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The evolution of order of authorship based on researchers' age

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Abstract
We examine the evolution of order of authorship based on seniority during 1975–2021. Results show that for small teams (≤ 5 authors), the likelihood of placing the most junior author first has been increasing since the nineties. Additionally, the likelihood of placing the most senior author in last place has also been increasing. The results are at least partially driven by digitization of bibliographic records that drastically facilitated assignment of citations to all authors. We interpret our findings as a growing trend of small author teams becoming fairer. We do not find any significant effects for larger teams suggesting different practices when team size increases. Given that team size is, slowly but steadily, increasing over the last decades, the debate over the ethical considerations around authorship practices should place significance on the number of co-authors.

Keywords Order of authorship · Alphabetical ordering · Author age · Fairness · Team size

JEL Classification O30 · O31

Introduction

Authorship order has perennially been a point of contention within research teams across disciplines (Floyd et al., 1994; Hodge & Greenberg, 1981; Riesenberg & Lundberg, 1990). There are multiple roots of this cause. Several institutions place weight in promotion criteria whether the researcher is listed first in papers (Baum et al., 2023; Levitt & Thelwall, 2013). Researchers themselves also perceive the first author as being the one that contributed the most in the paper (Maciejovsky et al., 2009). In addition, up until the nineties citations, a crucial metric in measuring a researcher's impact, could readily be counted only to the first listed author in the paper whereas measuring citations for the rest of the authors required additional work (Persson, 2001). To this end, in an early provocative study, Diamond (1985) showed that when listed first in a paper, a forward citation is worth more than when not listed first.

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As the first listed author is arguably the most prominent position, the ideal way of choosing this author would be based on the amount of contribution to the paper. In other words, the researcher with the most contribution should be placed first. However, quantifying contribution can be a daunting task; therefore, such a solution can be quite difficult potentially raising friction between team members (Engers et al., 1999). One potential solution would be for an alphabetic ordering implying equal contribution across co-authors. However, as research has shown, alphabetization varies significantly across disciplines (Fernandes & Cortez, 2020) indicating different practices across fields. Further, alphabetization could also disincentivize collaboration for authors with surnames' first letter late in the alphabet (Joanis & Patil, 2021; Weber, 2018).

The above discussion implies that research teams try to find author ordering schemes that can potentially satisfy all interested parties. Further the focus on authorship order implies potential ethical considerations and overall practices within research teams. For instance, studies have examined authorship norms through an ethical lens including ghost authorship (Teixeira da Silva & Dobránszki, 2016) and favoring certain authors to be placed first (Marušić et al., 2011).[1]

To this end, the primary motivation of this study is to shed light on ethical considerations with respect to order of authorship. We are primarily interested on the evolution of order of authorship as studies have shown that the overall rate of alphabetization has been falling (Waltman, 2012; Wohlrabe & Bornmann, 2022). Embarking from these findings, we examine whether authorship order norms are evolving. Whether they are evolving towards a fairer authorship order remains an open empirical question. As we cannot examine contribution of each author for millions of papers, we examine whether the academic age of authors plays a role in being placed first or last. More importantly, we examine the likelihood of the most junior author placed first has evolved over time.

To this end, the objective of the paper is to test the evolution of ordering based on author seniority during 1975–2021. Given the breadth of information, we also examine whether the rate of alphabetizing papers has been falling. To perform this large-scale analysis, we exploit an information technology advancement; namely, that most datasets that record bibliographic information have disambiguated authors. As a result, we can map an author's research history for each given published paper.

Consistent with the literature, we show that there is decrease in alphabetization. Embarking from this finding, we provide the main two results of the paper. First, for small teams the likelihood of placing the most junior author first has been increasing. Second, for small teams the likelihood of placing the most senior last has also been increasing. Placing these results though an ethical practices framework, we interpret them as a growing tendency of more fairness within scientific teams.

The paper contributes to the growing literature of understanding and navigating through different practices of ordering authors in a paper; for literature reviews see Frandsen and Nicolaisen (2010) and Marušić et al. (2011). Peidu (2019) proposes alternative ways including alphabetization, seniority or negotiation between co-authors. All these practices are obviously second-best to assigning the first position based on contribution (Baerlocher et al., 2007). Shen and Barabási (2014) provide a credit allocation algorithm that can capture each author's contribution. However, there are other factors to consider. Author

[1] Note that such considerations transcend the process of scientific search. For instance, similar practices have also been scrutinized in the technology sector and namely in assigning inventorship in patent documents (Lissoni & Montobbio, 2015).

teams will frequently collaborate in more than one paper. In addition, author teams may be embedded with various academic relationships including advisor-advisee or lab director-employee. In their survey, Smith et al. (2020) showed that authors aim to promote fairness while the incentives to first-author placement can have detrimental effects on the initially good intentions. In this paper, by examining the evolution of seniority and author placement, we aim to provide insights whether teams are trying to become fairer in order to promote a long-term collegial environment.

Literature review

Authorship order is a critical topic in academic research. The most prestigious position is naturally the first as it has been shown to be associated with more favorable outcomes in career advancement (Baum et al., 2023; Hilmer & Hilmer, 2005; Levitt & Thelwall, 2013), recognition by peers (Maciejovsky et al., 2009) and financial rewards (Diamond, 1985; Einav & Yariv, 2006). As a result, this topic has deep roots across several disciplines dating back at least to the works by Zuckerman (1968, 1969).

Several disciplines over the decades have attempted to alleviate pressure from being first by disclosing statements over the specific contributions of each author. Psychology discipline was the pioneer (Spiegel & Keith-Spiegel, 1970) with medical and other disciplines following suit (Rennie et al., 1997). Nowadays, many journals across disciplines require contribution statements across several disciplines (Bošnjak & Marušić, 2012; Sauermann & Haeussler, 2017). However, such policies whether they are discipline-specific or journal-specific also raise tensions across and within scientific teams over the correct way of employing such contribution statements (for a review see Ivaniš et al., 2011). Furthermore, authorship order still remains an important aspect of assigning credit as contribution statements require for the reader to locate within the paper such statements. Conversely, authorship order is readily visible to all researchers that merely examine the references. An additional issue to consider is the findings by Xu et al. (2022) where they found that teams where authors performed roughly similar tasks produced higher-impact works than hierarchal teams. This finding suggests the potential friction for teams where credit may be more difficult to assign and thereby the first position more difficult to agree on.

Therefore, due to the importance of being first, author ordering can raise friction between team members. Smith et al. (2020) showed that 37.9% authors have experienced at least once disagreement over author ordering. The process of deciding who would be placed first in a paper naturally implies fairness within research teams (Smith & Master, 2017). For instance, from the psychology literature, Costa and Gatz (1992) examined the ideal way of placing the first author by asking graduate students and advisors for two types of published papers: those that are part of the dissertation and those that are not. They found substantial heterogeneity between the seniority of the faculty member and the type of papers.

