covers all sciences, including social science.

In addition, the survey specifically asked the order of the authors: (1) contribution-based; (2) alphabetical; (3) senior first; (4) senior last; and (5) other.[7] Figure 2 shows the distribution of the types of ordering (% of each type of the order of the authors) across four categories of the papers (H papers and N papers in Japan and in the US). In each category of the papers, ordering by relative contribution accounts for the most (more than 60%), followed by senior last ordering, alphabetical ordering and then senior first ordering. In both countries, contribution based ordering is less used in H papers, and alphabetical and senior last ordering is more used in H papers. Contribution based ordering is more used in Japan than in the US.

(Figure 2)

We shows the distribution of the types of ordering by 21 scientific fields in Japan and the US in Figure 3. Although contribution based ordering accounts for more than a half of the papers in most sectors, there exist significant variations across fields. Alphabetical ordering has a near half to a dominant portion only in

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[6] http://www.iir.hit-u.ac.jp/iir-w3/file/WP11-09NagaokaIgamiWalshIjichi.pdf

[7] The respondents were asked to choose only one, although there was a response category ("other"). We treated "other" as a separate category which cover those cases where none of the four ordering rule dominated.

mathematics, and economics and business. It accounts for two thirds of the papers in mathematics and for more than 40 % of the papers in economics and business in the two countries. The ordering of "senior author last" also has a significant portion and accounts for more than 40% of the papers in biology & biochemistry, immunology, molecular biology, neuroscience & behavioral biology, and pharmacology & toxicology in the US. The share of this ordering is less dependent on the fields in Japan.

(Figure 3)

3.2 Nature of research

There is very strong correlation between the research method employed and the incidence of the alphabetical ordering across sectors. Figure 4 shows the percentages of the intensive use of theoretical analysis, and experiments and observations–results from the question of how intensively the team of scientists used three research methods (theoretical analysis, experiments and observations, and computations), measured by the Likert scale from no-use (0) to highly intensive use (5). Figure 4 uses the response of "highly intensive use". Since the question was included only in the Japanese survey, the figure shows only the data for Japan. As is shown, mathematics, and economics and business where the alphabetical ordering is highly prevalent are outstanding in terms of very high proportion of the intensive use of theoretical analysis. It exceeds 65%, followed by Physics where only 33% of the projects use theoretical analysis intensively. Economics and business is surprisingly close to mathematics in terms of the intensive use of theoretical analysis. We can also observe a relatively intensive use of theoretical analysis in physics where alphabetical ordering is prevalent, after mathematics, and economics and business.

(Figure 4)

Mathematics, and economics and business are also distinguished by the low percentage of intensive use of experiment and observations (5.1% and 7.7%), which is less than half of the third lowest field (computer science) in terms of the use of these research methods, although physics has a relatively high proportion of the projects using experiment and observations. The variation of the intensity of the two research methods goes a long way in explaining the variation of the use of alphabetic ordering across fields (mathematics and economics vs. the others), as shown in Figure 5. In this Figure only the Share of alphabetic ordering is based on the average of the US and Japanese responses. The importance of theoretical analysis relative to empirical analysis is given by the difference of the share of very intensive use of theoretical analysis and the share of very intensive use of observations and empirical analysis for each field. In our statistical analysis, we will further examine whether the project intensively using the theoretical analysis and using less the empirical analysis is more likely to use alphabetical ordering within each scientific field, controlling for the other attributes of the projects, including a number of authors.

(Figure 5)

Another important characterization of the research project is the objectives: the importance of seeking fundamental understanding and that of solving specific issues in real life as the objective of the research project. We would expect that alphabetical ordering will become more important as the importance of fundamental understanding as the objective of the research increases and that it becomes less important as the importance of providing a solution increases. We do not find strong cross section correlations between the research objectives and the incidence of alphabetical ordering among the fields, as we saw for the research methods and the incidence of alphabetical ordering. However, across projects, as shown in Figure 6, the share of alphabetical ordering increases with the importance of fundamental understanding as research objective, in both US and Japan. The senior author last ordering also tends to increase. More strongly, the share of alphabetical ordering decreases with the importance of solving a specific real world problem as the research objective increases, as shown in Figure 7.

(Figure 6 and 7)

The fact that solution orientation matters even in mathematics is indicated by Figure 8. This figure shows that the alphabetical ordering declines with the importance of solution orientation in mathematics (In mathematics, 84% of the papers regards seeking fundamental understanding as very important, so that the variation in this respect is small). The results also suggest that there exists a general principle operating across scientific fields.

(Figure 8)

3.3 Author size and locations

Figure 9 shows the distribution of the author ordering type by the author size. In both Japan and in the US, the share of an alphabetical order becomes initially smaller with the increase of author size from 2 authors per paper and then increases again. Thus, it follows a U-shaped pattern.

(Figure 9)

Figure 10 shows the distribution by the type of institutional affiliations of the authors. In both Japan and the US, the alphabetical ordering is less prevalent when all the authors are co-located in a domestic single institution. On the other hand, the ordering of "senior author last" becomes more prevalent with co-location and the share of ordering based on contributions is lower for international collaborations than domestic collaborations. These results suggest that distance makes monitoring less effective and/or less intensive, resulting more frequently in alphabetical ordering.

(Figure 10)

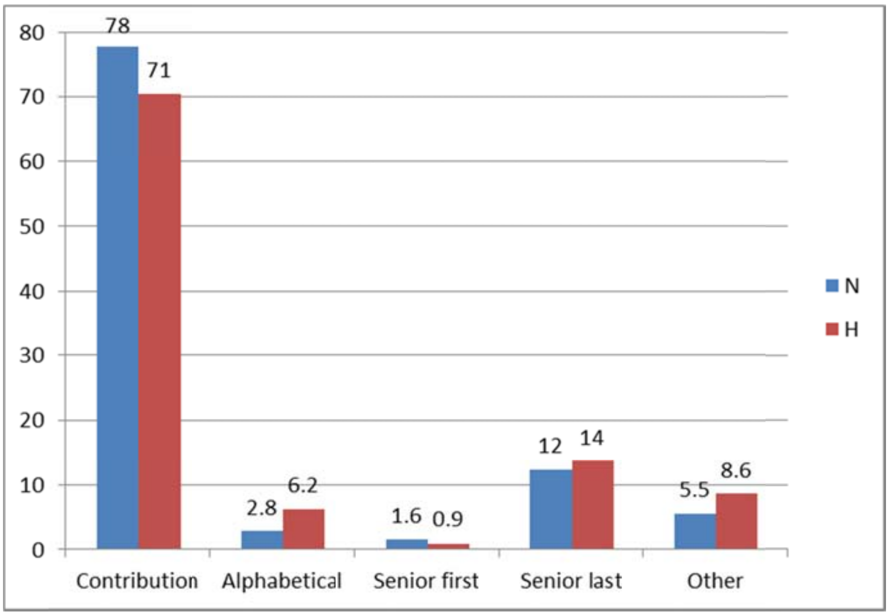
3.4 Research management as seen from corresponding authors

Figure 11 shows the relationship between the research management and the author ordering. The question we asked on management in the survey was whether the respondent (corresponding author) was PI or Co-PI, whether he played some management less than the role of PI or Co-PI, or whether he played no management role as well as whether the research management was unnecessary for the project. Out survey mainly went to the corresponding author. 80% (60%) of the respondents were PI or Co-PI in the US (Japan). No research management was necessary for 8% of the cases in Japan and 5% in the US. As shown in this Figure, research management existed significantly less in the papers with alphabetical ordering in the two countries.

