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Collaboration Trend and its Impact on the Research Productivity in Computer Science Research

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Abstract: *Apart from a few bibliometric studies of limited scope, the Pakistani scientific system is a scantily researched area requiring large-scale empirical evidence-based studies. This study aims to explore various features of collaboration in research and its impact on the performance of computer scientists in Pakistan. Over 15,494 SCOPUS-indexed publications in the area of computer science for the period 1997 to 2017, having at least one Pakistani author, were analyzed. The findings of the study disclosed the important role of collaboration in the citation count of the publications. International collaborative works and the more countries in collaboration significantly impacted the number of citations. The study's findings revealed that collaborative publications are more frequently cited and considered of high quality. This study is the first large-scale quantitative analysis of research collaboration, represented by co-authorship in computer science research in Pakistan.*

Key Words: Research Collaboration, Computer Science, Citation Analysis, Scientometric Analysis, Research Performance, Pakistan.

Introduction

Collaboration in research is an important research strategy involving the participation of two or more researchers to carry out and publish research. It has dominated high-impact research in all disciplines (Bozeman et al., 2013; Wuchty et al., 2007). This domination has been more visible in science & engineering, where collaborative work comprises more than 60% of total scientific research (Cantner

& Rake, 2014; Khan et al., 2016). Shrum et al. (2007), in a study of publications in science and engineering, have found that the number of researchers from more than one institution increased from one-third in 1981 to more than half in 1995. Similarly, publications having authors from multiple disciplines also increased from 20% to 25% in the same period.

This rise in collaboration in research has been

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A much-discussed topic among researchers of various disciplines, including biomedical engineering, scientometrics, mathematics, physics, biotechnology, computer science, and sociology (Bornmann, 2017; Hou et al., 2008; Igljč et al., 2017; Newman 2001a, 2001b, 2001c). The rise in collaboration has been associated with certain benefits and advantages over solo research endeavors. Previous studies have proved that collaboration in research has resulted in many benefits. These benefits include higher-level knowledge and resource sharing, better opportunities for funding, increased visibility and citations, improved quantity and impact of research, decreased risks and possible errors, expanded scope of research areas, and resolving complex social problems (Abramo et al., 2011; Aldieri et al., 2018; Bukvova, 2010; Eniayejuni, 2018; Lee & Bozeman, 2005; Puuska et al., 2014).

Co-authorship in research publications is a substantial and widely used proxy of research collaboration. Many inadequacies have been identified in the literature regarding the representation of research collaboration through co-authorship (Kahn, 2018). Some of these inadequacies included that not all the collaborations came up with publications; similarly, not all contributors became authors in a publication. Sometimes a person might be incorporated as an author for honorary purposes, whereas researchers sometimes include each other's names as co-authors without any actual contribution (Laudel, 2002). Despite all these shortcomings, co-authorship has been the most widely used measure of research collaboration. Digital footprints of research collaboration in the form of research publications are successfully traced and evaluated for collaboration analysis (Acedo et al., 2006; Newman, 2001a).

Due to substantial growth and expansion in scope, computer Science has become one of the most attractive research areas worldwide during the last few decades. Advances in computational technologies have done this, and other disciplines have become more computerized and data-oriented than ever. As a result, numerous academics, research organizations, universities, and funding agencies are

focusing more to foster research in the area of science (Hoonlor, Szymanski, & Zaki, 2013).

The government of Pakistan has followed the policies of supporting international collaboration. This has been done with the belief that these collaborations are helpful for the researchers, institutions, and the country. Some of these initiatives include the "Pakistan Program for Collaborative Research, Pak-France PERIDOT Research Program, and Social Integration Outreach Program" (Sabah et al., 2018). The dearth of information about collaboration and its possible benefits creates doubts about the success of these collaborations. Therefore, there appears to be a need for a study to describe the status of collaboration and its possible benefits in computer science research in Pakistan.

This paper is the first large-scale quantitative analysis of research collaboration, represented by co-authorship in computer science research in Pakistan, using data from the SCOPUS database. The study findings are an essential source of information about the collaboration patterns in computer science research in Pakistan for the last two decades and form a benchmark from which future collaboration trends can be gauged.