The above discussion highlights the importance of first position across disciplines. Nevertheless, the rate of ordering authors alphabetically varies significantly across fields implying different practices (Frandsen & Nicolaisen, 2010). Most importantly, several disciplines have rates of alphabetical authorship that exceeds what would be expected at random. This observation leads to the conclusion that contribution is not the sole driver of authorship order (Levitt & Thelwall, 2013).

To this end, the association with ethical considerations and the decrease in the alphabetization of authorship in published papers (Waltman, 2012; Wohlrabe & Bornmann, 2022) motivates the main question of this paper. Has academic age played an evolving role in the order of authorship? Such a question is usually implied in many of the studies examining the authorship order. In an early study, Zuckerman (1967) showed that Nobel laurates were more likely to be placed early on in their careers and forego such positions later. Conversely, non-laurates were less likely to be placed first early on in their careers and more likely later. The role of the academic age in the likelihood of being placed first is the core question of this paper.

Data compilation

The main source of data is OpenAlex (Priem et al., 2022) which is a free dataset covering all published works along with their associated bibliographic information. To date, studies across several fields have employed OpenAlex for bibliometric analyses (Korte et al., 2023; Ruffo et al., 2023). While the dataset covers more than two hundred million works, the main focus of this paper is on journal articles. To this end, we collected information on all journal articles published between 1975 and 2021 where all authors were listed, and each author was associated with a unique identifying number. Figure A1 of the Online Appendix shows the number of papers per year exhibiting a clear upward trend.

OpenAlex, in the tradition of Web of Sciences and Scopus, disambiguates authors and assigns to each a unique identifying number. Works with one author or more than fifteen were dropped from the analysis. To examine the amount of papers that were excluded from the analysis, Fig. A2 of the Online Appendix displays the annual share of papers that list two to fifteen authors. Over all papers, the share after 1980 is always above 80%. While there is a slight decrease in the decade 2000–2010 the long-term trend is positive. Interestingly, the share of these papers over all co-authored papers is constant and close to one until 2005 which decreases steadily afterwards. This finding complements early findings that team size increases over time (Wuchty et al., 2007; Nowell and Grijalva, 2011; Rath & Wohlrabe, 2016; Kuld & O'Hagan, 2018). However, the share of the focal papers still remains high ($>94\%$). Therefore, the core sample is comprised of 30,424,135 journal articles associated with 24,597,783 unique authors. The evolution of share by team size is displayed in detail in Fig. 1.

For all the authors, we then compile their publication history based on the entire OpenAlex database. Two key variables were constructed. The first is at the paper level and identifies papers for which the order of the authors was alphabetical. After replacing non-English characters (e.g. à, ü) with English letters, we generated a variable *ABC* that takes the value of 1 if a paper is alphabetized and 0 otherwise. The second variable is at the paper-author level. It computes the academic age of the authors listed in the paper at time of publication. Therefore, for each paper, we compute for each listed author the years they have lapsed since his/her first publication. Denote this variable as *Age*.

To provide potential mechanisms for the results, we also perform the following data tasks. First, from the Web Of Science (WOS), we extracted the list of journals that are listed in either of the three core indices by 2021. Namely, Science Citation Index (SCI), Social Science Citation Index (SSCI) and Arts & Humanities Citation Index (AHCI). Denote the papers in journals located in either the three core indices as WOS papers and the rest as no WOS papers.

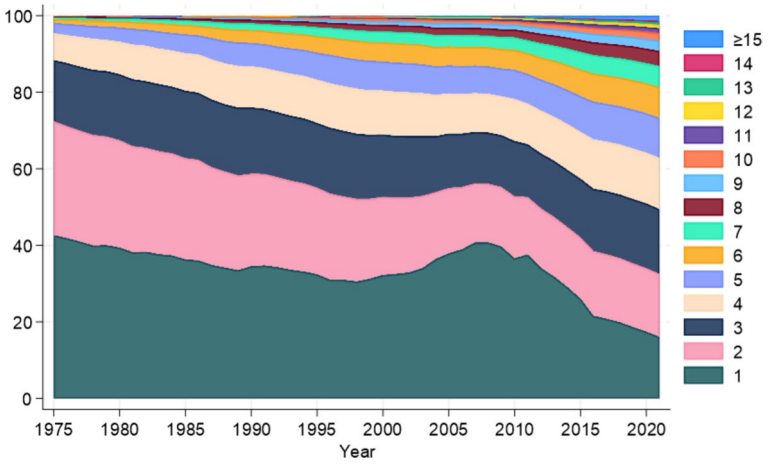

Fig. 1 Evolution of share of papers based on number of authors. Each shaded area shows the share of papers in any given year that discloses a given number of authors

Second, for each journal we compiled the following annual Impact Factor (IF). The IF for journal j in year t is calculated as follows. For papers published in year t in journal j, we count the citations they have accrued up until 2021. Then the IF for journal j in year t is calculated as the number of the aforementioned citations divided by the number of papers published in journal j in year t. Next, we assign each paper to a concept. OpenAlex, in the spirit of its predecessor Microsoft Academic Graph (MAG), has employed new techniques to assign papers to fields—noted as concepts (Shen et al., 2018). OpenAlex provides five levels of aggregation. By employing the nineteen broadest level-0 concept, we then can examine if a paper in a specific field in a specific year is published in a journal with an IF higher than the average of that year.

Methods

The objective of the paper is to examine how order of authorship has evolved over time with respect to alphabetization and seniority. To this end, the first specification is as follows:

$$ABC_{i,t} = a_0 + b_{1976}Year_{i,1976} + b_{1977}Year_{i,1977} + \ldots + b_{2021}Year_{i,2021} + Journal_i\_x\_Country_{i,t} \quad (1)$$

where $ABC_{i,t}$ takes the value of 1 if paper i that was published in year t is alphabetized and 0 otherwise. $Year_{i,1976}, Year_{i,1977}, Year_{i,12021}$ is a set of forty-six year dummies that identify in which year paper i was published. Note that $Year_{i,1975}$ is not included in the analysis. Therefore, all the coefficients are compared with the base year of 1975. $Journal_i$ is a set of dummies that identify the journal paper i was published. This set of dummies aims to account for different practices across scientific fields at a fine-grained level of detail. $Country_{i,t}$ is a set of dummies that identify the country the first author discloses in his/her affiliation for paper i that was published in year t. Therefore, the interaction term $Journal_i\_x\_Country_{i,t}$ accounts journal and first author's affiliation country jointly. To account for as much

heterogeneity possible, we included the interaction terms of these dummies. Results are similar when these sets of dummies enter independently in the regressions.