(Figure 11)

Figure 2 Author ordering by sample (H: highly cited papers, N: Normal papers)

(JP, the total sample size =1943, in which 546 papers are H papers)



(US, the total sample size=2058, in which 731 papers are H papers)

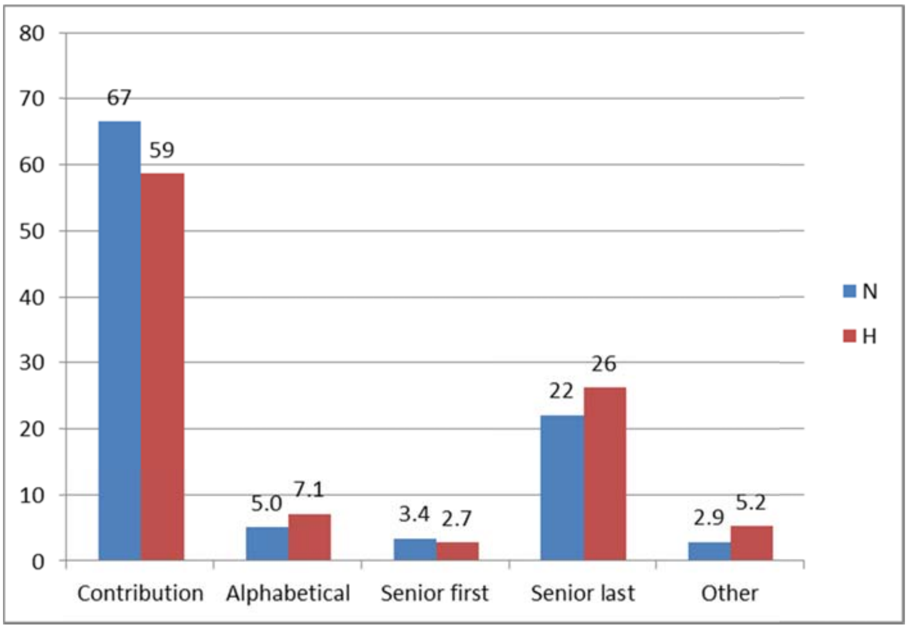
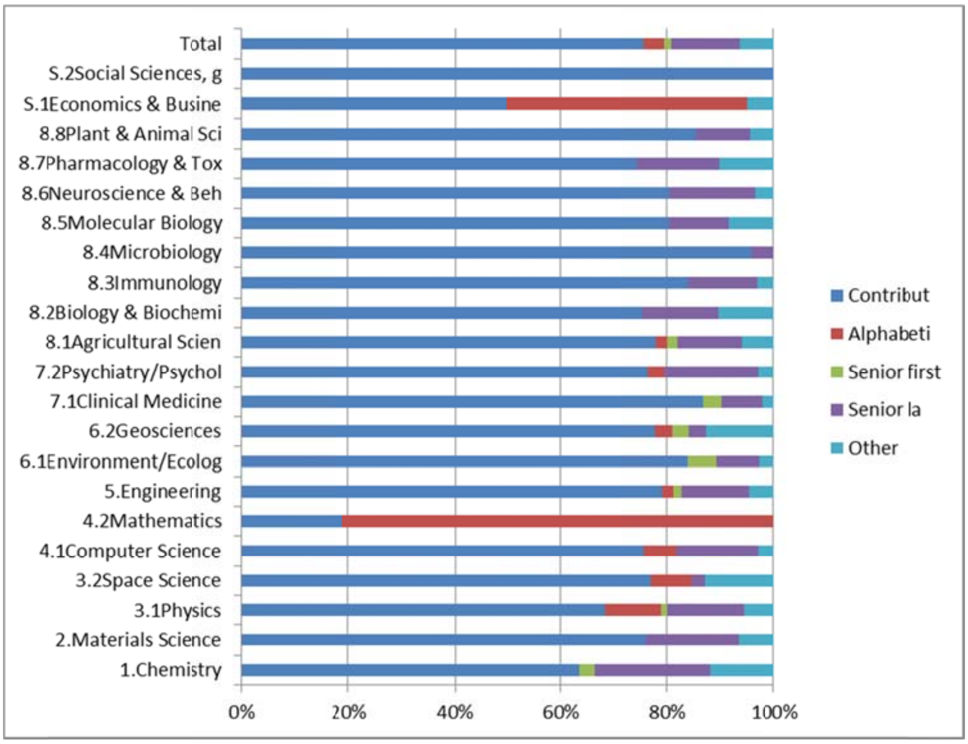


Figure 3. Author ordering by science fields (authors>=2)

(JP, sample size=1943)



(US, sample size =2058)

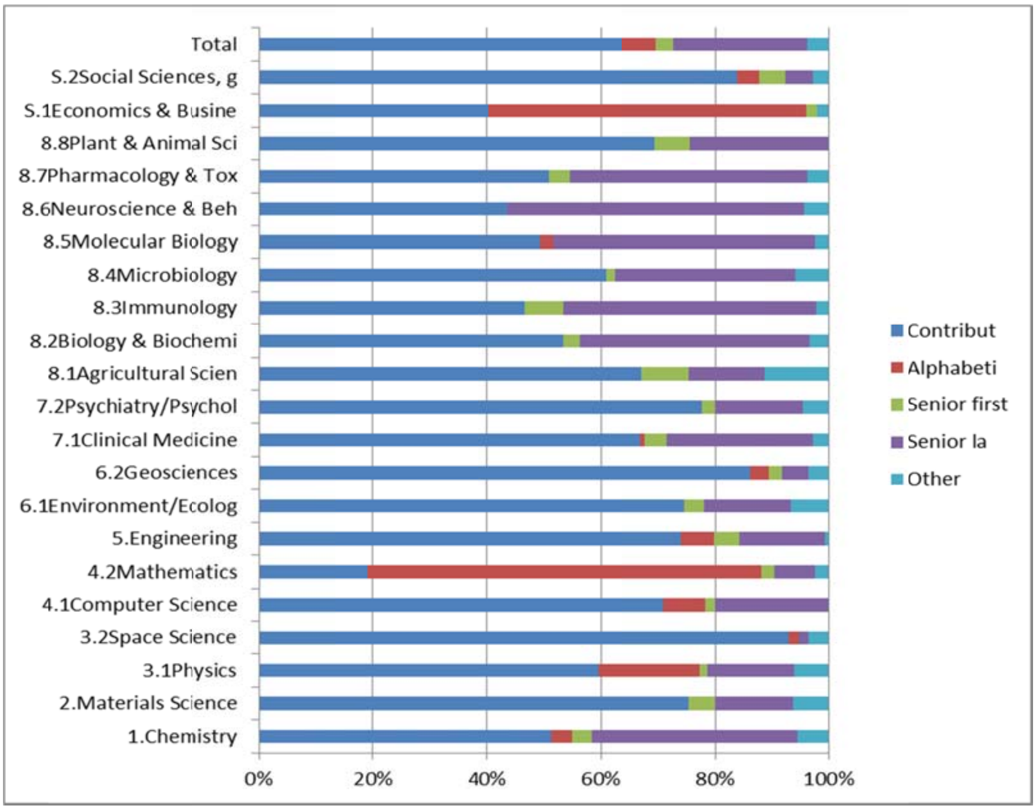


Figure 4. Frequency of the use of theoretical analysis and observations & experiments by scientific fields (Japan, % , " very frequent use")

