A Literature Review on the Impact of International Research Collaboration on Research Performance (Postprint)

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Abstract

[Purpose/Significance] Research collaboration is a cooperative research endeavor among different research entities focusing on specific scientific questions to achieve complementary advantages. International research collaboration is of significant importance for promoting research performance. Understanding the current state of research on the impact of international research collaboration on research performance provides references and insights for future studies in this area. [Method/Process] This paper systematically reviews studies on the impact of international research collaboration on research performance from three dimensions: research level, analytical indicators, and analytical methods, based on defining the two key concepts of international research collaboration and research performance. [Results/Conclusions] The analysis reveals that this research field is currently rich in achievements. Scholars both domestically and internationally have primarily examined the impact of international research collaboration on research performance from three levels: macro (countries, regions, etc.), meso (fields, institutions, teams, etc.), and micro (individual researchers), using simple counting and single-ratio international research collaboration indicators, as well as research performance indicators including research output quantity, research output quality, and h-index metrics, employing bibliometric methods, social network analysis methods, and statistical analysis methods. Future research should strengthen: studies at the scientist level and broaden the analysis of more research collaboration behaviors; exploration of comprehensive indicators that characterize both research collaboration and research performance; and creation of targeted analytical models while controlling for some significant variables.

Full Text

Preamble

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A Review of Research on the Impact of International Scientific Collaboration on Research Performance

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Abstract

[**Purpose/Significance**] Research collaboration is a cooperative research endeavor among different research entities focused on specific scientific problems to achieve complementary advantages. International research collaboration is of great significance for promoting research performance. Understanding the current state of research on the impact of international collaboration on research performance provides a reference for future studies in this area. [**Method/Process**] Based on clear definitions of "international research collaboration" and "research performance," this paper systematically reviews relevant literature from three dimensions: research level, analytical indicators, and analytical methods. [**Result/Conclusion**] The analysis reveals that this research field is rich in findings. Scholars primarily examine the impact of international collaboration on research performance at three levels—macro (countries, regions, etc.), meso (fields, institutions, teams, etc.), and micro (individual researchers)—using simple counting and single-ratio indicators for international collaboration, along with quantity-based, quality-based, and h-index composite indicators for research performance, and employing bibliometric methods, social network analysis, and statistical methods. Future research should strengthen: (1) studies at the scientist level and broaden the analysis of more collaborative behaviors; (2) exploration of comprehensive indicators characterizing both collaboration and performance; and (3) development of targeted analytical models while controlling for significant variables.

Classification Number: G250
Keywords: International research collaboration; Research performance; Research productivity; Output quantity; Output quality

2. The Connotation of International Research Collaboration and Research Performance

To systematically review research on the impact of international collaboration on research performance, it is essential to clearly define the scope of "international research collaboration" and "research performance."

2.1 International Research Collaboration

(1) Research Collaboration. Currently, there is no unified definition of research collaboration in academia. Scientometricians J.S. Katz and B.R. Martin define research collaboration as scientists working together with the common aspiration of creating new knowledge [12]. J. Ziman views research collaboration as a product of science reaching a certain "steady state," where collaborative effects play an increasingly important role in improving scientific knowledge output [13]. A.G. Heffner considers research collaboration an intense form of interaction among scientists, requiring intellectual exchange and communication to form an ideal collaborative model [14]. Zhao Rongying proposes that research collaboration refers to two or more researchers or organizations jointly committed to the same research task, cooperating and working synergistically to maximize research output, with its essence being resource sharing among collaborators [15].

Synthesizing these definitions, we argue that the motivation for collaboration among researchers (or teams) is greatly enhanced when research requires different instruments, data from different fields or sources, or unique resources. Collaboration seeks complementarity and sharing of ideas, equipment, data, and resources to jointly accomplish clearly defined research tasks and create new knowledge, technologies, and outcomes [16]. Throughout the research process, collaborative entities share resources (which can be intellectual, knowledge, reputation, funding, equipment, etc.) and establish cooperative relationships, such as data/resource/platform sharing, technology import, personnel exchange, international academic conferences, collaborative platform construction, and co-authored publications. Among these, co-authored publications and the formation of research intellectual property rights constitute the primary manifestations of research collaboration.

(2) International Research Collaboration. International research collaboration refers to cooperation and exchange among research teams from different countries or regions, sharing resources to achieve complementary advantages or 强强联合 (strong-strong alliances). When the aforementioned collaborative entities involve different countries or regions, international research collaboration occurs.