To examine the evolution based on seniority, the dependent variable in the above regression is replaced with either of two variables. The first variable $Junior_{i,t}$ takes the value of 1 if paper i that was published in year t discloses as first author the most junior author and 0 otherwise. We opted for this variable as it is likely to identify the researcher with lowest bargaining power when it comes to authorship practices. In other words, the most junior person is likely to be in the most disadvantageous position. The second variable, $Senior_{i,t}$ takes the value of 1 if paper i that was published in year t discloses as last author the most senior author and 0 otherwise. Similarly to before, the most senior person may identify either a lab director or a person with the highest recognition within the team. Therefore, we would expect to this person on average to hold the largest bargaining power when it comes to authorship order. Therefore, the examination of these two variables across time can reveal the dynamics between team members that are likely to possess asymmetric bargaining power for deciding on authorship order. Finally, we also include a variable that aims to capture the age variability between team members. This variable the coefficient of variation (CV) which the ratio of the standard deviation to the mean of the variable *Age* for each paper.

Since the dependent variable across all specifications is a dummy variable, a probit or a logit estimator could be considered. However, the specifications include a large number of fixed effects and as studies have shown such nonlinear estimators yield inconsistent estimates (Gomila, 2021; Greene, 2012). In contrast, Ordinary Least Squares (OLS) are better equipped to deal with the numerous fixed effects. To this end, all specifications are estimated via OLS. Finally standard errors are clustered at the journal-country level to avoid serial correlation (Bertrand et al., 2004).

Stylized facts

Figure 2 shows the likelihood that a paper was alphabetized by team size. The Figure shows teams up to seven co-authors. First, as the team is getting larger, the likelihood of alphabetical ordering diminishes; a result consistent with prior studies (Brown et al., 2011; Torgler & Piatti, 2013). Second, for small teams, the general trend is for papers to be less likely to disclose the authors in an alphabetical order. This finding is consistent with prior studies that also find a decrease in alphabetization of authors over time (Waltman, 2012; Wohlrabe & Bornmann, 2022). However, as teams getting larger (more than six authors), this trend does not appear as strong. Figure A3 of the Online Appendix shows the same trend in likelihood for teams with eight authors or more. Due to small sample of papers prior to 2000 there is no clear trend up to that period; after 2000 the trend is still not as strong as in the case of smaller teams.

Figure 3 shows the evolution of the likelihood that the *Age* of the first author is smaller than that of all his/her co-authors. In other words, we observe the likelihood that the most junior researcher is listed first. After 1990, there is a steady increase in such ordering although for larger teams (>4) this trend moderately reverses in recent years. Figure A4 of the Online Appendix again does not show any significant increase in the likelihood of the most junior researcher listed first in more recent years for larger teams.

Figure 4 shows the likelihood that the most senior researcher is listed last. For two-author teams the likelihood increases which is consistent with the previous Figure

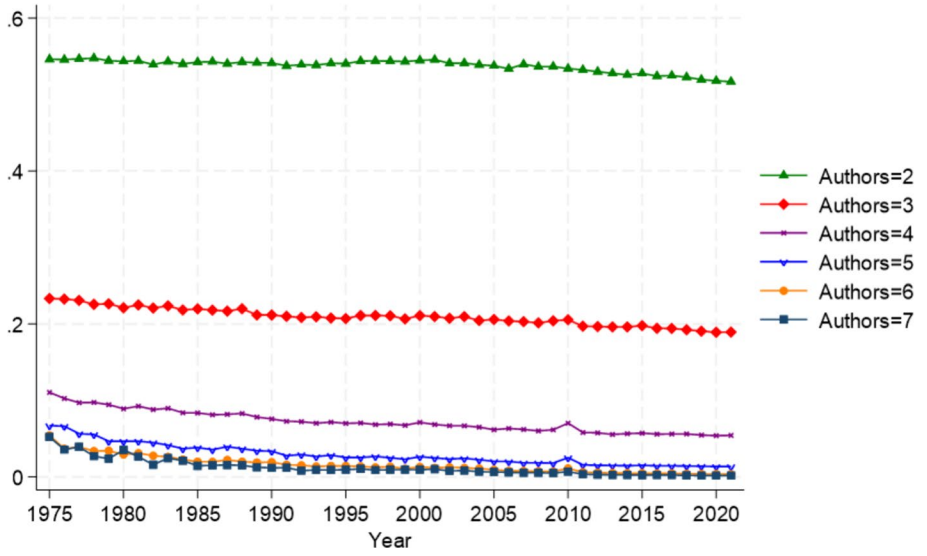

Fig. 2 Evolution of likelihood of papers ordered alphabetically by number of authors. Each line examines papers with different number of authors. Papers with author teams between two and seven are displayed. The line represents the likelihood that a paper is ordered alphabetically

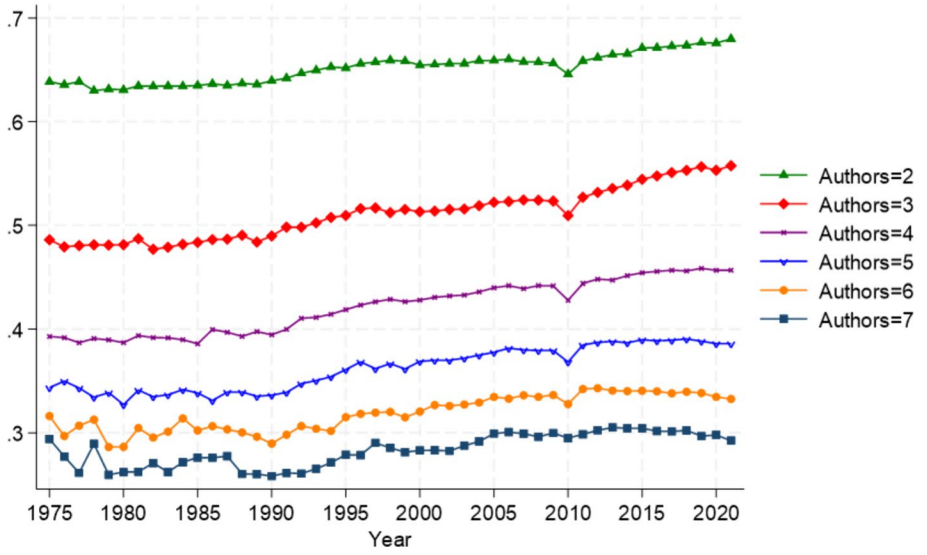

Fig. 3 Evolution of likelihood of papers for the most junior researcher ordered first. Each line examines papers with different number of authors. Papers with author teams between two and seven are displayed. The line represents the likelihood that a paper's most junior researcher is ordered first

suggesting a trend of the junior research listed first and the senior last. However, for larger team sizes, the trend is for the last author not to be listed last. Such a trend is also evident for larger teams as Fig. A5 depicts.