Research Questions

- a. What are the collaboration patterns of computer science research in Pakistan?
- b. Does the presence of collaboration in research has a corresponding effect on the citation count of papers?
- c. What are the differences between the citation counts for publications produced through various types of collaboration?

Literature Review and Hypotheses Development

Many previous studies on co-authorship have investigated the impact of collaboration in research on the productivity of the researchers. Wuchty et al. (2007) analyzed a large dataset comprising of millions of articles and patents in all subject fields for five decades. They found that publications through collaboration have increasingly dominated the

production of knowledge compared to solo authorship. Collaborated publications are more frequently cited, and the trend has continued with time, even in the fields previously dominated by solo authorship. The study found an increase in collaboration in the field of social sciences (17.5% in 1995 to 51.5 % in 2000) compared to sciences & engineering (50% to over 80%).

Kumar and Jan (2013) used regression analysis to examine if collaboration for publishing papers impacts total publications. The annual percentage of co-authored publications (the independent X variable) was measured to examine the impact of collaboration on the annual publication count (dependent Y variable). The findings showed that collaboration had no impact on the number of publications. Lee and Bozeman (2005) used correlation to measure publications' standard and fractional count. They found that collaboration has only a significant association with a standard number of publications and not on a fractional number. They calculated the fractional count by dividing each paper by the number of collaborators. Many other studies have shown a positive association between collaboration and the number of publications (Chuan-Yi & Chen, 2017; Sooryamoorthy, 2009).

H0 1: Co-authorship has no significant effect on the total publications of researchers

In a study of research collaboration in South Africa, Sooryamoorthy (2009) used the t-test to compare the citations of single-authored publications with co-authorship publications. Results clearly showed that collaborative publications are more frequently cited than solo publications. Shehatta and Mahmood (2016) also used an independent sample t-test to compare the citation difference between single-authored publications with collaborated papers. Results showed a significant difference at $p < 0.01$ in the citation of collaborated papers from single-authored papers.

H0 2: No citation difference exists between solo and collaborated publications.

Papers with international collaboration received more citations than papers written with local collaboration. (Abbasi et al. 2012; Annalingam et al.

2014; Antoniou et al. 2015; Frenken et al. 2009; Kumar and Jan 2013). Annalingam et al. (2014) used linear regression analysis with the number of internationally collaborated articles as the independent variable and the citation count of these publications as a dependent variable. The finding revealed that papers with international collaboration received considerably higher citations compared to papers with local collaboration.

H0 3: International collaborative publications do not get more citations than locally collaborative publications.

Previous literature showed a positive association between the team size and the number of citations of these papers (Abramo & D'Angelo, 2015; Wuchty et al., 2007). Annalingam et al. (2014) used linear regression analysis having citation count as the dependent variable and mean authors per publication as an independent variable. The number of authors had a significant impact (<0.001 p-value) on the number of citations received by these publications.

Ahmed et al. (2016) applied One-way ANOVA followed by Tukey post hoc to compare the number of citations for each group of co-authors (single author, two authors, three authors, etc.). The difference in citation count of one to four authored articles varied significantly. More precisely, four authors' papers received significantly fewer citations than one and two authored papers. Whereas the citation count of three authored articles was more than four authored papers, but the difference was not significant with a value of ($P=0.058$).

H0 4: There is no significant difference between the author's team size and the citation count of papers.

Sooryamoorthy (2017) used an independent sample t-test to compare the citation score of within organization and external collaboration and the results showed a statistically significant citation difference between internal institutional and external institutional collaboration. Abbasi and Altmann (2011) used a multiple regression model analysis to see the collaboration type's impact (external institutional/intra-organizational). They

used logarithmically transformed citation rates as the dependent variable. The findings exhibited that papers on inter-organizational collaboration received significantly more citations than papers produced through collaboration within one organization.

H0 5: There is no difference in the citation count for publications through intra vs inter-organizational collaboration.

Abbasi et al. (2012) employed logistic regression to explore the effect of the income category of countries on the citation count of papers. The odds ratio (OR) was used to test how every variable and every level inside that variable had an impact on the course and degree of variations in the dependent variable. An OR larger than 1 implies that publications with that characteristic have a higher probability of getting more citations than the reference group. Results showed that publications from countries with medium-level income (OR=0.54) had less probability to get more citations than high-income countries. Moreover, countries with low income also had lower OR as compared to high-income counterparts, although this variation was not statistically significant.