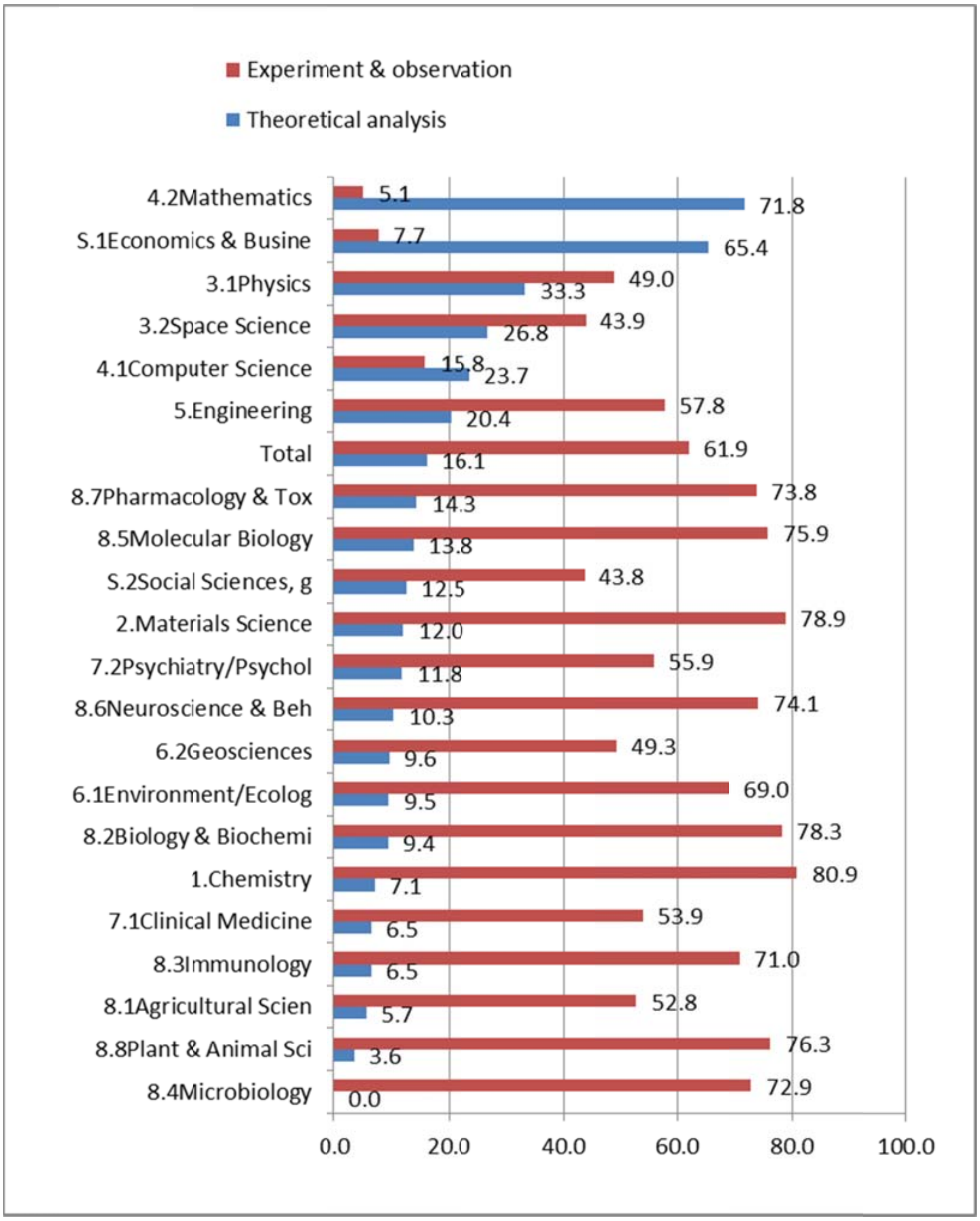
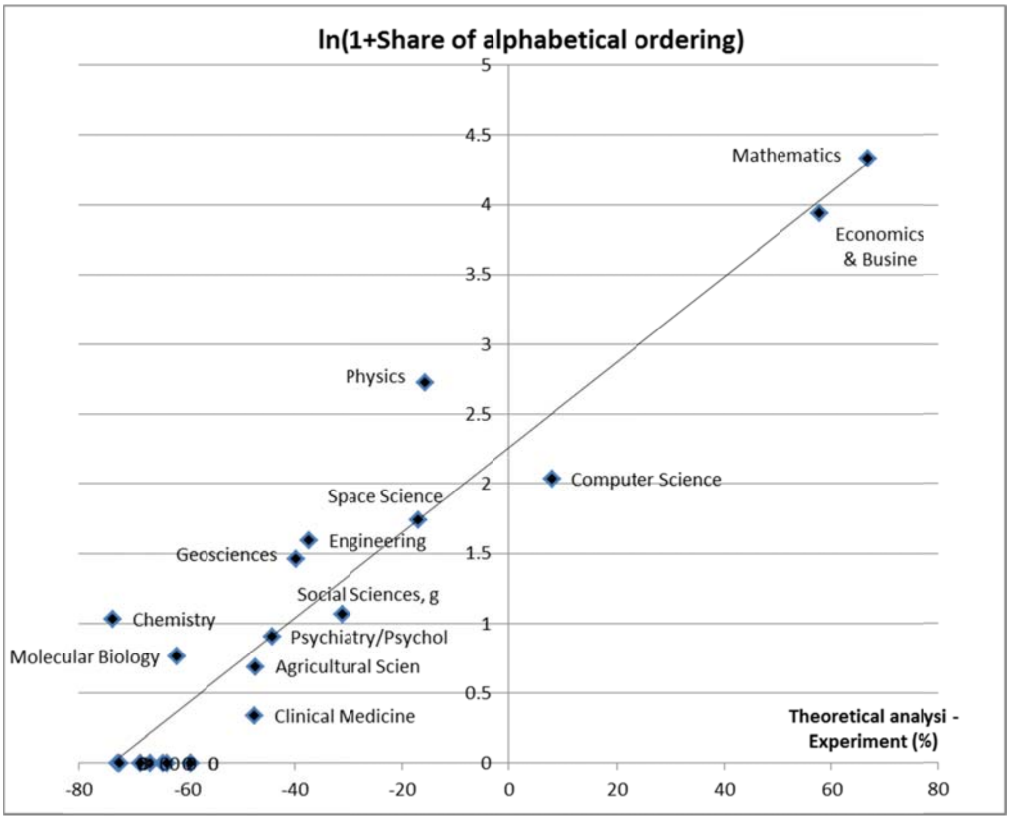


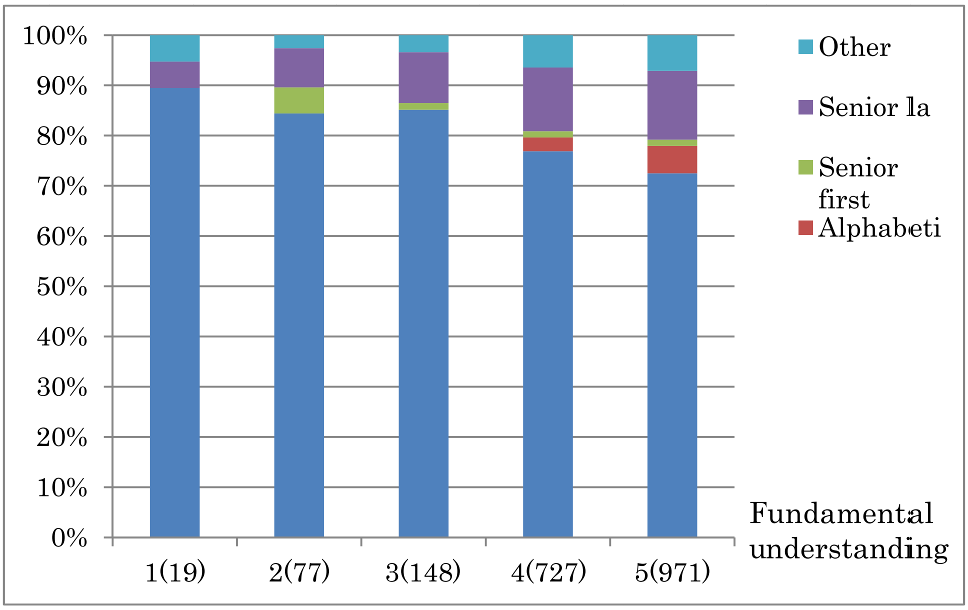
Figure 5. Alphabetical ordering and nature of research (the importance of theoretical analysis relative to empirical analysis) across 21 science fields



(Note) The Share of alphabetic ordering is based on the average of the US and Japanese responses. The importance of theoretical analysis relative to empirical analysis is given by the difference of the share of very intensive use of theoretical analysis and the share of very intensive use of observations and empirical analysis for each field.

Figure 6 Author ordering by the objective of research (Fundamental understanding, 1 not at all, 5 very important)

(JP)



(US)

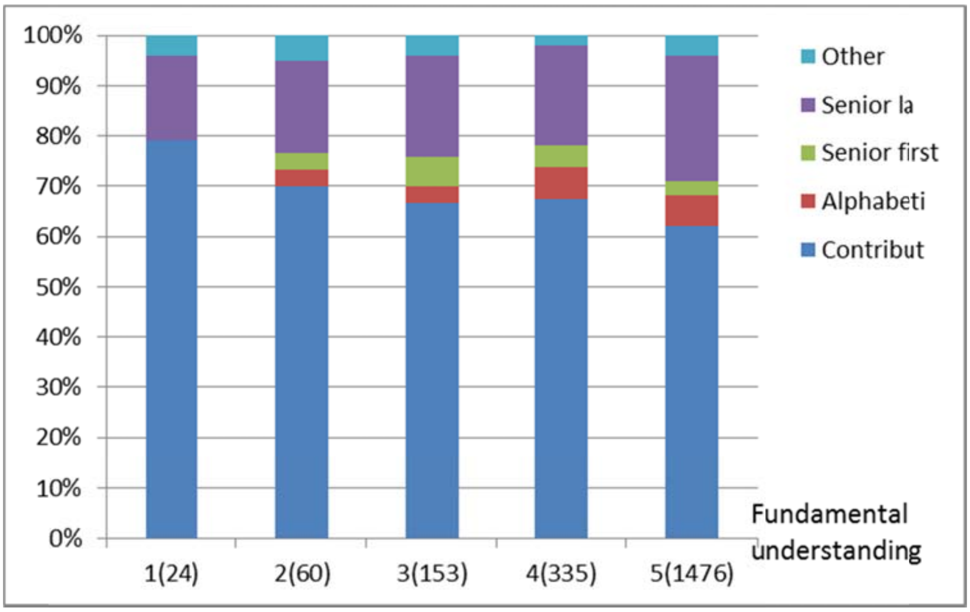
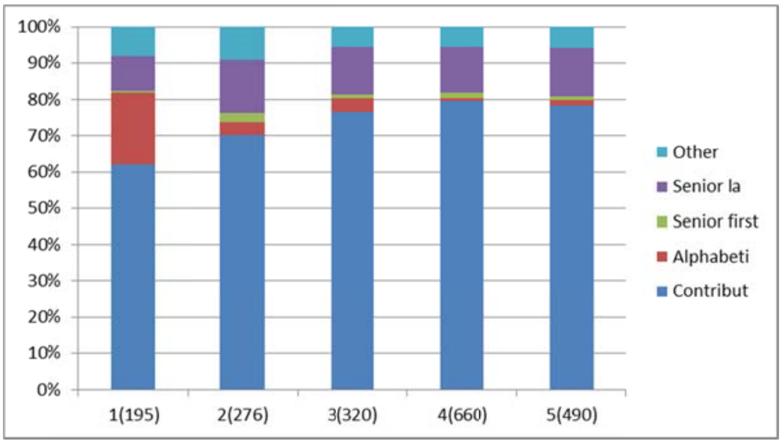