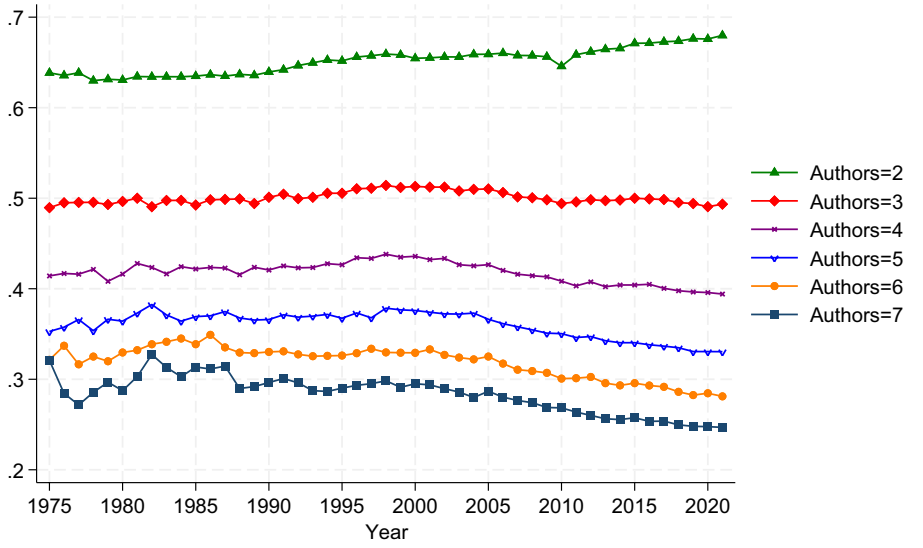

Fig. 4 Evolution of likelihood of papers for the most senior researcher ordered last. Each line examines papers with different number of authors. Papers with author teams between two and seven are displayed. The line represents the likelihood that a paper's most junior researcher is ordered first

We should note a comparison of the aforementioned probabilities with the unintentional probabilities of each of the three measures. Starting from n authors the unintentional likelihood of ordering them in alphabetical order is $1/n!$. To this end, a comparison with two authors reveals that intentional ordering is always greater than unintentional ordering as in 1975 it is 54.6% while in 2021, 51.6%. While the difference is relatively small, it is greater for larger teams. For instance, for five-author teams, the unintentional likelihood is 0.8% while the intentional likelihood ranges from 6.7 (1975) to 1.3% (2021). With respect to the junior author being placed first, the unintentional probability is $1/n$. The same calculation holds for the senior author placed last. Once again, the unintentional probabilities are distinctively different to the intentional ones. For instance, the intentional probability for two-author teams for the junior author placed first ranges from 63.9 (1975) to 68% (2021) where for five-author teams the figures are 34.4% (1975) and 38.6% (2021) respectively. These figures are quite different from the unintentional probabilities of 50% and 20% respectively. This difference remains similar when comparing with the intentional probabilities of the senior author last. For instance, for two-author teams the likelihood ranges from 63.9 (1975) to 68% (2021) where for five-author teams the figures are 35.3% (1975) and 33.1% (2021) respectively.

The above stylized facts show that there are significant trends in the order of authorship based on alphabetization and seniority. However, such trends could mask changes in the number of works across scientific fields and countries which may have different authorship norms. In the next section, we provide regression analyses by controlling for field and country heterogeneity while considering various data cuts.

Results

Baseline results

Table A1 of the Online Appendix displays the results for teams between two and seven authors for Eq. (1). For these and the following regressions results are available upon request for larger teams. For exposition and better illustration, Fig. 5 displays the coefficients of the year dummies along with their 99% confidence intervals. For smaller teams ($\leq$6 authors), there is a clear and significant downward trend corroborating the descriptive findings. However, for seven-author teams, while the coefficient turns significant in recent years, the coefficient is relatively stable over the last two decades. Figure A6 displays the coefficients for larger-author teams. For such teams, the coefficients are stable and statistically insignificant indicating that the rate of alphabetization for larger teams has remained stable over time.

To add further robustness, we consider the computation of the incidental alphabetical authorship order posited by Waltman (2012). Take any given year t and calculate the following variable:

$$\hat{p}_i = \frac{ABC_i - \left(1/n_i!\right)}{1 - \left(1/n_i!\right)}$$

where n_i is the number of authors in paper i. Then, we can use $\hat{p}_i$ as an alternative dependent variable to ABC_i. Results are similar to the baseline and available upon request. Further, as Waltman (2012) bundled all papers regardless of team size, he showed that the following estimator is an unbiased estimator of the average probability of ordering authors alphabetically:

$$\hat{p} = \frac{1}{N}\sum_{i=1}^{N}\hat{p}_i$$

In a similar spirit, we bundled all papers together and employ as dependent variable the $\hat{p}$. Results show an overall decrease in alphabetical order and are available upon request.

Table A2 of the Online Appendix displays the results for teams between two and seven authors for Eq. (1) after replacing $ABC_{i,t}$ with $Junior_{i,t}$. In addition, on the right-hand side the CV for *Age* is included. Interestingly, the CV is positive for teams larger than three. This implies that as the variation of a team's age is getting larger, authors may resort to the rule of placing the most junior as the first author. Figure 6 displays the coefficients of the year dummies along with their 99% confidence intervals. For small teams ($\leq$5 authors), there is a clear trend of placing the most junior author first. While for six and seven author teams there appears to be a trend, this is not statistically significant. Figure A7 shows the trend for larger teams. There is no apparent trend suggesting that for larger teams the likelihood of placing the most junior author first has remained constant over time.

Table A3 shows regression results from the variable $Senior_{i,t}$ for the first two to seven author teams. The illustration in Fig. 7 of the time year coefficients shows that for small teams ($\leq$5 authors), there is a general trend of placing the most senior author last. However, such trend turns insignificant for six- and seven-author teams and dissipates for larger teams (Fig. A8 of the Online Appendix).