H0 6: There is no difference in the number of citations of internationally collaborated papers based on the income group of the authors' countries.

Design of the Study

The study used scientometric analysis of the publication data. Scientometrics analysis mainly focuses on studying the quantitative aspect of science, has established its position as an independent research area, and has emerged as an independent research field with clearly defined boundaries, well-elaborated sets of research methods and procedures, a substantial number of practitioners, institutions, research conferences and research journals (Ivancheva, L. 2008). Publications in computer science with at least one author from Pakistan, indexed in SCOPUS for the period 1997 to 2017, were used to analyze the patterns of collaboration. The following search query was used

to extract records from SCOPUS.

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AFFILCOUNTRY (Pakistan) AND SUBJAREA  
(COMP) AND PUBYEAR > 1996 AND  
PUBYEAR < 2018.
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A total of 15,494 publications along with their citations were retrieved against the query. The type of publications were books, research articles, conference papers, book chapters, editorials, errata, letters, reviews, and short surveys. The conference papers were the largest number of publication types with 9581 counts, followed by journal articles with 5355 counts. Each record from the SCOPUS database contained the title, authors, affiliation, address, year of publication, citations, and other details. A total of 17 errata were not included in the further analysis as these are corrections or retractions of a previously published paper.

Various aspects of collaborative works were obtained through calculations through Microsoft Excel formulas. These statistics included the number of authors per paper, the number of organizations, and the countries in collaboration. Similarly, the type of collaboration (local or international) and income category of the author's countries were determined. Summarized publication data was exported to SPSS for further processing.

Results and Discussion

The primary aim of the research was to examine various attributes of collaboration and their impact on the research performance of scholars. The study's findings revealed phenomenal growth in collaboration and a strong relationship between the various types of collaboration and the research performance of the researchers in Pakistan.

Collaboration in Computer Science Papers: Figure 1 shows an increase in the collaboration in computer science research publications from 81.48% collaborated papers in 1997 to 97.37 % in 2017. The total publication count increased from 27 total publications in 1997 to 2849 papers in 2017. Figure 1 shows that co-authored publications increased from 2003 and showed a rapid rise during the last years.

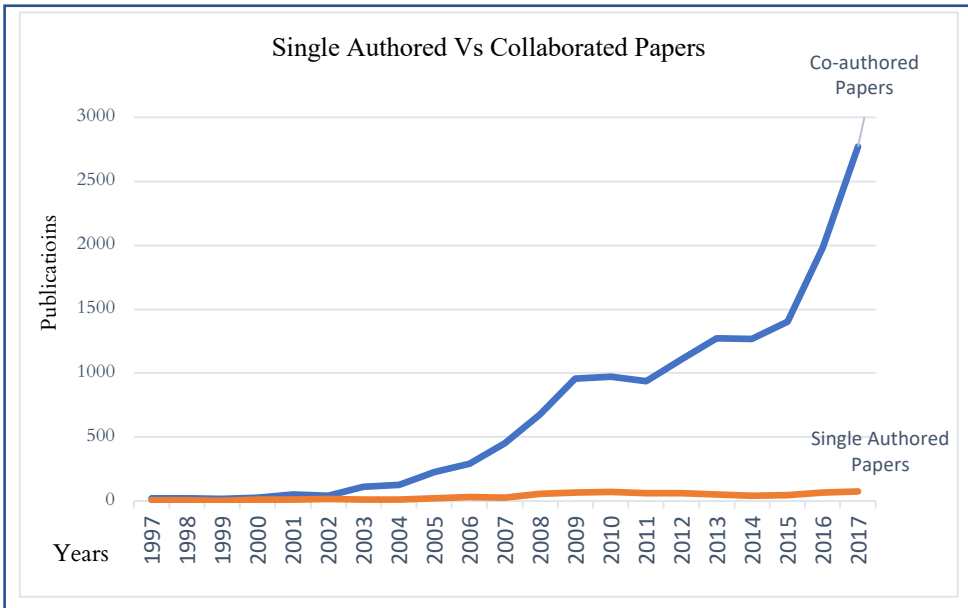


Figure 1: Comparison of Single Authored and Collaborated Publications

The increase in team size is also confirmed by the average number of authors per publication raised from 2.73 per paper in 1997 to 4.09 in 2017. The

