The Relationship Between Scientific Collaboration and Academic Impact Among Distinguished Scientists: A Panel Data Analysis of Nobel Laureates in Natural Sciences (Postprint)

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Abstract

[Purpose/Significance] To explore the relationship between research collaboration and academic impact among distinguished scientists, thereby providing a basis for optimizing research collaboration in the process of cultivating innovative talents. [Method/Process] This study employs unbalanced panel data analysis methods to investigate the relationship between collaboration indicators—including collaboration scale, collaboration breadth, and collaboration role—and academic impact among 242 British and American Nobel laureates in natural sciences from 1900 to 2018. [Results/Conclusions] Although the collaboration characteristics of non-first-author papers contribute more to the overall collaboration characteristics of all collaborative papers than do those of first-author papers, first-author papers contribute more to the academic impact of Nobel laureates than non-first-author papers. The collaboration scale of first-author publications constitutes an effective collaboration scale for Nobel laureates, which is positively correlated with the laureates' academic impact. Collaborating with a greater diversity of scholars is conducive to enhancing the academic impact of Nobel laureates. It is recommended that future research on the impact of scholars' collaboration characteristics in their publications on academic performance, or other collaboration-related studies, should separately analyze scholars' first-author and non-first-author publications, as this approach may yield more meaningful conclusions.

Full Text

Preamble

Research on the Relationship Between Scientific Research Collaboration and Academic Influence of Outstanding Scientists—Based on

Panel Data Analysis of Nobel Laureates in Natural Sciences

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Abstract: [Purpose/Significance] This study explores the relationship between research collaboration and academic influence among outstanding scientists, providing a basis for optimizing research cooperation in the cultivation of innovative talent. [Method/Process] Using unbalanced panel data analysis, we examine the relationship between collaboration indicators—such as collaboration scale, collaboration breadth, and collaboration roles—and academic influence among 242 British and American Nobel laureates in natural sciences from 1900 to 2018. [Result/Conclusion] Although collaborative characteristics of non-first-author papers contribute more to overall collaborative characteristics than first-author papers, first-author papers contribute more to Nobel laureates' academic influence than non-first-author papers. The collaboration scale of first-author papers represents an effective collaboration scale for Nobel laureates, positively correlated with their academic influence. Collaborating with diverse scholars benefits Nobel laureates' academic influence. We recommend that future studies examining how scholars' collaborative characteristics affect academic performance, or other collaboration-related research, should analyze first-author and non-first-author papers separately to yield more meaningful conclusions.

Keywords: Nobel laureates in natural sciences; collaboration scale; collaboration breadth; academic influence

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The world today is undergoing profound changes unseen in a century, with scientific and technological innovation becoming a key variable affecting and reshaping the global competitive landscape. Scientific and technological talent is crucial for enhancing independent innovation capabilities. In recent years, China's scientific and technological development has advanced rapidly, leading globally in many fields. However, there remains a considerable gap in the number of scientific and technological talents, particularly top-tier talent, compared to world-class standards. On March 12, 2021, Xinhua News Agency publicly released the "Outline of the 14th Five-Year Plan (2021-2025) for National Economic and Social Development and Long-Range Objectives Through 2035 of the People's Republic of China" [1], which proposed that "cultivating a reserve force of young scientific and technological talents with international competitiveness" is a strategic initiative based on current needs and long-term vision. Understanding the patterns of outstanding scientists' academic behaviors throughout their careers is essential for cultivating internationally competitive scientific talent. In the era of "big science," scientific collaboration has become increasingly common and represents a primary mode of scientific research activity. Nobel laureates in natural sciences are authoritative representatives of outstanding scientists. Studying the relationship between their research collaboration and academic influence throughout their careers helps understand the characteristics of outstanding scientists' collaborative practices, providing a basis for science policymakers to formulate optimized collaboration policies and guiding principles for young scientists' collaborator selection mechanisms.