We should mention an alternative explanation that is consistent with the observed evolution of authorship order. It could be the case that the likelihood of placing the most junior

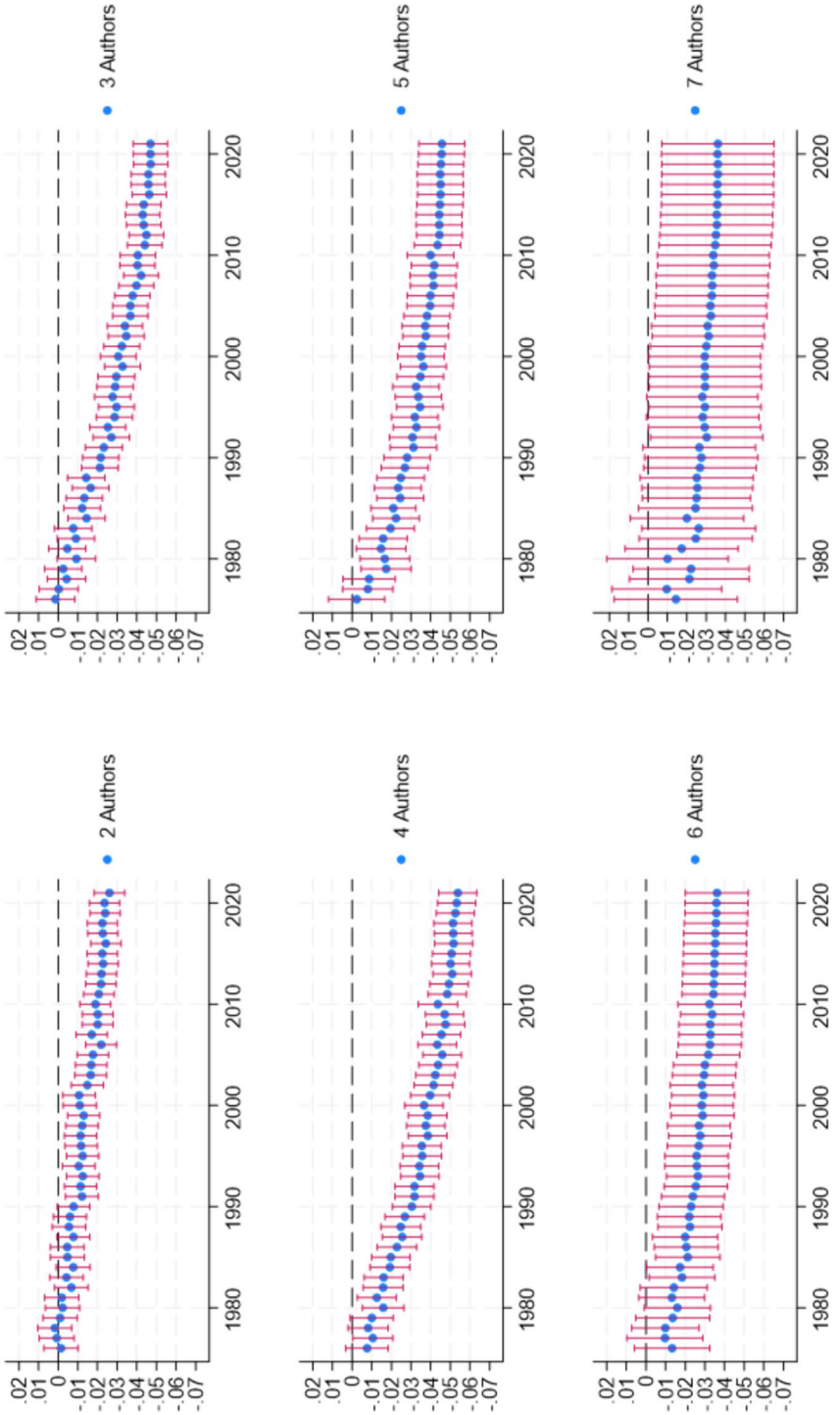

Fig. 5 ABC results. Coefficients with their 99% confidence intervals. Each graph displays the coefficients of the year dummies along with their 99% confidence intervals of Eq. (1) after estimating it for each team size separately

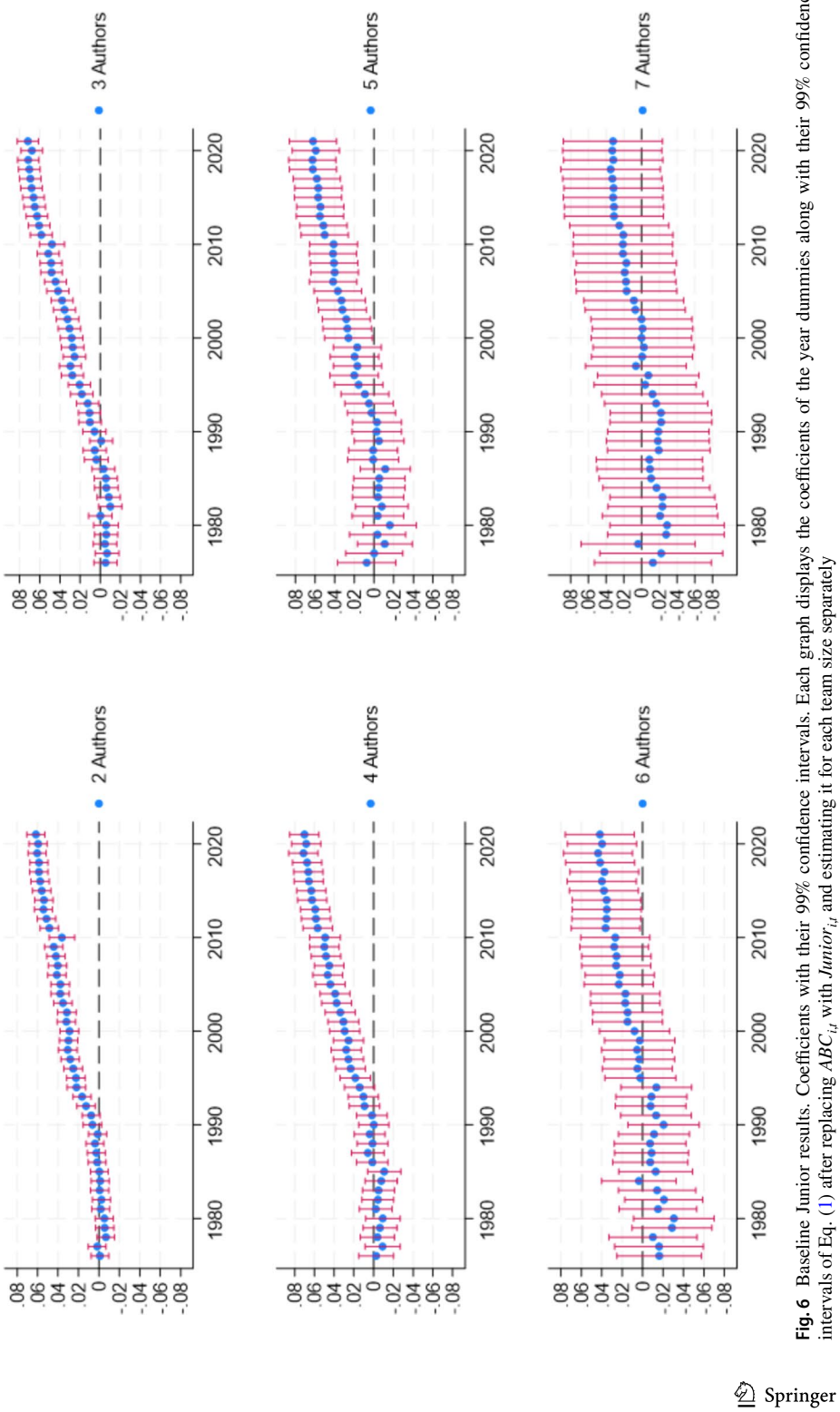

Fig. 6 Baseline Junior results. Coefficients with their 99% confidence intervals. Each graph displays the coefficients of the year dummies along with their 99% confidence intervals of Eq. (1) after replacing $ABC_{i,t}$ with $Junior_{i,t}$ and estimating it for each team size separately

