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RESEARCH ARTICLE

Publication Output and Citation Impact Indicators for Bibliometric Analysis of Research Publications of Pakistan

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Abstract

This study presents the publication output of Pakistan in the mainstream scientific literature for the seventeen-years-period 1996-2012. It analyses Pakistan's publication activity in terms of global share, share of international collaborative publications, and visibility & citation impact. This study also covers year-wise scientific output of Pakistan along with the discipline-specific publications and citations. Pakistan's performance has also been compared with top 14 Islamic countries. A set of bibliometric and impact indicators is used to analyze activity and impact patterns in publication output of Pakistan. This set comprises (1) publication output indicators such as activity index, transformative index and relative specialization index (2) citation impact indicators like relative impact index, attractivity index and publication effective index (3) collaboration indicators e. g; international collaborative index and affinity index. This bibliometric analysis showed that the volume of Pakistan's publications has increased markedly in recent years. It also showed that although the impact of Pakistan's publication output is below international values, it compare favourably among some of the top Islamic countries. The paper reveals that value of activity index for all fields of science except Earth Sciences and Engineering are more than world average and have increased during two block periods. This increase in activity reveals that the Pakistani Scientists are becoming more active and their productivity has increased as compared to world activity. The attractivity index for eight fields is more than world average. Similarly, international collaborative index for eight fields is more than world average reflects higher collaborative effort than the national average.

Introduction

Research in science and social science sectors play an important role in the country's communal and economic growth along with long-term sustainable development. Considering the rising significance of research in economic growth of a nation, many countries are reducing dependency on their natural resources and swiftly moving towards knowledge-based economy. Investment in research is important for the progress in science and technology as well as for social and economic development. In the present knowledge-based economy, the rising costs of research and the tight restrictions in funding call for more efficient systems of resource allocation. To this end, many countries have begun to impose national exercises in research evaluation. Hence, research is now evaluated via indicators concerning the input as well as the output where bibliometrics is the corner stone. It is a means for situating a country in relation to the world, an institution in relation to a country, and even individual scientists in relation to their own communities. By providing new information, bibliometrics can be an aid to decision-making and research management. To recognize and quantify the progress of research, bibliometric indicators are essential tools to understand the size, growth and global spread of research. Bibliometric indicators are frequently practiced to measure the scientific productivity, visibility and capacity of research publications with global science. These

indicators are mainly based on the number of scientific research documents (research papers) published and global citations received (cited by other researchers). Bibliometric indicators quantify the quantity, quality of research output and there are structural indicators as well which assess the association between authors, publications and areas of research in universal science.
In the United States of America, the National Science Foundation uses bibliometrics to monitor the health of American science and technology on a continuous basis; in Europe, the European Commission uses similar approaches to monitor the health of the European innovation system and the Organisation for Economic Cooperation and Development uses indicators for monitoring and comparative purposes. Similarly, following the example of Braun et al., a number of research articles that are published annually assess research systems, disciplines and relationships in the research system. Recently, Schmoch and Schubert investigated the possibility of substituting peer review with bibliometrics in order to alleviate the difficulties of peer reviews. The uses of bibliometrics are wide and expanding.

Objectives of the Study

The present study aims to analyze the publication output of Pakistan and other top Islamic countries with the application of bibliometric indicators. The key objectives of the study are as follows:

- To analyze research publications growth and share in global research output;
- To examine the impact of the research output using different impact indicators (Absolute Citation Impact and Relative Citation Impact);
- To study the breakdown of research publications and citations by field of science;
- To identify the most productive fields of research (Activity Index, Transformative Activity Index, Relative Specialization Index).
- To detect the fields with greatest visibility(Attractivity Index, Relative Impact Index, Publication Effective Index)
- To find out the share of international research collaboration and to discover the countries involved in research collaboration with Pakistan (International Collaborative Index, Affinity Index)

Materials and Methods

Scientific research usually culminates in the scientific writing leading to research publications published in scientific journals. The information that describes each scientific publication is registered in large bibliographic databases. A bibliographic database is primarily an information tool for researchers that can also be used to elaborate scientific indicators on countries, institutions, disciplines. Several database such as the Thomson-Reuter Institute of Scientific Information/Web of Science database (ISI), Scholar Google, Publish or Perish and Scopus offer bibliometric parameters such as number of publications (e.g; productivity) to total citations (e.g; total impact) by each author as well as by affiliation or key word. Data for the period 1996–2012 used for the present study was extracted from the scientometric tool SCImago Journal & Country Rank (SJCR, available at http://www.scimagojr.com), created by the SCImago Research Group, a Spanish research team belonging to the Institute of Goods and Public Policies (IPP-CSIC). SJCR offer a wide range of scientometric indicators, very useful for scientific and technological researchers and decision-makers.
This paper is structured as follows: section 2 describes the bibliometric indicators used to measure the results of publication output of Pakistan. Section 3 carried out bibliometric analysis of research output of Pakistan. Finally, section 4 presents the conclusions and recommendations.