1. Literature Review

Numerous studies have examined the relationship between scholars' research collaboration and academic influence, which can be categorized into three levels based on collaboration scope: macro (international collaboration), meso (inter-institutional collaboration), and micro (inter-scholar collaboration). Macro-level studies include: R. Sooryamoorthy [2], G. Abramo et al. [3], and M. Bordons et al. [4] studied scholars in pharmacology and pharmaceutical sciences in South Africa, Italy, and Spain, respectively, concluding that international collaboration enhances scholars' academic influence. S. Kyvik et al. [5] found that active participation in international collaboration helps increase researchers' academic productivity. Qiu Junping et al. [6], Xi Jihong et al. [7], Wang Junjing [8], and Li Wencong et al. [9] studied scholars in computer science, surgery, Shanghai Jiao Tong University, and prominent domestic life science research institutions, respectively, finding that international collaboration positively impacts academic influence. Meso-level studies include: G. Abramo et al. [10] found that inter-institutional collaborative papers are more likely to be published in high-quality journals. Lu Dong [11], using domestic library and information institutions as examples, found that higher degrees of international co-authorship correlate with higher research quality. Micro-level studies include: W.D. Figg et al. [12] discovered that citation frequency of papers published in high-impact journals positively correlates with both the number of co-authors and institutions. A.J. Parish et al. [13] studied over 20,000 scholars across eight disciplines, finding that scholars with more collaborators have higher h-index values. Sun Jianjun et al. [14] found that scholars' international collaboration positively correlates with research performance. M. Franceschet et al. [15] examined the relationship between co-authorship scale and citation volume, concluding that small-scale collaboration is more effective for increasing academic influence.

Many studies [16-18] have selected specific research fields to construct collaboration networks with scholars or papers as nodes, using centrality measures to characterize scholars' positions in collaboration networks and reveal how advantageous network positions affect knowledge output performance. A. Abbasi et al. [19] found that scholars' academic performance levels positively correlate with their individual collaboration network indicators. D. Stefano et al. [20] found that Italian scholars with higher status in academic collaboration networks demonstrate better academic performance. Guo Shiyue et al. [21] studied over 30,000 authors in the catalyst field, showing that co-authorship network patterns positively correlated with citation frequency are characterized by large scale and decreasing network centralization. Song Zhihong et al. [22] used Poisson regression to analyze the relationship between "star authors"' network positions and research output, finding that authors' ego-network scale, degree centrality, and betweenness centrality all positively impact academic influence, with betweenness centrality having a more significant effect. Sun Xionglan [23] studied over 10,000 researchers in international library and information science, finding that liaison status and enduring collaborative relationships positively impact academic performance.

In summary, existing research on the relationship between scholars' research collaboration and academic performance primarily focuses on designing collaboration indicators or generating collaboration metrics based on complex network theory from macro (international), meso (inter-institutional), and micro (inter-scholar) perspectives. However, these studies have limitations: (1) None have examined the relationship between collaboration characteristics and academic influence throughout the careers of outstanding scientists; (2) According to international convention, the first author is typically the primary contributor, directly involved in conceptual design, the entire or primary research process, and paper writing [24,25]. Therefore, first-author and non-first-author papers have different definitions and significance for scholars. No studies have separated collaborative papers into first-author and non-first-author categories to examine differential relationships between their collaborative characteristics and academic influence (hereinafter, papers published as first author are referred to as "first-author papers," and those published as non-first author as "non-first-author papers").

2. Research Design

2.1 Data Sources

First, this study selected British and American scholars who received Nobel Prizes in Physics, Chemistry, or Physiology/Medicine from 1900 to 2018 from the official Nobel Prize website (https://www.nobelprize.org/), including 73 Nobel laureates in Physics, 65 in Chemistry, and 104 in Physiology or Medicine. Second, based on each laureate's resume from the official Nobel Prize website, we retrieved their publication and citation data from the Web of Science Core Collection (search period: March 2020 to May 2020) and constructed a database of publication and citation information for British and American Nobel laureates in Physics, Chemistry, and Physiology or Medicine.

2.2 Variable Description

(1) **Academic Influence (ai):** The scope and depth of a scientist's influence on other individuals and their research activities within the scientific field through published papers. This study collected 13 common indicators for calculating scholars' academic influence (see Table 1), calculated values for all 13 indicators for each laureate, and conducted factor analysis and principal component analysis to derive a comprehensive academic influence metric, ai.

(2) **Collaborative Publication Quantity (p):** The number of collaborative papers published by a scientist.

(3) **First-Author Publication Quantity (p1):** The number of collaborative papers published by a scientist as first author.

(4) **Non-First-Author Publication Quantity (p0):** The number of collaborative papers published by a scientist as non-first author.