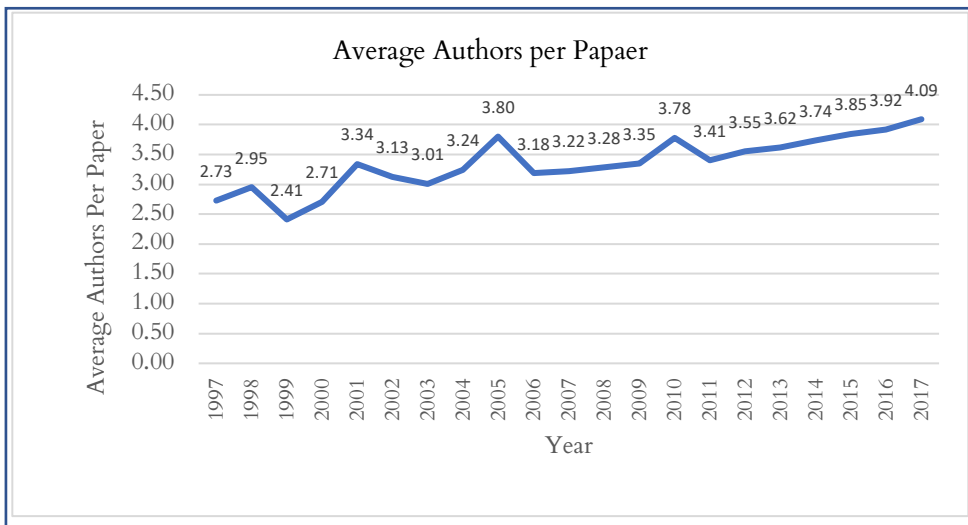


Figure 2: Increase in Team Size in Collaboration

Local vs International Collaboration: Figure 3 shows an increase in the number of international collaborations during the second decade, and publications with international collaborations

increased, whereas local collaboration was dominant in the first decade. Collaborations involving at least one author from outside Pakistan are considered international collaboration.

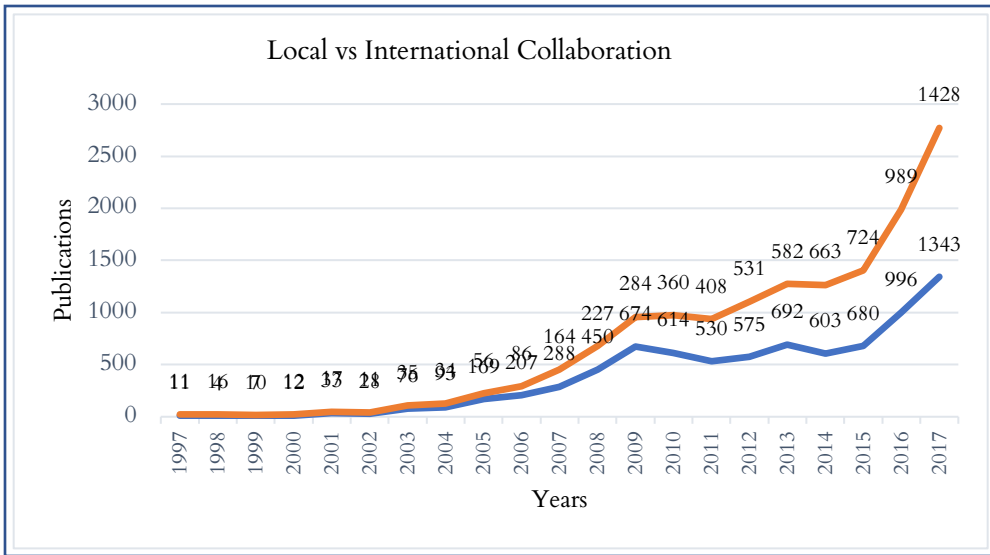


Figure 3: Comparison of Local & International Collaborations

Citation Count for Publication Based on the Team Size: Figure 4 graphically presents the citation count of papers as per the team size involved from 1997-2017; it illustrates an increased number of citations for publications involving a larger number of

authors. The largest team, with 5 and more authors in collaboration produced the most frequently cited works, followed by research teams with 4 and 3 authors.