Figure 7. Author ordering by the objective of research (Solution of a specific real world problem, 1 not at all, 5 very important)

(Japan)



(US)

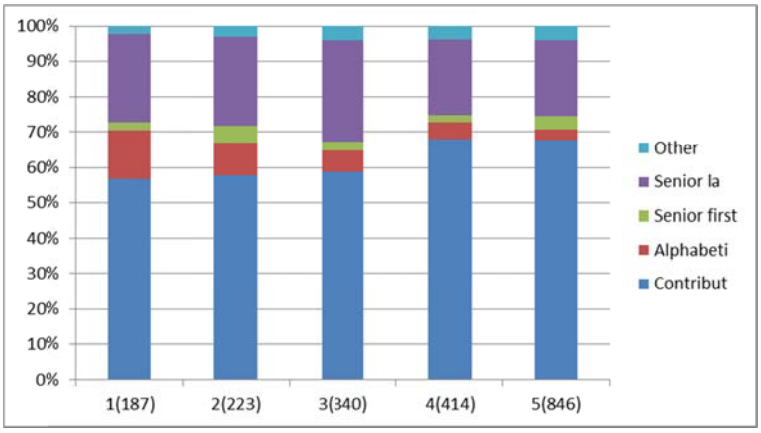
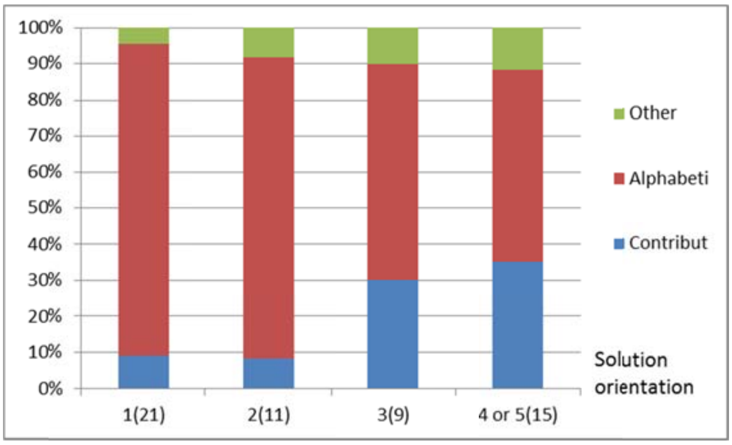


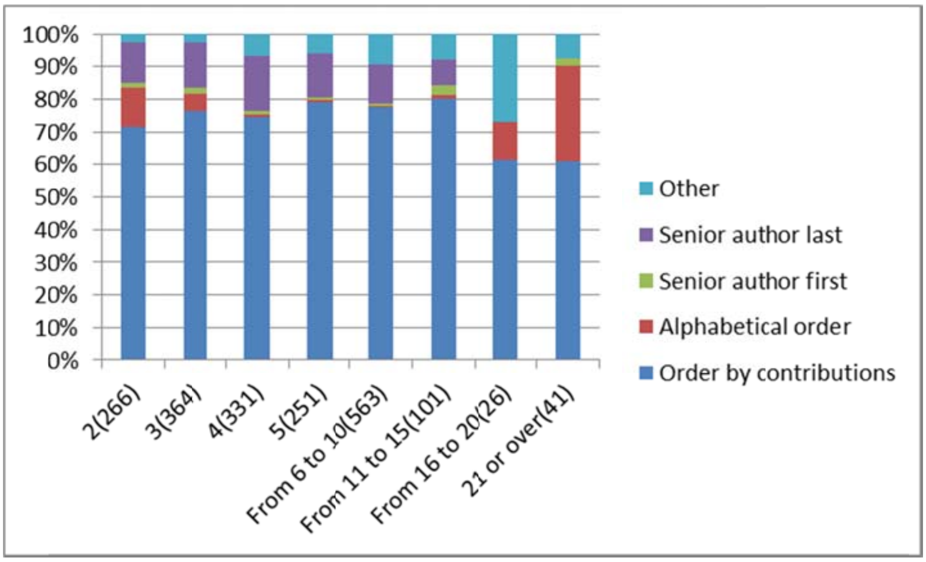
Figure 8 Author ordering by the objective of research in mathematics (Solution of a specific real world problem, 1 not at all, 5 very important)



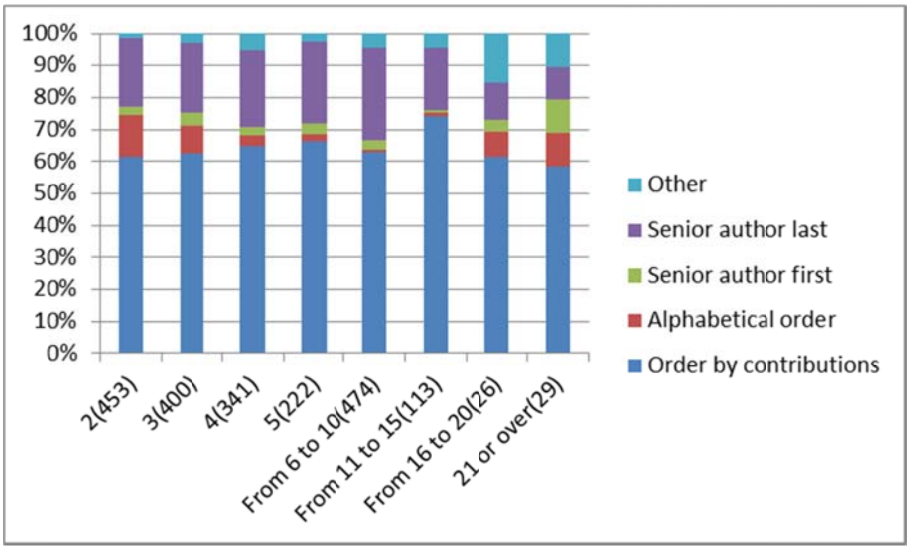
Note: the number in the bracket indicates the author size.

Figure 9. Author size and the author order

(Japan)



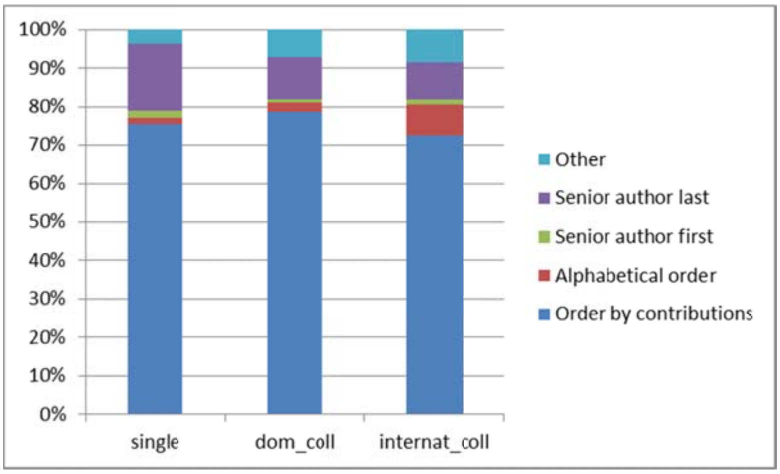
(US)



Note: the number in the bracket indicates the author size.