(5) **Collaboration Scale:** The total number of authors across all collaborative papers divided by the number of collaborative papers, i.e., the average number of authors per paper (copp, average number of authors per paper).

(6) **Collaboration Breadth:** The number of unique co-authors across all collaborative papers (cops, number of co-authors per stage).

(7) **First-Author Collaboration Scale (copp1):** The collaboration scale of papers published by a scientist as first author.

(8) **Non-First-Author Collaboration Scale (copp0):** The collaboration scale of papers published by a scientist as non-first author.

(9) **First-Author Collaboration Breadth (cops1):** The collaboration breadth of papers published by a scientist as first author.

(10) **Non-First-Author Collaboration Breadth (cops0):** The collaboration breadth of papers published by a scientist as non-first author.

2.3 Panel Data Structure of Research Collaboration Characteristics and Academic Influence

Following R.K. Pan [26], this study adopts the conclusion that Nobel laureates' papers exhibit exponential citation decline five years after publication, calculating collaboration characteristic variables and academic influence values in five-year intervals. This approach also avoids citation inflation caused by the Matthew effect after major scientific discoveries and Nobel Prize awards [27-28]. The calculation method for all variables is as follows: If a laureate published their first paper in 1965 (career start year) and their last paper in 2015 (career end year), variables are calculated using five-year windows: 1965-1969, 1966-1970, 1967-1971, …, 2010-2014, 2011-2015. The cutoff year for all variable calculations is either the year of the laureate's last publication or 2018 (if their academic career had not ended). The resulting unbalanced panel data structure for Nobel laureates' academic influence variables, academic age variables, and collaboration variables is shown in Table 1 .

2.4 Econometric Model Design

Based on previous research on the relationship between scientists' collaboration scale, collaboration breadth, collaboration roles, and academic influence, this study designs the following econometric models:

In models (1)a, (1)b, and (1)c, aiit represents scientist i's academic influence during period t-4 to t. pit represents the number of collaborative papers published by scientist i during period t-4 to t. p1it represents the number of first-author papers published by scientist i during period t-4 to t. p0it represents the number of non-first-author papers published by scientist i during period t-4 to t. i denotes individual scientists, and t denotes year. C is the intercept; Vi represents individual effects reflecting unobservable individual characteristics; β represents parameters to be estimated; and it is the random disturbance term following a Gaussian distribution.

aiit = C + βi pit + Vi + it (1)a
aiit = C + βi p1it + \$ \$2 p0it + Vi + it (1)b
aiit = C + βi p1it + \$ \$2 p0it + Vi + it (1)c

In model (2), coppit represents the collaboration scale of collaborative papers published by scientist i during period t-4 to t. copp1it represents the collaboration scale of first-author papers published by scientist i during period t-4 to t. copp0it represents the collaboration scale of non-first-author papers published by scientist i during period t-4 to t.

aiit = C + βi coppit + Vi + it (2)a
aiit = C + βi copp1it + \$ \$2 copp0it + Vi + it (2)b

In model (3), copsit represents the collaboration breadth of collaborative papers published by scientist i during period t-4 to t. cops1it represents the collaboration breadth of first-author papers published by scientist i during period t-4 to t. cops0it represents the collaboration breadth of non-first-author papers published by scientist i during period t-4 to t.

aiit = C + βi copsit + Vi + it (3)a
aiit = C + βi cops1it + \$ \$2 cops0it + Vi + it (3)b

Based on these econometric models, the research framework is designed as shown in Figure 1 [Figure 1: see original paper].

3. Empirical Analysis

3.1 Establishment of a Composite Academic Influence Index for Nobel Laureates

Given the numerous existing indicators for evaluating individual academic influence with different perspectives, this study selected 13 common academic influence evaluation indicators from existing literature [29], with definitions shown in Table 2 . First, KMO and Bartlett's tests were conducted to examine multicollinearity among the 13 indicators, followed by principal component analysis to extract common factors, resulting in a comprehensive academic influence metric, ai.

The KMO values for Nobel laureates in Physics, Chemistry, and Physiology or Medicine were 0.843, 0.830, and 0.844, respectively, with significance levels of

0.000, indicating strong correlations among the 13 variables suitable for factor analysis. Using Chemistry laureates as an example, correlation analysis results for the 13 academic influence indicators are shown in Table 3 .