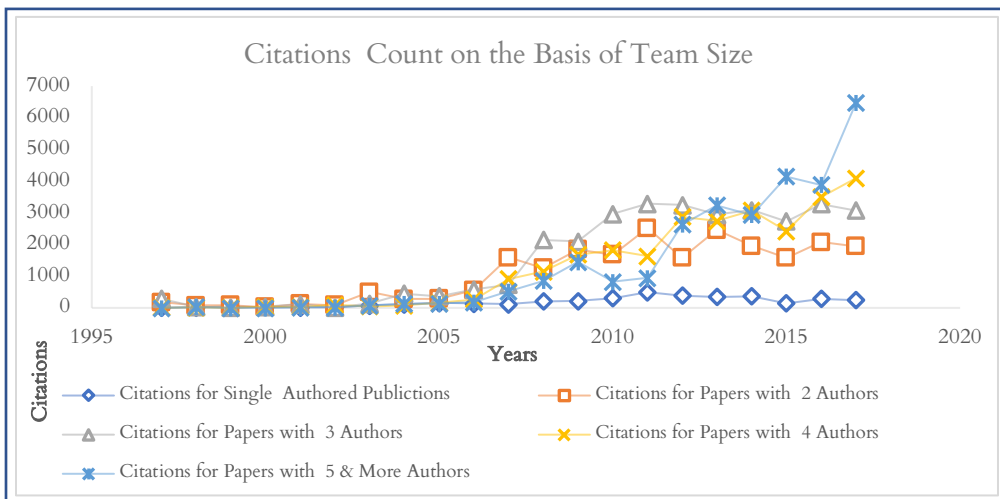


Figure 4: Citation Count of Papers for Number of Authors in Collaboration

Testing of Hypothesis

The relationships between publication and citation count with collaboration were explored by using inferential statistics.

Table 1. Relationship of Collaboration/Types with Citation Count

Variables	Mean	Statistics	Sig.
Single Authored Papers	5.04	t = -4.602	.000**
Collaborated Papers	7.42		
Local Collaboration	5.15	t = -15.137	.000**
International Collaboration	10.19		
Intra Organization Collaboration	4.74	t = 12.206	.000**
Inter-Organization Collaboration	8.78		
Rich Countries	1.00	F = 1.702	.164
Upper Medium Income	9.08		
Lower Medium Income	9.03		
Low Income	10.52		

*Significant at $p < .05$, **Significant at $p < .001$

Citation for Single Authored Vs Collaborated Papers:

An Independent sample t-test was employed to compare the citation count of single-authored papers with the collaborated papers. The findings of the t-test exhibited (Table 1) a statistically significant variation in the citation count of single-authored papers (M=5.04, SD=13.413) and collaborated papers (M=7.42, SD=19.019). The t value of 4.602 and p-value of .000 rejected our null hypothesis and collaborated publications received significantly more citations than solo publications. Previous studies by Sooryamoorthy (2009) in South Africa and Shehatta and Mahmood (2016) in Saudi Arabia found similar findings of collaborated publications yielding more citations than solo-authored papers.

Impact of Collaboration on Publications: The annual percentage of collaborated papers was tested for impact on the publication count per year. The

results of linear regression analysis showed a correlation coefficient β -value 59.355 and a P-value of 0.001 (Table 2.), which rejects our null hypothesis that collaboration in research does not have any impact on the publication count produced. The results exhibited a strong impact of the percentage of collaborated publications on total annual publications. The results approve the findings of previous studies, which show a positive relationship between collaboration and the publication count (Chuan-yi & Chen, 2017; Lee & Bozeman, 2005; Sooryamoorthy, 2009). However, some studies have shown contradicting results and showed no effect of collaboration on the number of publications of researchers (Kumar & Jan, 2013; Lee & Bozeman, 2005). In the further analysis of these contradicting results, it was noted that the study of Kumar & Jan, (2013) was based on the analysis of only 160 research papers having Malaysian authors in the area of Business and Management area.