Figure 10. Institutional affiliations and author ordering

(Japan)



(US)

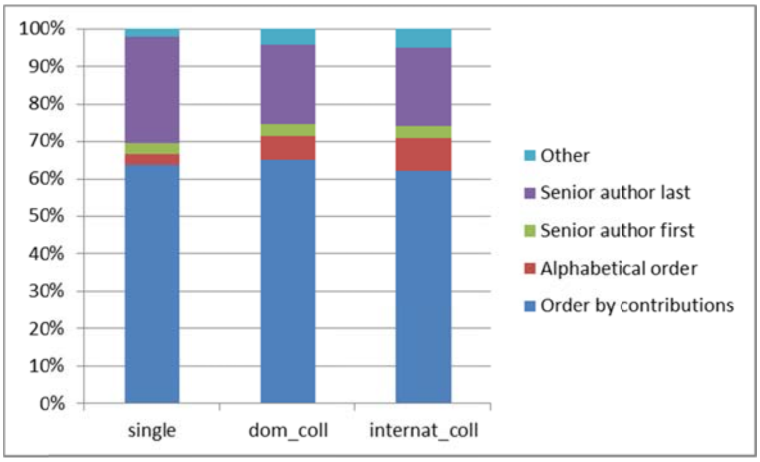
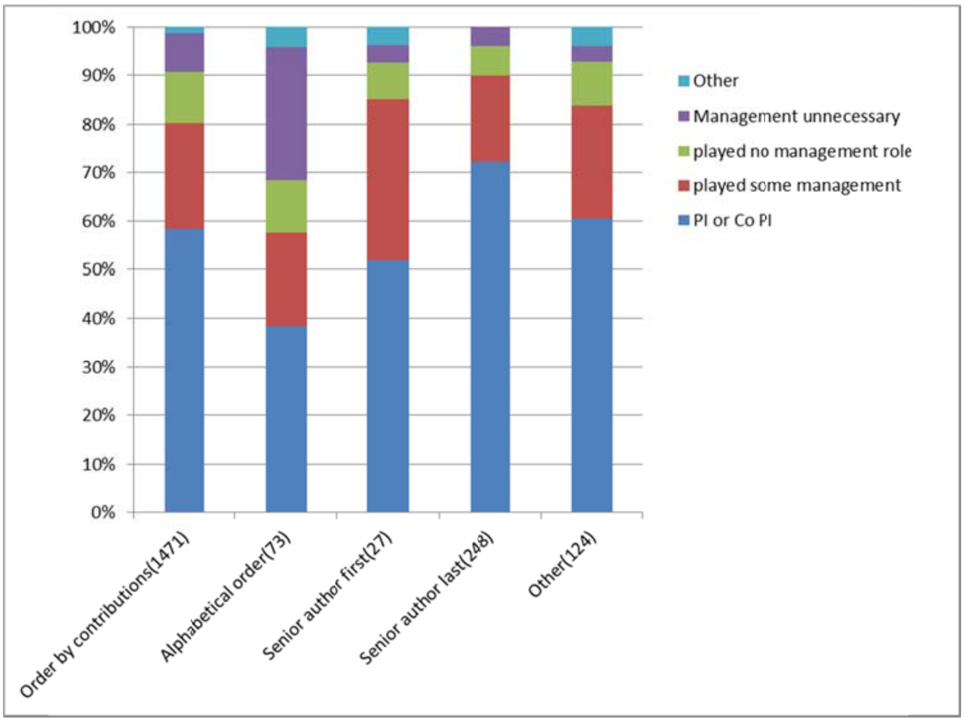
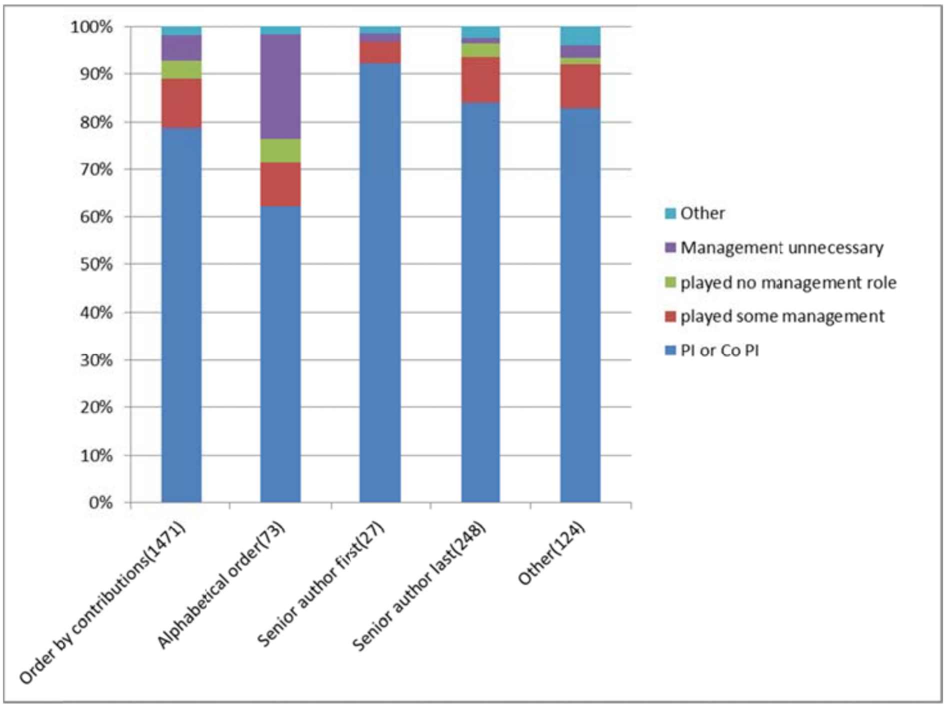


Figure 11. Research management and the author order

(Japan)



(US)



Note: The first three choices are those by the responding author.

4. Estimation models

4.1 Choice of alphabetical ordering

We examine Hypotheses 1 to 3 by examining the determinants of the choice of alphabetical ordering at project level. The dependent variable is the dummy for alphabetical ordering: 1 for alphabetical ordering and 0 otherwise.

$$Dummy\ for\ alphabetical\ ordering_i = \Sigma\,\alpha_i(Reserach\ objectives_i) + \Sigma\,\beta_i(Research\ methods_i) + \Sigma\mu_i(Number\ of\ authors_i) + \gamma_i(Co-location\ \text{of authors}_i) + \Sigma\rho_i(Team\ structure_i) + \delta_i(Research\ management_i) + the\ other\ controls + \varepsilon_i \quad (1)$$

where the summation Σ indicates that $Reserach\ objectives_i$, $Research\ methods_i$, $Number\ of\ authors_i$, and $Team\ structure_i$ are multi-dimensional vectors of dummies for the corresponding categorical variables by abusing notation.

In order to characterize the nature of research we use the information on the objectives for the research project and the research method employed. We hypothesize that the measurement cost of relative contribution based ordering is larger when the number of authors (*lnauthors*) is large, and when the authors are not co-located and belong to different institutions (not a single institution). In order to reflect potential nonlinearity, we also introduce the square of *lnauthors*: *lnauthors_sq*. For identifying the co -location, we use a dummy (*co_location*) which is set to 1 if all authors belong to a single domestic institution, and set to 0 otherwise.

We also control for the team structure because it is quite possible that heterogeneous team members expect their contributions unequal among the members from the beginning and thus find it difficult to agree with alphabetical ordering. One measure of heterogeneity is the existence of non-research authors who provided only research inputs other than research work, such as research materials, access to external research equipment, software or database or money (*nonresearch_author* which is a dummy). We also use two dummies to indicate whether all authors are senior (no assistant professors, post-doctoral fellows nor students, a dummy *homogneous_o*) and whether all authors are junior (undergraduates, graduate students, postdoctoral fellows, or assistant professor, a dummy *homogneous_y*).

We also introduce a dummy on whether the research management was necessary or not (*mnt =0* if unnecessary, 1 otherwise) to assess the existence of a PI. We also introduce the sample type (*citedness*, H papers or N papers) to account for the sample selection effect, including the effect as analyzed in Joseph, Laband, and

Patil (2005)—high-quality papers have disproportionally high share of the papers with alphabetical order ex-post simply because authors are more likely to agree with alphabetical order when all members succeed in contributing to the project. Twenty one science field dummies and the publication year are included as further controls. We use the entire sample separately for the US and Japan.

4.2 Existence of research management

We are interested in under what circumstances a PI who specializes in research management exists. One problem is that we do not have the exact information about whether the research team has a PI or not unless the correspondence author is a PI or co-PI. As the second best, we use the same indicator used in the above equation (1)–whether the research management was necessary or not (mnt =1 if management was necessary, 0 otherwise). Since it is quite possible that some management role is shared among members without a PI, we use the following two samples to examine the robustness of results: the whole sample and the sample with either no management or with the corresponding author being either PI or co-PI. The specification is given by the following equation, with the dummy for the existence of a management or PI:

$$Dummy\ for\ the\ existence\ of\ management\ or\ PI_i = \Sigma\,\alpha_i(Reserach\ objectives_i) + \Sigma\,\beta_i(\text{Research methods}_{\ i}) + \Sigma\mu_i(Number\ of\ authors_i) + \gamma_i(Co-location\ \text{of authors}_i) + \Sigma\rho_i(team\ structure_{i)} + \theta_i(\text{Research resources}_{\ i}) + the\ other\ controls + \varepsilon_i \qquad (2)$$

where the summation Σ indicates that $Reserach\ objectives_i$, $Research\ methods_i$, $Number\ of\ authors_i$, and $Team\ structure_i$ are multi-dimensional vectors of dummies for the corresponding categorical variables. Except for the variables for research resources, we use the same set of explanatory variables as equation (1). As the measures of research resources, we introduce a budget size (*lnres_fund*) and the number of non-author researchers, such as technicians and students (*ln1non_authors*). Since PI mobilizes resources as well as manages the project, we expect that PI is more likely to exit, if the project has a large budget, and a large scale of non-author researches (such as technicians and students), as stated in Hypothesis 4. Furthermore, we expect that nature of research, author co-locations and the team structure will have similar (although the opposite signs) effects on the existence of research management as in the analysis in Section 4.1. The number of authors would positively affect the existence of research management as it reflects the scale of resource mobilization.