2.2 Research Performance

During research, driven by objective needs, subjective motivations, and existing collaborative foundations, research entities engage in various forms of collab-

oration, generating direct and indirect benefits such as papers, patents, and monographs (direct benefits), as well as improvements in collaborators' knowledge, skills, and reputation (indirect benefits). The scope is broad (see Figure 3 [Figure 3: see original paper]). Current research commonly uses terms such as research output, research productivity, research performance, research impact, and research quality to express the benefits of collaboration. In terms of connotation, research output and productivity generally measure the quantity of research output or its attention; research performance has a slightly broader scope, possibly including difficult-to-measure indirect benefits; while research impact and quality typically refer only to the attention received by research outcomes. This paper uses "research performance" to represent the benefits generated by international research collaboration.

3. Research on the Relationship Between International Collaboration and Research Performance

3.1 Research Levels of International Collaboration

Analysis of domestic and international literature on the relationship between international collaboration and research performance reveals that studies are conducted at three levels: macro (countries, regions, etc.), meso (fields, institutions, teams, etc.), and micro (individual researchers).

3.1.1 Macro-Level Analysis At the macro level of countries, regions, or areas, scholars focus on two main aspects:

(1) Impact of international collaboration on national research performance. These studies examine how different collaboration modes affect research performance. J.S. Katz et al., using UK papers from 1981-1991, found that collaborative papers had greater impact than single-authored papers, with international collaboration having the greatest impact [17]. N. Ma et al. compared Chinese molecular biology papers from 1999-2003, concluding that international collaboration enhances the international communication and influence of Chinese papers [18]. Z. Hayati et al. studied Iranian SCIE papers from 1998-2007, finding that internationally co-authored papers received far more citations than non-collaborative papers [19]. Wang Wenping analyzed Chinese international papers, comparing the quality of international versus non-international collaborative papers and the impact of collaboration modes on paper quality [20]. Overall, participation in international collaboration generally has a positive effect on national research performance.

(2) Comparative analysis of benefits from international collaboration across countries. These studies examine whether different countries gain differently from international collaboration, considering factors such as the number of collaborating countries and national research influence. S. Arunachalam et al. analyzed international co-authorship patterns in developed and developing countries, concluding that internationally co-authored papers are generally

published in higher-impact journals and receive more citations [21]. J. Adams et al. comprehensively analyzed the UK's international collaboration patterns with major partners, showing that the average impact of UK's international collaboration papers significantly exceeded its overall research impact [22]. V.P. Guerrero Bote et al. quantitatively analyzed collaborative papers from 37 countries/regions (including the US, Russia, and China) regarding citation rate improvements from international collaboration, finding that more collaborating countries and greater influence enhance benefits, though a country's own scientific influence doesn't significantly affect its own gains but positively impacts collaborating partners [23]. B.S. Lanchó-Barranés et al. analyzed citation impacts of collaborating with different countries for nine high-output nations and 60 countries with over 1,000 publications, showing that international collaboration increases citation rates, though the boost is smaller when collaborating with highly influential countries [24]. These comparative studies conclude that international collaboration papers are generally of higher quality and more likely to be published in high-impact journals; more collaborating countries in a field generally increase research impact (e.g., the 2016 gravitational wave paper in *Physical Review Letters* co-authored by 1,011 authors from over 20 countries, with over 2,000 citations and three Nobel Prize winners); collaboration between scientifically advanced and less advanced countries clearly enhances the latter's research influence.

3.1.2 Meso-Level Analysis At the meso level, scholars focus on:

(1) Impact of field-level international collaboration on research performance. Studies analyze either single fields (e.g., biomedicine [25], finance [26], astronomy [27], biology [28], chemistry [29], ecology [30]) or compare across fields [31]. M. Bordons et al. found that in Spanish biomedicine, international collaboration papers were of higher quality than non-collaborative papers, and international collaborators were more productive [25]. N.K. Avkiran found no significant quality difference between collaborative and non-collaborative finance papers [26]. A.F.J. Van Raan found that in Dutch astronomy, international collaboration papers had higher self-citation rates, though self-citation wasn't the main reason for their higher impact [27]. F. Narin et al. studied 28 European fields, finding that international collaboration papers had higher citation impact, though benefits varied by field [31]. H.M. Puuska et al. analyzed Finnish publications from 1990-2008, showing disciplinary differences in how international and domestic collaboration affect citations [35]. These studies conclude that international collaboration improves research quality in most fields, though the degree varies due to field development and research environments.