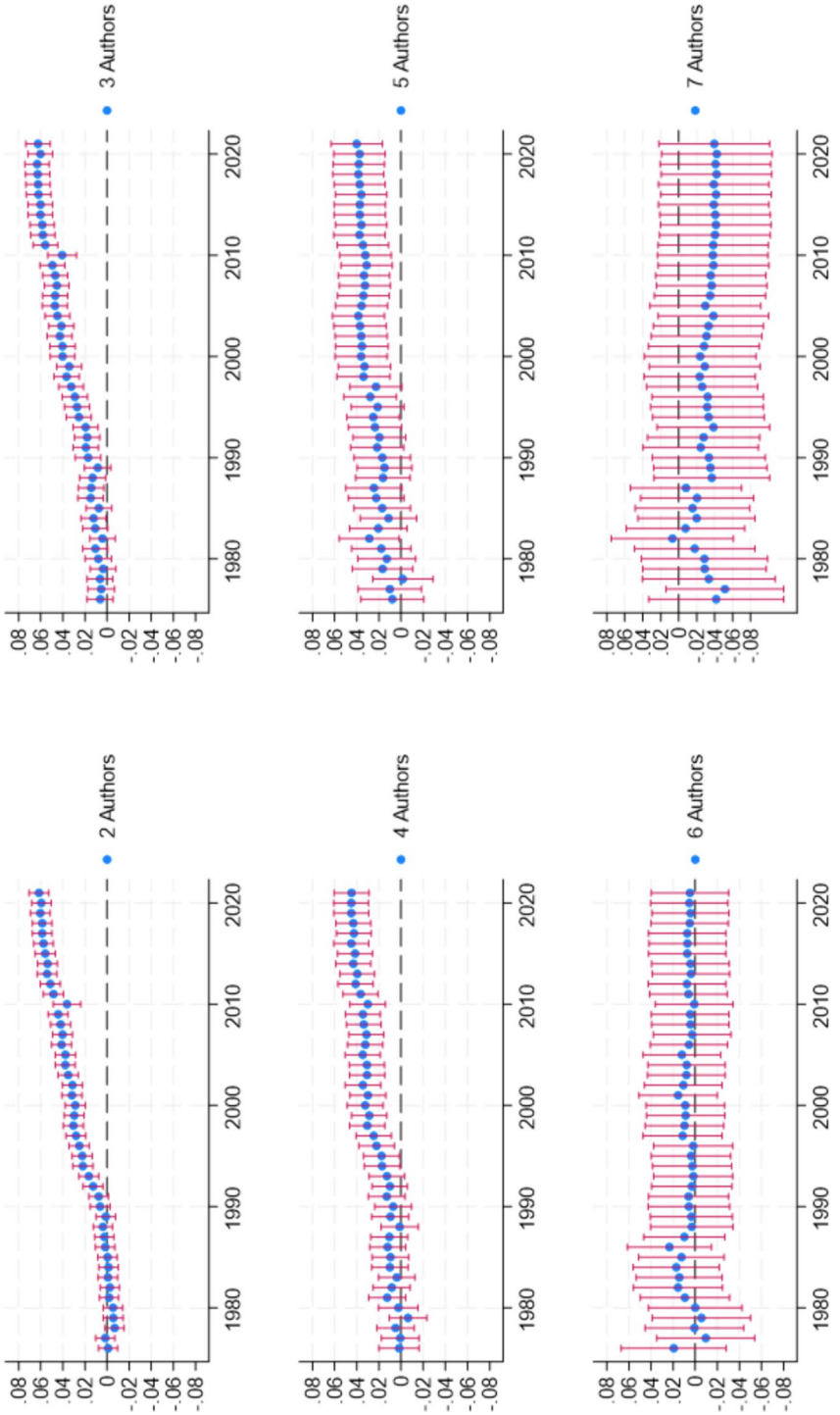

Fig. 7 Baseline Senior results. Coefficients with their 99% confidence intervals. Each graph displays the coefficients of the year dummies along with their 99% confidence intervals of Eq. (1) after replacing $ABC_{i,t}$ with $Senior_{i,t}$ and estimating it for each team size separately

researcher first is driven by the growth of PhD students. Therefore, it could very well be the case that junior researchers are becoming more likely to be placed first since their first papers are works where they are the main contributors as they will end up in their dissertations. To provide robustness, we exclude papers which have at least one author with $Age \leq 3$ years. To this end, we drop from the sample papers that have probably been co-authored by PhD students as their academic age is likely to be quite small. Results remain qualitatively similar to the baseline results and are available upon request.

Examining the science citation index effect

The general trend for relatively small teams of authors to place the most junior author as first author and the most senior in the last, more honorary, position could be driven by a change that took place during the nineties. Up until that time, the main resource for bibliographic analysis was the Citation Indices initially founded by the Institute for Scientific Information (ISI) spearheaded by Eugene Garfield. The three major indices were the following: SCI, SSCI and AHCI. These indices and the information regarding authors' output and overall scientific impact approximated by citations had a measurable effect in how researchers were able to advance. In a recent study, Hager et al. (2023) showed that researchers where their output was better represented in the early version of the reports of the SCI published in 1963, landed jobs in "better-ranked" departments.

A major problem with the three prominent citations indices, was that, due to space constraints, citations could only be readily available to the first author. This was a well-known problem. As Garfield pointed: "*If you search the Citation Index for the cited work of a given scientist, you will find only those publications in which the scientist was listed as first author… Obviously, this characteristic can affect the accuracy of someone's citation rate*." (Garfield, 1979, p. 368). This changed with the introduction of digitization and online search platforms. For instance, in 1997, the Web Of Science (WOS) was launched that covered the aforementioned citation indices and could readily assign citations to authors regardless of order of authorship (Garfield, 1997).

As such, one would expect for order of authorship to become less significant after the nineties for papers in WOS journals where citations could be attributed to all authors. To examine this mechanism, we re-perform each estimation for each group of papers (WOS and no WOS) separately. Figure 8 shows the difference in the likelihood of placing the most junior member first between papers listed in WOS journals and papers not listed. There is a significant difference between the two groups. For small teams and papers published in WOS journals there is a significant upward trend of placing the most junior researcher first starting during the nineties. However, we do not observe any such trend for no WOS papers. Figure 9 shows the difference in the likelihood of placing the most senior author last. Results corroborate the previous findings. For small teams, the most senior researcher tends over time to be placed last for WOS papers. Nevertheless, there is no such trend present for no WOS papers. As with the baseline results, any effect dissipates once we focus on larger teams as Figs. 8 and 9 and their counterparts A9 and A10 for teams larger or equal to eight show.