Correlation analysis reveals information redundancy among the 13 academic influence indicators for Chemistry laureates, justifying principal component analysis. Similar analyses for Physics and Physiology or Medicine laureates each extracted one factor, with variance contribution percentages of 78%, 80.33%, and 81.03%, respectively. For Chemistry laureates, the composite academic influence ai is calculated as: ai = 0.802AIF + 0.867h + 0.883g + 0.976e + 0.820hg + 0.938w + 0.990R + 0.837A + 0.981p + 0.922S + 0.928T + 0.713m + 0.950*q2. Table 4 presents the rotated factor component matrices for the 13 academic influence indicators across the three disciplines.

3.2 Testing of Unbalanced Panel Data

Since this study employs unbalanced panel data, IPS and Fisher-type tests were used for unit root testing of all variables. Results show that all variables are stationary under both tests. Table 5 presents the test results for Physics laureates as an example.

3.3 Research Results

3.3.1 Relationship Between Collaborative Publication Quantity and Academic Influence of Nobel Laureates Table 6 shows the relationship between collaborative publication quantity and academic influence. Each additional collaborative paper increases academic influence by 0.258, 0.097, and 0.135 units for Nobel laureates in Physics, Chemistry, and Physiology or Medicine, respectively. Thus, increased collaborative publication quantity correlates with enhanced academic influence.

3.3.2 Relationship Between First-Author and Non-First-Author Publication Quantity and Academic Influence Table 7 presents the relationship between first-author/non-first-author publication quantity and academic influence. Each additional first-author paper increases academic influence by 0.358, 0.214, and 0.366 units for Physics, Chemistry, and Physiology or Medicine laureates, respectively. Each additional non-first-author paper increases academic influence by 0.1002, 0.0871, and 0.116 units, respectively. Both first-author and non-first-author publication quantities positively correlate with academic influence, but the relationship is more pronounced for first-author papers.

3.3.3 Relationship Between Collaboration Scale and Academic Influence Table 8 shows the relationship between collaboration scale and academic influence. Each one-unit increase in collaboration scale decreases academic influence by 0.1992, 0.1986, and 0.130 units for Physics, Chemistry, and Physiology or Medicine laureates, respectively. Thus, collaboration scale negatively correlates with academic influence; higher average authors per paper does not enhance and may reduce academic influence.

3.3.4 Relationship Between First-Author/Non-First-Author Collaboration Scale and Academic Influence Table 9 presents the relationship between first-author/non-first-author collaboration scale and academic influence. Each one-unit increase in first-author collaboration scale increases academic influence by 0.298, 0.151, and 0.259 units for Physics, Chemistry, and Physiology or Medicine laureates, respectively. Each one-unit increase in non-first-author collaboration scale decreases academic influence by 0.497, 0.350, and 0.0418 units, respectively. First-author collaboration scale positively correlates with academic influence, while non-first-author collaboration scale negatively correlates. First-author collaboration scale represents an effective collaboration scale for Nobel laureates.

3.3.5 Relationship Between Collaboration Breadth and Academic Influence Table 10 shows the relationship between collaboration breadth and academic influence. Each one-unit increase in collaboration breadth increases academic influence by 0.184, 0.0167, and 0.0245 units for Physics, Chemistry, and Physiology or Medicine laureates, respectively. Collaboration breadth positively correlates with academic influence; collaborating with diverse scholars benefits Nobel laureates.

3.3.6 Relationship Between First-Author/Non-First-Author Collaboration Breadth and Academic Influence Table 11 presents the relationship between first-author/non-first-author collaboration breadth and academic influence. Each one-unit increase in first-author collaboration breadth increases academic influence by 0.291, 0.171, and 0.142 units for Physics, Chemistry, and Physiology or Medicine laureates, respectively. Each one-unit increase in non-first-author collaboration breadth increases academic influence by 0.027, 0.016, and 0.0120 units, respectively. Both first-author and non-first-author collaboration breadth positively correlate with academic influence, but the effect is substantially stronger for first-author papers.

4. Discussion

The analysis reveals that while Nobel laureates' non-first-author papers exceed first-author papers in quantity, collaboration scale, and collaboration breadth, the increase in academic influence derives more from first-author than non-first-author papers. Young scholars should prioritize publishing high-impact first-author papers.