4.3 Last author as a signal of managerial contribution and the first author as a signal of the largest research contribution

When non-alphabetical order is chosen, the order of the authors is used to signal contributions. Our analytical discussions (Hypothesis 5) suggest that the authors may wish to send two different contributions by the authors: one for signaling the largest contribution of a researcher in the research tasks and the other for signaling the contribution in terms of initiating and managing the research project (PI task). Thus, we test whether the first author is used for signaling the largest research contribution and the last author for signaling the management contribution. Thus, the dependent variables are the dummies indicating whether the corresponding author is the first author (*First author*) or the last author (*Last author*). The estimation model is given by

$$Dummy\ for\ the\ first\ or\ the\ last\ author_i =$$
$$\Sigma\alpha_i(Reserach\ or\ managerial\ contribution_i) + \beta_i(Number\ of\ authors, log) +$$
$$\Sigma\delta_i(\text{Ex}_{\text{ante}}\text{knowledge contributions}) + \Sigma\gamma_i(Rank\ of\ corresponding\ a_i) +$$
$$the\ other\ controls + \varepsilon_i \qquad (3)$$

We use the sample where the respondent chose ordering other than alphabetical ordering rule, given that author ordering is essentially random in the case of alphabetical ordering. The focal explanatory variables are the dummy indicating whether the corresponding author contributed most to the research which led to the paper (*res_role_d*), the dummy indicating whether the corresponding author was PI or Co-PI (*mnt_role_d*), and the dummy indicating whether he/she played the both roles (*both_res_mnt_d*). For this, we collected information from the survey on whether the corresponding author made the largest contribution in research among the researchers as well as whether he was a PI or a Co-PI.

We introduce the following control variables. The first one is author size (*lnauthors*), which tends to reduce the probability of any author becoming the first or the last author. However, if the role of corresponding author is more likely to be delegated to those other than PIs in larger teams and the focal point is the first author who benefits most from the name ordering, the chance that the first author becomes the corresponding author may be increasing in the size of the research team. If the latter effect is important, the corresponding author is more likely to be the first author when the team size is large. If there exist important external ex-ante knowledge contributions that helped initiating the project, the relative role of the corresponding author in generating the research outcome will decline. We recognize the knowledge embodied in humans (*cncpt_hum*, for example, visiting scholar, advisor in a graduate program, or corporate partner) and that embodied in literature (*cncpt_lit*). We also control for the rank of the corresponding author. A lower ranked corresponding author may be more likely to be the first author, since such credit is more important for young scholars in the labor market. The other controls are the type of the sample, and 10 science field dummies.

We use liner probability model for estimations.

5. Estimation Results

5.1 Alphabetical ordering

Table 1 presents the results of econometric estimations based on a linear probability model for a pooled sample for each of Japan and the U.S. and Table 2 shows the results for Japan separately estimated for the two fields where alphabetical ordering is prevalent (mathematics, and economics and business) and for all the other fields. We start by discussing Table 1. Model 2 and 4 in Table 1 introduces the dummy for the existence of a research manager (*mnt*). Consistent with Hypothesis 1, papers from research projects oriented to finding a solution to a specific real world problem and employing experimental method are less likely to follow alphabetical ordering, while those employing theoretical analysis intensively are more likely to use alphabetical ordering.

More specifically, the results suggest that when the importance of finding a solution to a specific practical problem as the research objective increases by 4 points from 1 to 5 in the Likert Scale, the probability that the paper follows alphabetical ordering declines by 6 percentage points in Japan and 4 percentage points in the US (see Model 1 and 3). Very consistent with these results, according to the result from a Japanese sample (Model 1), the research project using the theoretical method very intensively is 6 percentage points more likely to use alphabetical ordering, compared to the research project which does not use a theoretical method. Furthermore, the research project using the experimental method very intensively is 10 percentage points more likely to use contribution based ordering, compared to the research project which does not use an experimental method. The use of computation method has a similar effect, although the size of the effect is around a half. As for the US sample, the research project which significantly led to the improved facilities is less likely to use alphabetical ordering (2.5 percentage points if yes). These effects are very substantial and strongly support Hypothesis 1. On the other hand, it is found that the score of fundamental understanding objective does not significantly affect the choice, controlling for the other variables characterizing the nature of research.

(See Table 1)

The number of authors has a clearly U-shaped relationship with the choice of alphabetical order. Its share initially declines and then increases with the number of authors in both countries, supporting Hypothesis 2. The minimum is achieved at 5 authors in Japan (Model 1) and at 7 authors in the US (Model 3). The initial decline would suggest the decline of an incentive effect of an alphabetical ordering and the latter increase would reflect the benefit of saving the cost of monitoring and evaluation in a big team. A U-shaped relationship between the author size and the choice of alphabetical order is not affected much even if we control for the necessity of project management (compare Model (1) and (2) as well as Model (3) and (4). This may indicate that the research management variable largely captures the necessity of resource allocation and task coordination rather than that of monitoring.

When the authors are co-located (all affiliated with one institution), the paper is significantly more likely to be non-alphabetical in both US and Japan. The coefficients are larger in the US. The results signify the negative effect of distance on the cost of implementing contributions based ordering, thus supporting Hypothesis 3.

The team structure does not have significant coefficients, except for the homogeneous young scholars dummy in the US. If the team is exclusively made up of junior researchers, they tend to adopt alphabetical ordering in the US, consistent with our expectation. On the other hand, *nonresearch_author* is found to have no significant coefficient. The coefficient of research management (*mnt*) is negative but only weakly significant at 10 % level (model 2 and 4), suggesting that the existence of a research manager such as a PI reduces the use of alphabetical ordering. This result provides some support for Hypothesis 4.

Finally, Table 2 presents the results for two subsamples: mathematics and economics/business, and the other sciences using only Japanese data. The specification is parsimonious, reflecting a small sample for the first subsample. Among four variables for nature of research (*use*, *theoretical research, experiment and observation,* and *computation*), except for *experiment and observation* in Model (5), have highly significant coefficients with the same signs for both subsamples. However, the size and significance of the estimated coefficient are much larger for mathematics and economics/business—roughly 10 times greater coefficients. Thus, for an example, one point increase in the intensity of the use of theoretical analysis increases the incidence of alphabetical ordering by 12% for mathematics and economics/business but only 1% for the rest of the fields. One interpretation of this stark difference is that the degree of collaboration required in theoretical analysis may differ significantly across fields. Another interpretation is that a field norm may augment or weaken the impact of the nature of research because the signaling effect of contribution-based ordering could differ across fields depending on the norm. These results together with Figure 5 imply that the nature of research can significantly explain both the variation within a field as well as that across fields of the incidence of alphabetical ordering.

(Table 2)

5.2 Existence of a PI or research management

The estimation results in Table 3 show that the project is significantly more likely to have research management, when the research budget is large in the two countries. The semi-log elasticity coefficient is significantly larger in Japan: 0.02 vs. 0.008. The number of the authors has positive and similar sized coefficients in both countries and it is significantly positive in the US. These results support Hypothesis 4 that the mobilization of large research resources makes managerial control important.

Co-location makes research management more likely to exist in both countries (5% significant), consistent with the results on hypothesis 3. Our interpretation is that co-location makes the cost of management lower so that a PI is more likely to exist. Heterogeneity of a research team is also associated with the incidence of PI or someone taking a managerial role. When a research teams consists of all senior members, it requires less research management and thus unlikely to have a PI. The existence of non-research coauthors is also significantly positive in Japan, but it is not in the US.

Unlike the choice of alphabetical ordering relative to contribution based ordering, the nature of research does not significantly affect the existence of research management, except that the use of experiment, as measured by the improvement of facilities, has a significantly positive coefficient in the US and the use of a computational method has a positive and weakly significant coefficient in Japan.

5.3 Signals from the first author and the last author

The Estimation results reported in Table 4 (linear probability model) suggest that the first author and the last author do clearly represent different types of contributions of the authors when non-alphabetical ordering is chosen. The author with the largest research contributor is likely to become the first author and not the last author in both countries. At the same time, the PI/Co-PI author is likely to become the last author in both countries. These results strongly support Hypothesis 5. If the same author performs both, he/she tends to become the first author.