(2) Research performance of institutions/teams in international collaboration. A. Basu et al. studied Indian SCIE papers from 1997, finding that international collaboration positively affected both institutional output volume and average impact factor, with larger institutions benefiting more [36]. S. Goldfinch et al. analyzed nine New Zealand research institutes, showing that

numbers of collaborating authors, institutions, and countries all positively affected citations [37]. L.F. Frederiksen analyzed how international collaboration and author numbers affected citations in Danish industrial research, finding significant effects in fields where multi-author and international papers were common [38]. G. Prathap measured how international collaboration enhanced institutional research output value [39]. F. Barjak et al. found positive effects of international collaboration on both quantity and quality of EU life science research teams [9]. N. Carayol et al. analyzed over 80 labs at Louis Pasteur University, finding no evidence that international collaboration improved lab productivity [40]. These studies conclude that larger institutions benefit more from international collaboration, and more collaborating countries, institutions, and authors generally produce higher-quality papers.

(3) Impact of field/institutional collaboration network structure on research performance. These studies use social network metrics to examine how network structural features affect performance. S. Uddin et al. analyzed a 20-year longitudinal dataset in steel structures, finding that international collaboration papers had higher citation efficiency, and that degree centrality and betweenness centrality positively correlated with average citation efficiency, while closeness centrality had no effect [41]. J.L. Ortega used Microsoft Academic Search to construct ego networks, analyzing whether network structure differences across fields relate to performance and how different collaboration forms (intra-institutional, domestic, international) affect performance [42]. Li Wencong et al. analyzed Chinese stem cell research institutions, examining how position, relationship, and structural embedding in international and domestic collaboration networks affect research output measured by publications and citations [43]. These studies demonstrate that network structural features significantly influence research performance.

3.1.3 Micro-Level Analysis Micro-level studies of individual researchers are relatively scarce. M.J. Kim compared Korean physicists' international versus domestic collaboration performance, finding that collaboration's citation impact depends on partner countries [44]. Z.L. He et al. studied 65 New Zealand biomedical scientists over 14 years, finding that at the paper level, both intra-institutional and international collaboration positively affected quality, while at the scientist level, only international collaboration positively affected future output (quantity and quality) [45]. R. Sooryamoorthy analyzed South African scientists, showing that collaboration types affect citations, and that discipline and institution influence citations regardless of collaboration [46]. G. Abramo et al. studied scientists at 82 Italian universities (2001-2005), finding positive correlations between internationalization and both research quality and quantity [47]. Another study by Abramo et al. showed that highly productive and impactful scientists tend to have higher international collaboration levels, though the reverse isn't necessarily true [48].

3.2 Analytical Indicators for International Collaboration and Research Performance

Scholars use various indicators to quantify collaboration and performance. This section reviews these indicators.

3.2.1 International Collaboration Indicators Based on Pu Mo et al.'s classification, we categorize indicators into simple counting and single-ratio types (see Table 1):

(1) Simple counting indicators include: - International Collaboration Intensity (ICI): number of papers with non-domestic co-authors - International Collaboration Amplitude (ICA): number of foreign countries involved - Number of Countries (NOC) and Number of Authors (NOA) - Degree Centrality (DC): a node's connections in the collaboration network

(2) Single-ratio indicators include: - International Collaboration Rate (ICR): ratio of international papers to total output - Degree of Bilaterality (DB): proportion of bilateral collaboration papers - Capacity of Country (CAP): research influence of partner countries

Some scholars also use network features like betweenness centrality (BC), closeness centrality (CC), network density (D), and clustering coefficient (CC) to measure collaboration relationships [41, 42, 53].

3.2.2 Research Performance Indicators Performance indicators vary by study. Scholars typically use quantity, quality, and h-index composite indicators:

(1) Quantity indicators include total publications (productivity) and fractional productivity (FP), where FP sums researchers' relative contributions (the inverse of author count per paper). For example, if a researcher publishes m papers with n authors each, their FP = $\Sigma(1/n)$ [48-49, 51].

(2) Quality indicators include both classic and derived metrics (see Table 2):

Classic metrics: total citations (C), citations per paper (CPP), highly cited papers (NHCP), and journal impact factor (IF). These are widely used and recognized [28, 47, 51, 55].

Derived metrics: more complex and less frequently used, including: - Uncited International Collaboration Paper Rate (UICPR) - Efficiency Score (E): annual average citations per paper since publication - Relative Citation Rate (RCR) and Relative Citation Impact Index (RCII) - Mean Normalized Journal Score (MNJS) and Mean Normalized Citation Score (MNCS) - Bilateral Citation Degree (CDB), Crown Indicator (CI), Citation Gain (CG) - Citation Rate Increment from Collaboration (CRIC) - Incremental Citation Impact (Δk)

These derived indicators attempt more nuanced quality measurement but have limited generalizability. Complex quantitative approaches to determining paper

quality face inherent limitations, and qualitative judgment by the academic community remains most authoritative.