Table 2. Regression Analysis for Impact of Collaboration Types on Citation

Variables	β	Sig.
Percentage of Collaborated Papers	59.355	.001**
Total Annual Publications		
Team Size	.165	.000**
Citation Count		

**Significant at $p < .001$

Local vs International Collaboration: An independent sample t-test was employed to

compare the citation count of publications having international authors with locally collaborated

publications. The findings of the t-test revealed, as shown in Table 1, that number of citations for international collaboration is statistically different, with local collaboration having a Mean of 5.15 with a Standard Deviation of 11.97, whereas the mean value of citations for international collaborative work is 10.19 and the Standard Deviation is 25.091. The p-value .000 rejects our null hypothesis and internationally collaborative works received more citations than locally collaborative works in computer science research. This finding is also in accordance with the previous studies of (Abbasi et al., 2012; Annalingam et al., 2014; Antoniou et al., 2015; Frenken et al., 2009; Kumar & Jan, 2013). Most of the studies showing increased productivity or citation for international collaboration are from developing countries, whereas the U.S based study of Lee & Bozeman, (2005) showed no impact of collaboration on the performance of the scholars. It shows that international collaboration might be more advantageous for developing countries like Pakistan compare to developed countries.

Impact of Authors' Team Size on Citation Count:

Linear regression analysis was used to test the impact of the authors' team size (independent variables) in collaboration on the citation count (dependent variable) of collaborated papers. The results showed (Table 2) an F value of 14.448, β value of .165, and P-value of .000, showing considerable effects of the team size on the citation count of collaborated papers. The hypothesis was rejected, and the number of authors significantly impacted the citation count. The result supported the findings of (Abramo & D'Angelo, 2015; Wuchty et al., 2007).

Intra vs Inter-Organizational Collaboration: An independent sample t-test was conducted to compare the citation count of publications produced through collaboration within organizations and collaboration involving more than one organization. The study's results showed a significant variation in the number of a citation for publications involving intra-organization collaboration (M=4.74, SD=10.357) and inter-organization collaboration (M=8.78, SD=22.016), t

= 12.206. The significant P value of .000 showed that inter-organization collaboration significantly impacted the citation count compared to collaboration within an organization. The finding rejects our null hypothesis and showed significant variation in the citation count of papers based on intra and inter-organization collaboration. The result was in harmony with the findings of the previous studies of Sooryamoorthy (2017) and Altmann (2011), which showed a significant variation in the citation count of intra and inter-organizational collaboration.

Citation Difference on the Basis of Country's Economic Group:

One Way ANOVA test was used to compare the citation count of internationally collaborated papers based on the income categories of the author's country. The World Bank has divided the world's economies into four income groups: rich, upper-middle, lower-middle, and poor (The World Bank, 2019). The results shown in Table 1 showed a p-value of .164 showed no significant difference in the mean citation between groups. Multiple comparisons also show no significant difference between the citations of publications from different income groups. Thus the hypothesis is accepted, and no difference was found between citation counts of papers involving authors from countries of various income groups. The test result contradicted the findings of Abbasi et al. (2012), which showed that the collaboration with high-income countries yielded more citations than publications involving middle and low-income countries.

Conclusion

The study was conducted to investigate the collaboration trends in the area of computer science research in Pakistan. The study also explores the impact of various collaboration strategies on the research performance of scholars in Pakistan's computer science research field. The analysis was based on the publication data retrieved from the SCOPUS database from 1997 to 2017.

The findings of the study revealed the exponential growth in the total publications in the area of computer science research in Pakistan

during the second decade from 2008 to 2017. The publication counts for the year 1997 was 27, which was raised to 2846 in 2017. The trend of collaboration also showed a rapid rise as the number of collaborated publications increased from 81.48 % of total publications in 1997 to 97.36% of total publications in 2017.

Collaborative research in computer science in Pakistan is more prevalent and beneficial as the number of publications and citations involving collaboration is rising. On the contrary, the economic conditions of the authors' countries had no impact on the citation count of that paper. The study's findings revealed that collaborative publications are more frequently cited and considered of high quality. Thus, there is a strong need for more organized collaboration efforts at all levels.

The study will enrich the body of knowledge in the area of co-authorship analysis in Pakistan. Analysis of collaboration networks has not only provided an understanding of the collaboration network but has also shown the impact of the collaboration on the publication output of the researchers in Pakistan. The study will have significant policy and research contributions at various levels. It will provide useful information for computer scientists in Pakistan to make an informed choice for selecting co-authors for their publications. At the institutional level, the study will provide an analysis of the research performance of the researcher of these institutions through their collaboration activities and the impact of these collaborations on the quality and quantity of research publications.

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