In addition, when the number of authors is large, a corresponding author is significantly less likely to become the last author in the two countries. But it is more likely to become the first author in the US (10% significance). This contrast might reflect a difference between the two countries in the way that managerial tasks are shared within research teams. As Figure 11 shows, the corresponding author is more likely to be the one who played some management role in Japan than in the U.S.. If managerial tasks are more likely to be shared among multiple co-authors rather than one PI, the role of corresponding author may be more likely to be assigned to one of them rather than the first author. Finally, corresponding author with a junior position is more likely to be the first author to a similar degree in the US and Japan.

(Table 4)

6. Conclusions

This paper has examined empirically what drives author ordering in scientific research. While there is substantive existing literature, they do not explain well the reasons why the alphabetical ordering is significantly used only in a limited number of fields and why there are significant variations across fields. We hope that this paper made contributions for deepening our understanding.

We first discussed a theoretical framework for the choice between relative-contribution-based ordering and alphabetical ordering, focusing on nature of research, in particular, the importance of collaboration in the context of incomplete contract, measurement cost and the role of a principal investigator (PI). Based on this, we hypothesize that (1) alphabetical ordering is more used in theoretical research or one pursuing a fundamental understanding, relative to empirical research or one pursuing a solution to a specific real world problem, (2) it is also more used when the measurement cost of contribution-based ordering is large (a large team and distant locations), and (3) a PI exists to mobilize financial resources and enables the use of contribution-based ordering by monitoring the members' outputs.

Our empirical examinations, based on the new large scale original scientists' surveys in the US and Japan, show the results consistent with these hypotheses. In particular, an alphabetical ordering is more used when the research is theoretical and has less empirical component and when the team size is large and not co-located. In particular, the variation of research method goes a long way in explaining the variation of the incidence of alphabetical name ordering across fields (mathematics and economics vs. the other fields) as well as a significant variation within a field.

We also find that PI or Co-PIs are more likely to exist when the project uses more resources but also when the team is more heterogeneous. We find that author ordering sends two signals in contribution based ordering, the first author for the largest research contribution and the last author for the PI or Co-PI.

There exists a number of remaining research issues. One is to examine the effects of author ordering on performance, which will further clarify the efficiency ground for the choice of author ordering. The past literature suggests that the papers with alphabetical ordering are often highly cited. Our results reported in Figure 2 also suggest that highly cited papers are more likely to use alphabetical ordering in both countries. However such tendency disappears in Japan once we control for the size and nature of the project, as reported in Table 1.

Table 1 Choice of alphabetical (dependent variable order_alpha_adj : 1 if alphabetical and 0 otherwise, Linear Probability Model, All sample and authors>=2)

		JP		US	
		Model (1)	Model (2)	Model (3)	Model (4)
	VARIABLES		with management		with management
Research objective (5 point Likert scale)	fundamental	0.00471	0.00496	0.00321	0.00359
		(0.00320)	(0.00322)	(0.00381)	(0.00380)
	use	-0.0166***	-0.0163***	-0.0110***	-0.0109***
		(0.00350)	(0.00349)	(0.00395)	(0.00395)
Research methods (6 points Likert scale in Japan and a dummy in the US)	jp_theoretical	0.0118***	0.0118***		
		(0.00254)	(0.00253)		
	jp_experiment	-0.0198***	-0.0194***	-0.0252***	-0.0234**
	(imprv_facilities US)	(0.00379)	(0.00378)	(0.00923)	(0.00920)
	jp_computation	-0.0101***	-0.00973***	0.00274	0.00268
	(imprv_comput US)	(0.00319)	(0.00314)	(0.00971)	(0.00965)
Number of authors	lnauthors	-0.190***	-0.188***	-0.152***	-0.148***
		(0.0227)	(0.0227)	(0.0351)	(0.0352)
	lnauthors_sq	0.0581***	0.0579***	0.0399***	0.0393***
		(0.00628)	(0.00626)	(0.0103)	(0.0104)
Author co-locations (domestic single institution)	co_location	-0.0149**	-0.0136*	-0.0393***	-0.0379***
		(0.00717)	(0.00714)	(0.00925)	(0.00917)
Team structure	nonresearch_author	-0.00768	-0.00719	-0.00821	-0.00998
		(0.00591)	(0.00591)	(0.00907)	(0.00905)
Only senior	homogeneous_o	-0.00486	-0.00644	-0.0123	-0.0131
		(0.00766)	(0.00761)	(0.0121)	(0.0121)
Only young	homogeneous_y	0.0906	0.0859	0.113**	0.116**
		(0.109)	(0.105)	(0.0504)	(0.0502)
Research management	mnt		-0.0361*		-0.0587*
			(0.0186)		(0.0337)
Sample (H type)	citedness	0.0147	0.0147	0.0244**	0.0235**
		(0.00904)	(0.00901)	(0.00998)	(0.0100)
	Observations	1,931	1,931	1,754	1,748
	R-squared	0.428	0.431	0.375	0.384
	Adjusted R-squared	0.418	0.421	0.363	0.372
	RMSE	0.145	0.144	0.180	0.179
	Log Likelihood	1012	1016	537.8	545.6
	Robust standard errors in parentheses				
	*** p<0.01, ** p<0.05, * p<0.10				

Note. 21 field dummies (see Table 3 for the results from 3 fields) and year effect not displayed.

Table 2. Choice of alphabetical (mathematics & economics/business vs. the other fields, dependent variable order_alpha_adj, Linear Probability Model, Japan sample and authors>=2)

		JP	
		Model (5)	Model (6)
	VARIABLES	Mathematics & Economics/Business	Other fields
Research objective (5 point Likert scale)	use	-0.121***	-0.0146***
		(0.0420)	(0.00333)
Research methods (6 points Likert scale in Japan and a dummy in the US)	jp_theoretical	0.124**	0.00959***
		(0.0464)	(0.00252)
	jp_experiment	-0.0259	-0.0183***
		(0.0407)	(0.00369)
	jp_computation	-0.114***	-0.00724**
		(0.0243)	(0.00311)
Number of authors	lnauthors	-0.933	-0.183***
		(1.403)	(0.0226)
	lnauthors_sq	0.320	0.0567***
		(0.650)	(0.00630)
Author co-locations (domestic single institution)	co_location	-0.0969	-0.00954
		(0.126)	(0.00650)
Sample (H type)	citedness	0.256	0.0126
		(0.155)	(0.00891)
	Observations	41	1,899
	R-squared	0.710	0.276
	Adjusted R-squared	0.613	0.266
	RMSE	0.303	0.133
	Log Likelihood	-2.875	1148
	Robust standard errors in parentheses		
	*** p<0.01, ** p<0.05, * p<0.10		

Note. 21 field dummies (see Table 3 for the results from 2 fields) and year effect not displayed.

Table 3. Existence of a PI or research management (Linear Probability Model)

		JP		US	
		Model (7)	Model (8)	Model (9)	Model (10)
	VARIABLES	all	part (PI or CoPI vs. no management)	all	part (PI or CoPI vs. no management)
Research objective (5 point Likert scale)	fundamental	0.00267	0.00406	0.00488	0.00603
		(0.00675)	(0.00788)	(0.00606)	(0.00640)
	use	0.00306	0.00275	0.00306	0.00311
		(0.00532)	(0.00596)	(0.00404)	(0.00424)
Research methods (6 points Likert scale in Japan and a dummy in the US)	jp_theoretical	0.000501	0.00147		
		(0.00453)	(0.00489)		
	jp_experiment	−0.000200	0.00161	0.0217**	0.0249**
	(imprv_facilities US)	(0.00485)	(0.00564)	(0.0101)	(0.0108)
	jp_computation	0.00796*	0.00851*	0.00484	0.00431
	(imprv_comput US)	(0.00424)	(0.00464)	(0.0120)	(0.0127)
Number of authors	lnauthors	0.0423	0.0287	0.0465**	0.0479**
		(0.0271)	(0.0298)	(0.0212)	(0.0227)
	lnauthors_sq	−0.00702	−0.00521	−0.00519	−0.00550
		(0.00493)	(0.00547)	(0.00449)	(0.00480)
Author co-locations (domestic single institution)	co_location	0.0335***	0.0351**	0.0214**	0.0236**
		(0.0129)	(0.0141)	(0.0107)	(0.0113)
Team structure	nonresearch_author	0.0208*	0.0279**	−0.0128	−0.0145
		(0.0114)	(0.0127)	(0.0109)	(0.0114)
Only senior	homogeneous_o	−0.0403***	−0.0443***	−0.0264*	−0.0286*
		(0.0144)	(0.0161)	(0.0156)	(0.0165)
Only young	homogeneous_y	−0.0763	−0.196	0.0392	0.0403
		(0.157)	(0.248)	(0.0281)	(0.0323)
Resources (fund, nonauthor researchers)	lnres_fund	0.0200***	0.0233***	0.00828***	0.00910***
		(0.00361)	(0.00399)	(0.00252)	(0.00268)
	ln1non_authors	0.00876	0.0110*	0.00342	0.00304
		(0.00565)	(0.00622)	(0.00462)	(0.00488)
Sample (H type)	citedness	−0.0287**	−0.0373**	−0.0135	−0.0124
		(0.0133)	(0.0152)	(0.0109)	(0.0114)
	Observations	1,872	1,669	1,733	1,644
	R-squared	0.091	0.109	0.100	0.108
	Adjusted R-squared	0.0735	0.0899	0.0815	0.0892
	RMSE	0.246	0.258	0.196	0.200
	Log Likelihood	−16.49	−85.86	380.2	327.1
	Robust standard errors in parentheses				
	*** p<0.01, ** p<0.05, * p<0.10				

Note. 21 field dummies and year effect not displayed.