WOS was probably the biggest at the time digital platform launched; however, it was also associated with significant subscription costs. To this end, while authors could be aware of this change in citation assignment, they may had limited access to the service. One however would expect that for high impact journals, even if not listed in WOS, that they would be more likely to be digitized thereby facilitating citation assignment. In

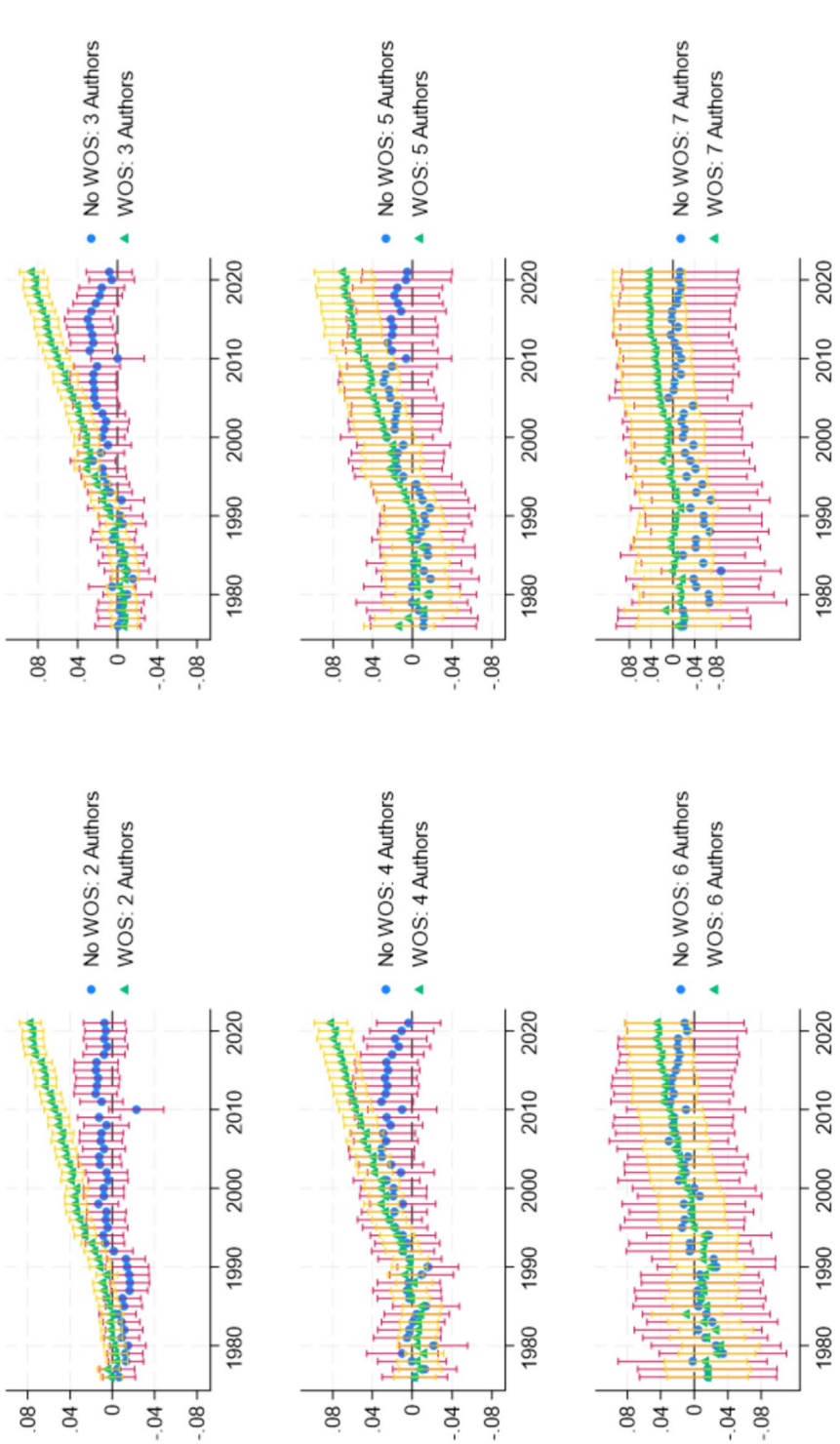

Fig. 8 Junior results by group of journals. Coefficients with their 99% confidence intervals. Each graph displays the coefficients of the year dummies along with their 99% confidence intervals of Eq. (1) after replacing $ABC_{i,t}$ with $Junior_{i,t}$ and estimating it for each team size and type of journal (WOS and No WOS) separately