Collaboration scale does not necessarily enhance academic influence; excessive average authors per paper may reduce rather than increase impact. First-author collaboration scale represents an effective collaboration scale for Nobel laureates, positively correlating with academic influence. Collaborating with diverse scholars benefits Nobel laureates, with first-author collaborations yielding higher academic influence than non-first-author collaborations.

These findings suggest: (1) When studying scholars' collaborative characteristics, particularly for high-impact scholars, researchers should distinguish between first-author and non-first-author papers, as their definitions, significance, and collaborative features differ, potentially producing different effects on academic influence. (2) Nobel laureates' academic influence increases more from first-author papers, though whether other first-author collaborative characteristics (e.g., closeness centrality, betweenness centrality, structural holes) have greater positive impact than non-first-author papers requires verification. (3) Young scholars should not overemphasize building large collaboration teams, as excessive team size may not necessarily improve research quality. However, they should increase collaboration breadth, as it generally enhances research quality regardless of team size. (4) Young scholars should focus on the quality and efficiency of first-author collaborations, seeking partnerships with scholars who can enhance their research to increase first-author publication impact.

5. Conclusions and Future Directions

Based on panel data analysis of Nobel laureates in Physics, Chemistry, and Physiology or Medicine, this study reveals the relationship between outstanding scientists' collaborative characteristics and academic influence:

(1) Although Nobel laureates' non-first-author papers exceed first-author papers in quantity, collaboration scale, and collaboration breadth, academic influence increases more from first-author than non-first-author papers. Young scholars should emphasize publishing high-impact first-author papers.

(2) Higher average authors per collaborative paper does not enhance academic influence; excessive collaboration scale may reduce impact. First-author collaboration scale represents an effective collaboration scale for Nobel laureates, positively correlating with academic influence.

(3) Collaborating with diverse scholars enhances Nobel laureates' academic influence, with first-author collaborations yielding greater impact than non-first-author collaborations.

(4) Because first-author and non-first-author papers differentially affect Nobel laureates' academic influence, future research on scholars' collaborative characteristics and academic performance should analyze these categories separately to yield more valuable conclusions.

Future research directions include: (1) Examining how Nobel laureates' collaborative characteristics as corresponding authors affect academic influence and comparing these effects with first-author and non-first-author papers. (2) Investigating whether long-career ordinary scientists exhibit similar patterns regarding how collaborative characteristics affect academic influence, and whether their collaborative characteristics derive primarily from first-author or non-first-author papers, and how these characteristics relate to academic age.

References

[1] Outline of the 14th Five-Year Plan for National Economic and Social Development and Long-Range Objectives Through 2035 of the People's Republic of China [EB/OL]. [2021-07-20]. http://www.gov.cn/xinwen/2021-03/13/content_{5592681}.htm.

[2] SOORYAMOORTHY R. Do types of collaboration change citation? Collaboration and citation patterns of South African science publications [J]. Scientometrics, 2009, 81(1): 177-193.

[3] ABRAMO G, D'ANGELO CA, SOLAZZI M. The relationship between scientists' research performance and the degree of internationalization of their research [J]. Scientometrics, 2011, 86(3): 629-643.

[4] BORDONS M, APARICIO J, COSTAS R. Heterogeneity of collaboration and its relationship with research impact in a biomedical field [J]. Scientometrics, 2013, 96(2): 443-466.

[5] KYVIK S, REYMERT I. Research collaboration in groups and networks: differences across academic fields [J]. Scientometrics, 2017, 113(2): 951-967.

[6] Qiu Junping, Zeng Qian. Does international collaboration improve research impact? A case study of computer science [J]. Information Studies: Theory & Application, 2013, 36(10): 1-5.

[7] Xi Jihong, Han Xi, Wu Qianqian. Research on the role of international collaboration in enhancing paper impact: a case study of surgery [J]. Journal of Intelligence, 2015, 34(1): 92-95.

[8] Wang Junjing. Research on the impact of international collaboration on research paper quality [D]. Shanghai: Shanghai Jiao Tong University, 2013.

[9] Li Wencong, He Jing, Dong Jichang. The impact of international collaboration and overseas experience on researchers' paper quality: a case study of life sciences [J]. Management Review, 2018, 30(11): 68-75.

[10] ABRAMO G, D'ANGELO CA, DICOSTA F, et al. University-industry collaboration in Italy: a bibliometric examination [J]. Technovation, 2009, 29(6/7): 498-507.