Table 4 What does the first and the last authors signal? (linear probability model, authors>=2, sample excluding alphabetic ordering)

		(1)	(2)	(3)	(4)
		JP	US	JP	US
	VARIABLES	First author		Last author	
Largest contribution in research	res_role_d	0.580***	0.550***	-0.113***	-0.205***
		(0.0305)	(0.0470)	(0.0292)	(0.0479)
PI or Co-PI	mnt_role_d	0.0216	0.0415	0.0909***	0.186***
		(0.0338)	(0.0380)	(0.0324)	(0.0387)
Both largest research contribution and PI/CoPI, additional effect	both_res_mnt_d	-0.180***	-0.148***	-0.0297	-0.113**
		(0.0408)	(0.0519)	(0.0391)	(0.0529)
Author size	lnauthors	-0.0210	0.0349*	-0.0437**	-0.131***
		(0.0179)	(0.0179)	(0.0171)	(0.0183)
Ex-ante knowledge contribution (embodied in humans)	cncpt_hum	-0.0306***	0.0111	0.00542	-0.0320***
		(0.00810)	(0.00939)	(0.00777)	(0.00957)
Ex-ane knowledge (literature)	cncpt_lit	0.0121	0.000453	-0.00836	0.0214
		(0.0104)	(0.0142)	(0.00993)	(0.0145)
Sample (H papers)	citedness	-0.0752***	-0.0260	0.00397	0.0653***
		(0.0216)	(0.0215)	(0.0208)	(0.0219)
Rank of correspoinding author (Base: professor)	Associate professor	0.210***	0.0801***	-0.0870***	-0.0637**
		(0.0228)	(0.0279)	(0.0218)	(0.0284)
	Lecturer/assistant	0.314***	0.136***	-0.140***	-0.116***
		(0.0271)	(0.0302)	(0.0260)	(0.0308)
	Post doctoral fellow	0.332***	0.323***	-0.148***	-0.367***
		(0.0492)	(0.0413)	(0.0472)	(0.0422)
	Technicians	0.320**	-0.00793	-0.190	-0.157
		(0.142)	(0.121)	(0.136)	(0.123)
	PhD	0.361***	0.326***	-0.132**	-0.344***
		(0.0576)	(0.0423)	(0.0553)	(0.0431)
	Master	0.320**	0.189*	-0.112	-0.319***
		(0.128)	(0.102)	(0.123)	(0.104)
	Other	0.273**	0.220***	-0.200*	-0.215***
		(0.108)	(0.0519)	(0.104)	(0.0530)
	Unknown	0.412	0.127	-0.209	-0.221**
		(0.396)	(0.0924)	(0.380)	(0.0943)
	Observations	1,875	1,665	1,875	1,665
	R-squared	0.385	0.380	0.077	0.324
	Log Likelihood	-904.9	-806.1	-826.8	-839.2
	Standard errors in parentheses				
	*** p<0.01, ** p<0.05, * p<0.1				

Note. 10 science field dummies and year effect not displayed.

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Appendix.　Descriptive statistics

JP	Total					Contribution		Alphabetical		Senior last	
Variable	Obs	Mean	Std. Dev.	Min	Max	Obs	Mean	Obs	Mean	Obs	Mean
order_alpha_adj	1943	0.04	0.19	0	1	1471	0	73	1	248	0
fundamental	1958	4.31	0.85	1	5	1471	4.27	73	4.73	247	4.42
use	1957	3.51	1.28	1	5	1470	3.58	73	2.05	247	3.55
jp_theoretical	1957	3.57	1.69	1	6	1470	3.51	73	5.53	247	3.42
jp_experimental	1958	5.02	1.65	1	6	1471	5.09	73	2.26	247	5.34
jp_computational	1958	3.24	1.86	1	6	1471	3.26	73	3.41	247	3.07
authors	1959	6.71	15.82	2	327	1471	5.87	73	29.45	248	4.83
co_location	1959	0.35	0.48	0	1	1471	0.35	73	0.14	248	0.48
nonresearch_authors	1959	0.39	0.49	0	1	1471	0.41	73	0.23	248	0.38
homogeneous_o	1959	0.32	0.47	0	1	1471	0.33	73	0.51	248	0.21
homogeneous_y	1949	0.00	0.07	0	1	1466	0.00	72	0.06	246	0.00
lnres_fund	1883	11.58	2.20	4.6	19.5	1417	11.48	66	11.12	243	12.01
ln1non_authors	1959	1.03	0.99	0.0	6.4	1471	1.03	73	0.79	248	1.06
citedness	1959	0.28	0.45	0	1	1471	0.26	73	0.47	248	0.30
mnt	1959	0.92	0.27	0	1	1471	0.92	73	0.73	248	0.96
corre_first	1957	0.50	0.50	0	1	1471	0.58	73	0.32	248	0.25
corre_last	1957	0.20	0.40	0	1	1471	0.17	73	0.38	248	0.23
res_role_d	1957	0.67	0.47	0	1	1470	0.68	73	0.63	247	0.66
mnt_role_d	1959	0.59	0.49	0	1	1471	0.58	73	0.38	248	0.72
both_res_mnt_d	1957	0.45	0.50	0	1	1470	0.45	73	0.33	247	0.50
cncpt_hum	1954	0.78	1.19	0	6	1466	0.77	73	0.86	248	0.80
cncpt_lit	1956	0.81	0.92	0	4	1468	0.80	73	0.99	248	0.82
publication_year	1959	2003.454	1.695343	2000	2007	1471	2003.41	73	2003.5	248	2003.6

US	Total					Contribution		Alphabetical		Senior last	
Variable	Obs	Mean	Std. Dev.	Min	Max	Obs	Mean	Obs	Mean	Obs	Mean
order_alpha_adj	2058	0.06	0.23	0	1	1313	0	119	1	485	0
fundamental	2091	4.55	0.84	1	5	1305	4.52	119	4.69	483	4.63
use	2052	3.74	1.35	1	5	1288	3.84	113	3.00	470	3.64
imprv_facilities	1989	0.35	0.48	0	1	1240	0.35	102	0.16	470	0.39
imprv_comput	2010	0.42	0.49	0	1	1249	0.45	108	0.43	476	0.33
authors	2101	5.57	10.95	2	375	1313	5.29	119	7.04	485	5.40
co_location	2101	0.37	0.48	0	1	1313	0.37	119	0.18	485	0.44
nonresearch_authors	2101	0.31	0.46	0	1	1313	0.31	119	0.24	485	0.30
homogeneous_o	2101	0.22	0.41	0	1	1313	0.24	119	0.45	485	0.10
homogeneous_y	1931	0.02	0.15	0	1	1210	0.02	109	0.06	458	0.02
lnres_fund	2026	11.74	2.06	8.52	18.42	1267	11.70	114	10.63	473	12.04
ln1non_authors	2101	0.59	0.87	0.00	5.80	1313	0.63	119	0.34	485	0.51
citedness	2101	0.36	0.48	0	1	1313	0.33	119	0.44	485	0.40
mnt	2095	0.95	0.22	0	1	1308	0.95	119	0.78	485	0.99
corre_first	1873	0.46	0.50	0	1	1174	0.56	111	0.56	440	0.15
corre_last	1873	0.39	0.49	0	1	1174	0.29	111	0.34	440	0.70
res_role_d	2093	0.59	0.49	0	1	1309	0.65	116	0.55	485	0.45
mnt_role_d	2095	0.80	0.40	0	1	1308	0.79	119	0.62	485	0.84
both_res_mnt_d	2087	0.50	0.50	0	1	1304	0.53	116	0.45	485	0.39
cncpt_hum	2051	0.67	1.08	0	7	1283	0.66	115	0.68	472	0.66
cncpt_lit	2024	0.66	0.72	0	4	1269	0.67	115	0.79	462	0.65
publication_year	2101	2003.429	1.726076	1999	2007	1313	2003.39	119	2003.3	485	2003.6