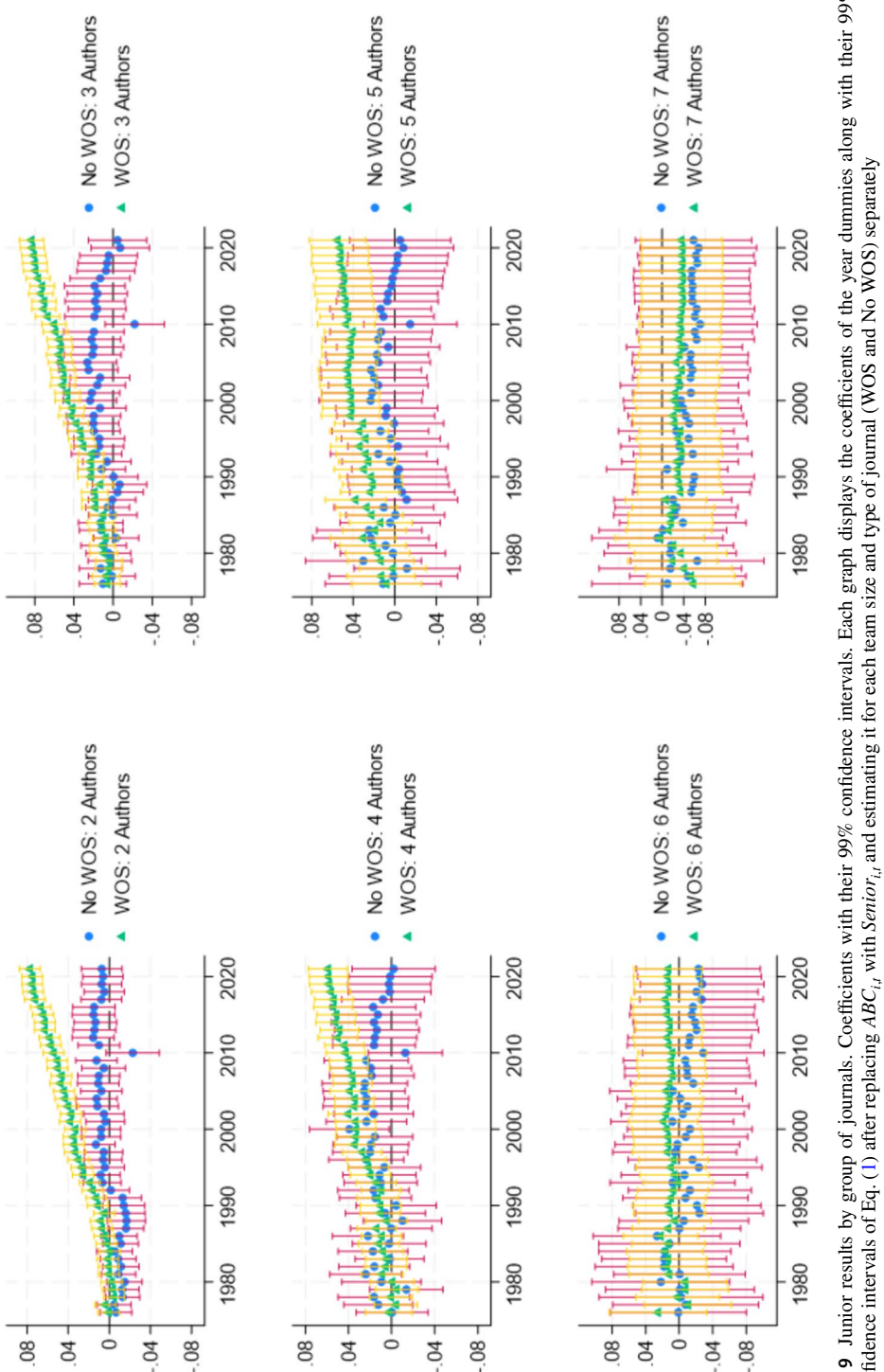

Fig. 9 Junior results by group of journals. Coefficients with their 99% confidence intervals. Each graph displays the coefficients of the year dummies along with their 99% confidence intervals of Eq. (1) after replacing $ABC_{i,t}$ with $Senior_{i,t}$ and estimating it for each team size and type of journal (WOS and No WOS) separately

addition, Joseph et al. (2005) through a game-theoretic model showed that as research quality increases, authors may revert to alphabetization perhaps indicating a fairer distribution of credit.

Motivated by the above discussion to provide robustness to a potential WOS effect, we examine the evolution of order of authorship based on the journal's IF. Results of the coefficients across the different groups are displayed in Figs. A11–A14 of the Online Appendix. First, we observe that for all WOS papers, regardless of IF, there is a trend for the junior author placed first and the senior last. While high impact journals exhibit a higher tendency, low-impact journals also display a positive trend (Figs. A11, A13).

However, for no WOS papers, there is a clear difference between high impact and low impact journals. For papers published in high IF journals, there is a growing trend of junior and senior placements as with the case of WOS papers. Nevertheless, for low IF journals, there is no such trend. This latter finding could imply that research teams perceived high IF journals, even if not listed in WOS, to had greater visibility to their low IF counterparts. To this end, assigning citations to all authors for these papers could be an easier task once such works were uploaded to the internet. In this section we posited, a potential reason for the change in authorship norms. However, there may be other reasons than digitization and online search platforms for the change of the authorship practices.

Discussion

In this paper we examined the evolution of order of authorship based on seniority. The primary motivation of the paper was twofold. First the growing debate over how to order authorship. Second, a stylized fact related to alphabetization (Waltman, 2012; Wohlrabe & Bornmann, 2022); since the rate of alphabetization decreases over time it begs the question on whether teams are struggling to find alternative authorship schemes to maximize both the quality of research output and long-term collaboration across team members.

As with prior literature, we show that the decrease in alphabetization is robust after accounting for field and country heterogeneity. To this end, we examine the two most important positions in a published paper; the first and the last. While, in case of many authors, papers will be known by the first author's last name, the last position in the author list may also signify an honorary position (Fox et al., 2018). We find that for small teams the likelihoods of placing the most junior author first and the most senior last have been increasing. We also find some evidence that this evolution started during the launch of the internet era where one could more easily create a research profile with works and citations to those works regardless of placement in the author list.

We interpret these results as a growing tendency of more fairness within scientific teams. Small teams are more likely to concede the first place in the author list to the person that likely needs it the most; i.e., the most junior researchers. More senior authors in turn may benefit from the last position in the authorship list. The fairness interpretation is further promoted by the literature that examines the authorship positions between male and female researchers. While male authors in the past had been dominating first and last positions, in recent decades, the likelihood of a female author placed first has increased (Oertelt-Prigione, 2012; West et al., 2013).

For larger teams, we find no significant trends. In larger teams, the first place carries more weight. For instance, holding a paper's quality the same, a second-placed author in a three-authored paper can be seen as more integral to this paper vis-à-vis a fifteen-authored

paper. Further, for a paper that requires a large team, it is very likely to have a principal investigator or research director that assembles the team in the first place. To this end, the general order of authorship is likely to have been drawn from inception. The difference between smaller and larger teams over time is the main contribution of this paper, especially in light of Fig. 1 that shows that team size has been increasing.

We aimed to uncover potential mechanisms for this evolution. We start from the observation that the digitization during the nineties facilitated for forward citations to be counted to all authors. Forward citations are viewed as rewards by researchers as higher citations accumulated approximate a researcher's scientific impact. This diffusion of rewards was correlated positively with the evolution of junior author placed first and senior author placed last.

This paper is not without its limitations. The primary focus has been on order of authorship and academic age. With respect to the latter, younger researchers are not the only group that might be in a disadvantageous position when assigning credit. While the recent study by Yang et al. (2022) shows that gender-diverse teams produce novel and high-impact works, studies have shown that gender disparities exist (Aksnes et al., 2019; Oertelt-Prigione, 2012; West et al., 2013). However, OpenAlex does not readily produce gender classification of its authors. While there are solutions to name-to-gender classification (e.g. Namsor software), this goes beyond the scope of this paper that opted to examine in-depth the relationship between age and authorship order. Moreover, there can be other groups in disadvantageous positions where data cannot readily allow for their identification. Finally, order of authorship is an important issue when considering ethical practices and fairness within scientific teams. However, it is not the only as studies have examined other issues such as ghost authorship (Teixeira da Silva & Dobránszki, 2016; Pruschak & Hopp, 2022). To this end, examining the evolution of other aspects of ethical practices from the viewpoint of younger researchers and other groups that might be in a disadvantageous position can be avenues for future research.

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