Biblimetrics and Bliometric Indictors

Bibliometrics

Bibliometrics is usually defined as the application of mathematical and statistical methods to the entire scientific literature, books and documents included (Pritchard, 1969). It has become a generic term for a range of approaches directed at quantifying output levels, collaboration patterns and impact characteristics of scientific research (OECD, 1997). Bibliometric studies become more and more good tool to evaluate the scientific power of research institutions

and countries. This quantitative analysis may be used as indicator of scientific productivity to judge the research horizontally for different disciplines and vertically between institutions or countries. Essentially, bibliometrics is the application of quantitative analysis and statistics to publications such as journal articles and their accompanying citation counts. Quantitative evaluation of publication and citation data is now used in almost all nations around the globe with a sizeable science enterprise. Bibliometrics has become a standard tool of science policy and research management in the last decades. All significant compilations of science indicators heavily rely on publication and citation statistics and other, more sophisticated bibliometric techniques. In addition, many extensive bibliometric studies of important science fields appeared during the last two decades. Aim of these studies was to measure national research performance in the international context or to describe the development of a science field with the help of bibliometric means (for instance, Braun et al., 1987).

For these reasons and others, nations with significant science enterprises have embraced bibliometrics. Today, bibliometrics programs with large teams of analysts are firmly established in many nations, and these groups issue bibliometric reports, often called science indicators studies, at regular intervals. A few such groups are the National Science Foundation (United States); the European commission; France's l'observatoire des sciences et des techniques (OST); and Japan's National Institute for Informatics (NII), National Institute for Science and Technology policy (NISTEP), and Ministry of Economy, Trade and Industry (METI). Other nations with active bibliometrics groups include Argentina, Australia, Belgium, Brazil, Chile, china, Finland, France, Germany, Israel, Italy, the Netherlands, New Zealand, Norway, Portugal, South Africa, South Korea, Spain, Sweden, Switzerland, and Taiwan. In almost all cases, the publication and citation data of Thomson Reuters form the basis of their bibliometric analyses. Bibliometrics is a set of methods to quantitatively analyse scientific and technological literature (Bellis 2009). Citation analysis and content analysis are commonly used bibliometric methods. In fact, many research fields use bibliometric methods to explore the impact of their field, the impact of a set of researchers, or the impact of a particular paper. Bibliometrics are now used in quantitative research assessment exercises of academic output which is starting to threaten practice based research (Henderson et al. 2009).

Bibliometric Indicators

Indicators are generally used in making systematic comparison of scientific output and assess the status of S&T across institutions and geographical regions/countries. They provide quantitative basis to measure the "health of science" in a country, and its strengths and weaknesses on comparative basis. Two types of indicators, namely absolute and relative indicators are generally used for bibliometric analysis. Publications count, journals count, citations count, and institution count, etc. are the examples of absolute indicators. These are used frequently for bibliometric analysis. The count of scientific papers published in peer-reviewed journals provides an estimate of the volume of research activity and related knowledge generation. On the other hand, relative indicators, such as activity index (AI), and relative citation Index (RCI) are used to assess the strengths and weaknesses of a country or a region on relative basis. For example, activity index of a sector, e.g. R&D sector, in a particular subject field can be used to compare publication activity against average publication activity of the country, which is taken as the benchmark for comparing publications activity of various sectors. It can also be used to identify research priorities of different countries or regions within the country. Similarly, RCI can be used to compare citations impact of country's output and world's output in a particular subject field against a well-defined benchmark. It also helps to understand the strength of the country in various subjects. The various indicators used in the present study for measuring the publications and citations output of the country across disciplines, institutions, and geographical regions were as follows:

Publication output and Citation Impact Indicators

The basic output indicators used are number of published papers and their impact manifested as citations. For appraising the quality of scientific publications, in addition to the basic indicators (publications and citations) other performance indicators have been adopted by scientometricians. Important among are peer review, total or mean Impact Factor of source journals, Absolute Citation Impact (ACI) and Relative Citation Impact (RCI) and others. Presently performance indicators: Absolute Citation Impact and Relative Citation Impact are used for analysis. Presently, quantitative and qualitative analysis of research publications is being assessed based on various standardized scientometric indicators for the time period 1996–2012. For quantitative and qualitative evaluation of research output during 1996-2012, the raw data for publication counts and citation counts are drawn from SCOPUS database for the time span under study. From this raw data, the following scientometric indicators are computed for

charting research efforts of various countries and for extracting the trends along with cross comparison among nations.

Publication output Indicators

Activity Index (Al)

The activity index (Al) was introduced by Frame. It characterizes the relative research effort a country devotes to a given field F. Its definition is: A = [(the country's share in the world's publication output in the given field F)/ (the country's share in the world's publication output in all science fields)]. AI= 1 indicates that the country's relative effort in the given field corresponds precisely to the world average; AI> 1 indicates higher activity than the world average, and AI< 1 indicates lower than average effort dedicated to the field. The major advantage of using activity index over absolute count of publications is that it takes into account both the size of the institution as well as the size of the discipline.

Transformative Activity Index (TAI)

The transformative activity index (TAI) was suggested by Guan and Ma; as the absolute output of publications is confounded by the size of the country as well as the size of the specialty. TAI is a relative indicator and takes into consideration the effect of the size of the country as well as the size of the sub-domain. TAI is similar to activity index, first suggested by Frame and elaborated by Schubert and Braun. Mathematically, TAI = [(Ci/Co)/(Wi/Wo)] × 100. where Ci is the number of publications of the unit (particular country or institution) in the ith block, Co is the total number of publications of the unit during the period of study, Wi is the number of publications of all units in the ith block and Wo is the number of publications of all the units during the period of the study.

Relative Specialization Index (RSI)

National publication profiles can preferably be measured and visualised using the Relative Specialisation Index (RSI). This measure indicates whether a country has a relatively higher or lower share in world publications in a particular science field than its overall share in the world total (see REIST-2 1997), and is closely related to the Activity Index (AI) introduced by Frame (1977). The Activity Index is defined as: AI = [(the share of given field in the publications of the given country)/(the share of given field in the world total of publications)]. The RSI is then defined as: RSI= [(AI – 1)/ (AI + 1)]. RSI takes its values in the range [-1, 1]. It indicates whether a country has higher-than-average activity in a scientific field (RSI >1) or a lower-than-average activity (RSI <1). RSI = 0 reflects a completely balanced situation. It is important to note that RSI reflects a certain internal balance among the fields in the given country, i.e. positive RSI values must always be balanced by negative ones (no country can have its RSI values all positive or all negative). Furthermore, low values indicate homogenous distributions between the various research fields. A benchmark used for all research fields is RSI = 0, which corresponds to the world standard case.

Citation Impact Indicators

Attractivity Index (AAI)

The attractivity index (AAI) characterizes the relative impact of a country's publications in given research field as reflected by the citations they attract. Its definition is AAI = [(the country's share in citations attracted by publications in the given field F)/ (the country's share in citations attracted by publications in all science fields)]. AAI=1 indicates that the country's relative impact in the given field corresponds precisely to the world average; AAI >1 indicates higher than the average, AAI < 1 indicates lower than average relative impact.

Relative Impact Index

The relative impact index for a country (a region, or an institution) in the world is defined as the ratio of the world share of citations for that entity to its world share of publications. Relative impact index in discipline "i" = [(Citation world share of a country in discipline "i")/(Publication world share of a country in discipline "i")]. A relative impact

index of 1 in the discipline "i" implies that the visibility of the country's publications is equal to the average visibility of worldwide publications in that discipline. When the relative impact index is greater than 1, the country's visibility is better than the world average. When the relative impact index is less than 1 the country's visibility hasn't reached world average visibility in discipline "i".

Publication Effective Index (PEl)

The indicator is the ratio of the proportion of the impact (TNIMP%) to the proportion of the publications (TNP%), where, TNIMP% = (Total normalized impact for an institution or discipline / Total normalized impact)x 100 and TNP% = (Total publications output of an institution or discipline / Total publication output) x 100.The measure indicates whether the impact of publications of an institution or a discipline commensurate with the publication effort devoted to it. A value of PEl >1 indicates that the impact of publications is more than the research effort and vice versa.