[11] Lu Dong. Analysis of the impact of author co-authorship patterns on research quality in library and information science: a sample analysis of high-productivity institutions in China based on SciVal [J]. Modern Information, 2015, 35(9): 111-115.

[12] FIGG WD, DUNN L, LIEWEHR DJ, et al. Scientific collaboration results in higher citation rates of published articles [J]. Pharmacotherapy, 2012, 26(6): 759-767.

[13] PARISH AJ, BOYACK KW, IOANNIDIS J. Dynamics of co-authorship and productivity across different fields of scientific research [J]. PloS one, 2018, 13(1): e0189742.

[14] Shi Yanqing, Sun Jianjun. Research on the relationship between scholars' research performance and international collaboration degree in China's library and information field [J]. Information Science, 2017, 35(11): 114-120.

[15] FRANCESCHET M, COSTANTINI A. The effect of scholar collaboration on impact and quality of academic papers [J]. Journal of informetrics, 2010, 4(4): 540-553.

[16] ABBASI A, ALTMANN J, HOSSAIN L. Identifying the effects of co-authorship networks on the performance of scholars: a correlation and regression analysis of performance measures and social network analysis measures [J]. Journal of informetrics, 2011, 5(4): 594-607.

[17] YAN E, YING D. Applying centrality measures to impact analysis: a co-authorship network analysis [J]. Journal of the Association for Information Science & Technology, 2014, 60(10): 2107-2118.

[18] BORDONS M, APARICIO J, GONZALEZ-ALBO B, et al. The relationship between the research performance of scientists and their position in co-authorship networks in three fields [J]. Journal of informetrics, 2015, 9(1): 135-144.

[19] ABBASI A, CHUNG KSK, HOSSAIN L. Egocentric analysis of co-authorship network structure, position and performance [J]. Information processing & management, 2012, 48(4): 671-679.

[20] DESTEFANO D, FUCCCELLA V, VITALE MP, et al. The use of different data sources in the analysis of co-authorship networks and scientific performance [J]. Social networks, 2013, 35(3): 370-381.

[21] Guo Shiyue, Li Rui. Research on the correlation between co-authorship network patterns and paper output quantity and quality: a case study of Chinese catalyst field journal paper co-authorship networks [J]. Journal of the China Society for Scientific and Technical Information, 2013, 32(3): 314-327.

[22] Song Zhihong, Wu Tianlan, Shi Yuying. Research on the relationship between star authors' network positions and research output: a case study of the "competitive intelligence" field [J]. Information Studies: Theory & Application, 2015, 38(5): 55-59.

[23] Sun Xionglan, Teng Guangqing, Wang Siming, et al. Research on the correlation and impact of research collaboration status and academic performance [J]. Information and Documentation Services, 2019, 40(4): 6-14.

[24] WELTZIN JF, BELOTE RT, WILLIAMS LT, et al. Authorship in ecology: attribution, accountability, and responsibility [J]. Frontiers in ecology and the environment, 2006, 4(8): 435-441.

[25] Xue Lei. On the authorship issue of first authors in academic papers [J]. Acta Editologica, 2003(1): 33-34.

[26] PAN RK, FORTUNATO S. Author impact factor: tracking the dynamics of individual scientific impact [J]. Scientific reports, 2014, 4: 4880.

[27] CHAN HF, GLEESON L, TORGLER B, et al. Awards before and after the Nobel Prize: a Matthew effect and/or a ticket to one's own funeral? [J]. Research evaluation, 2014, 23(3): 210-220.

[28] FRANDSEN TF, NICOLAISEN J. The ripple effect: citation chain reactions of a Nobel prize [J]. Journal of informetrics, 2010, 4(4): 437-447.

[29] Gao Zhi, Zhang Zhiqiang. Research on calculation methods for individual scientists' academic influence over time [J]. Modern Information, 2017, 37(5): 66-71.

[30] Zhang Lihua, Tian Dan, Qu Jiansheng. Analysis of patterns in research collaboration modes and researcher role changes: a case study of authors with careers of at least 30 years in virology [J]. Journal of the China Society for Scientific and Technical Information, 2020, 39(7): 719-730.

[31] VERBREE M, HORLINGS E, GROENEWEGEN P, et al. Organizational factors influencing scholarly performance: a multivariate study of biomedical research groups [J]. Scientometrics, 2015, 102: 25-49.

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Note: Figure translations are in progress. See original paper for figures.