(3) h-index composite indicators: The h-index, proposed by J.E. Hirsch in 2005, combines quantity and quality [61]. Variants used in collaboration studies include: - GIFCOL (Gain in Impact through Foreign Collaboration): measures dual effects on quantity and quality [36, 39] - Index of Foreign Collaboration (IoFC) and Index of Evenness of Collaboration (IoEC) [39]

3.3 Main Analytical Methods

Three main methodological approaches are used:

3.3.1 Bibliometric Methods The most common approach, particularly citation analysis, uses mathematical and statistical methods to analyze citation relationships, measuring citation age, quantity, and country patterns to assess paper impact [38, 45].

3.3.2 Social Network Analysis This integrated mathematical/statistical/graph-theoretic approach treats collaboration entities as networks. Metrics like centrality (degree, betweenness, closeness), density, and clustering coefficient characterize network structures and their relationship with performance [42-44, 54].

3.3.3 Statistical Analysis Methods Most frequently used for exploring collaboration-performance relationships:

(1) Descriptive statistics: Simple quantitative analysis without complex calculations [57, 60]. For example, Zhu Shiqin et al. used expectations and frequency ratios to show that international collaboration papers at East China University of Science and Technology far outperformed domestic and non-collaborative papers [63].

(2) Hypothesis testing: Includes t-tests, Mann-Whitney U tests, Kruskal-Wallis H tests, chi-square tests, and ANOVA to examine significant differences. For instance, Wang Junjing used t-tests and chi-square tests to compare citations and uncited rates between international and non-international papers [55].

(3) Correlation analysis: Measures relationships between variables. Spearman correlation reveals relationships between collaboration indicators (ICI, ICR, ICA) and performance metrics (P, C, IF) [42, 50, 51].

(4) Regression analysis: Determines specific forms and causal relationships, including linear regression [9, 17, 35, 54, 66], tobit regression [50], logistic regression [67], and negative binomial regression [37, 44, 52]. Wang Wenping built models for impact factor (linear) and citations (negative binomial) to analyze effects of partner influence, China-US collaboration scale, corresponding author country, and funding [20].

(5) Self-built models: Custom models for specific research needs. Examples include non-overlapping generations models (NOLG) for European universities [68-69], cross-lagged panel models [70], and power-law models showing Matthew effects in Cuban science (international collaboration papers exhibit stronger citation advantage) [71].

4. Conclusions and Future Directions

This review examined literature from three dimensions: research level, indicators, and methods. Current findings show:

(1) Analysis levels: Macro- and meso-level studies dominate, while micro-level (scientist-level) analysis is weak. Studies focus on co-authorship due to measurability. Future research should strengthen scientist-level studies and expand to diverse collaboration behaviors (patents, projects, exchanges, platform construction, conferences). The challenge lies in quantifying non-co-authorship collaborations. Comparative analysis of different collaboration behaviors' impacts on performance is needed.

(2) Indicators: Many studies use single collaboration indicators, though indicators may interact. Results from isolated factors may differ from comprehensive analyses. Performance indicators often measure only direct benefits, with some using quantity and others quality, providing incomplete assessment. Future research should explore comprehensive indicators, examining interaction effects among collaboration indicators and comparing multiple performance metrics rather than single measures.

(3) Methods: Traditional statistical methods dominate, with relatively few modeling approaches. Future studies should develop targeted analytical models controlling for important variables such as inherent research influence of countries, institutions, fields, and authors, as well as collaboration scale.

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Chen Xiujuan: Collected, organized, and analyzed research materials; drafted and revised the manuscript.
Zhang Zhiqiang: Proposed the research idea; participated in manuscript revision.

A Review of the Impact of International Collaboration on Research Performance

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Abstract: [Purpose/significance] Research collaboration is a collaborative research work between different scientific research subjects on specific scientific issues to achieve complementary advantages. International research collaboration is of great significance to promoting research performance. Understanding the current research status of the impact of international research collaboration on research performance will provide reference for future research in this area. [Method/process] Based on the definition of international research collaboration and research performance, this paper analyzes the literature on the impact of international research collaboration on research performance from three dimensions: research level, analysis indicators, and analysis methods. [Result/conclusion] The analysis shows that the current research field is rich in results. Domestic and foreign scholars mainly analyze the impact of international research collaboration on research performance at three levels: macro (country, region, etc.), meso (field, institution, team, etc.), and micro (individual researchers). They use simple counting and single-ratio indicators for international research collaboration, as well as quantity-based, quality-based, and h-index composite indicators for research performance, employing bibliometric methods, social network analysis, and statistical analysis. Future research needs to strengthen: (1) scientist-level studies and broaden the analysis of more research collaboration behaviors; (2) exploration of comprehensive indicators characterizing both collaboration and performance; and (3) creation of targeted analysis models while controlling for important variables.

Keywords: International research collaboration; Research performance; Research productivity; Output quantity; Output quality

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