Co-publications Indicators

This indicator measures interactions and scientific relationships between networks, teams, institutions and countries. A co-publication is the result of co-operation between representatives of each entity and each country taking part in a particular joint research programme. Such research forges links between the parties (scientists, laboratories, institutions, countries, etc.) that have worked together to produce a scientific paper. The total number of links instituted by particular participants can be defined, depicted and measured by co-authorship. Using an indicator of co-authorship, it is therefore possible to outline these relationships.

International Collaborative Index (ICI)

International Collaborative Index (ICI) was suggested by Grag and Padhi. ICI was calculated as ICI= [(Ii/Io)/(Io/Ioo)] *100. Where Ii = number of internationally co-authored papers in a particular block of year. Iio = total output in that particular block. Io = total number of internationally co- authored papers. Ioo = total Pakistan's output.

Affinity Index

The indicator used to evaluate the relative rate of scientific exchanges between one country (A) and another (B), over a given period of time (and, if desired, in a specific area of science), and in relation to all international co-operation between these same two countries over the same period, is called the "affinity index". The formula for computing the affinity index is as follows: [COP(A−B)/COP (A− WD)] x 100. Where COP (A-B) represents the number of scientific links (co-operation) between A and B and COP (A-WD) is the number of co-operative links between A and the world. This indicator measures not only the links between countries, but also their equilibrium level, i.e. the "balance of power" underlying the flows; it shows the strongest areas as well as the weakest. The higher the share of co-publications of country A with country B (comprised between 0 and 100%), the more the country B can be considered as a scientific partner of country A.

Analysis

Publication output and Citation Impact of Pakistan and other productive Islamic Countries

This analysis focused on the output of Pakistan's growing research effort. Various indicators have been used to assess the growth and impact of Pakistan's science in relation to other productive Islamic countries. We also analyzed collaboration patterns among Pakistani scientists across the borders of the countries. A basic measure of scientific output is the number of publications. Citations for these publications are the best available measure of research quality often referred to as citation impact. For appraising the quality of scientific publications, in addition to the basic indicators (publications and citations) other performance indicators Absolute Citation Impact and Relative Impact are used for analysis. To compare Pakistan's research output with other Islamic countries, the present study analyzed the 17 years combined publication and citation data of top 10 Islamic countries during 1996-

2012. Research publications of Pakistan and other Islamic countries, their percentage of world share and relative growth rate are presented in [Table 1] and citations attracted are shown in [Table 2].

Table 1 Publication Output of Pakistan and other productive Islamic Countries

	Rank	Publication output			World share of Publications			Relative Growth 1996-2003
Country		**1996-2003**	**2004-2012**	**1996-2012**	**1996-2003**	**2004-2012**	**1996-2012**	**2004-2012**
Turkey	20	68654	238272	306926	0.68	1.28	1.96	247
Iran	25	14961	187846	202807	0.13	0.96	1.09	1156
Malaysia	40	10322	88865	99187	0.15	0.34	0.58	761
Egypt	42	24153	65336	89489	0.24	0.45	0.60	171
S.Arabia	45	15303	43537	58840	0.15	0.22	0.37	184
Pakistan	46	9610	48523	58133	0.09	0.25	0.34	405
Nigeria	51	8596	32356	40952	0.09	0.17	0.26	276
Tunisia	52	6408	31926	38334	0.06	0.17	0.23	398
Morocco	55	8905	18348	27253	0.09	0.10	0.18	106
Algeria	57	4102	21612	25714	0.04	0.11	0.15	427

Publication profile of Pakistan and other productive Islamic Countries

Total Publications

Publication profile is an indicator of the scientific activity of a country. The research publications are major or most significant indicator of productivity. The productivity of any country's research can be measured by using various bibliometric techniques like year-wise growth and distributions, relative growth rate and collaboration. This section aims to review the trends in publication activity in Pakistan and other most productive Islamic countries. The analysis presents both absolute and relative indicators to characterize the trends and enable comparisons between the countries. Present study spans a duration of 17 years, 1996-2012. Total publication activity is calculated for two blocks, 1996-2003 and 2004-2012. From [Table 1] a clear rise in publication activity for all countries during the 17-year period has been seen. During this period, top 10 Islamic countries have contributed 947635 research papers. The publication output is highly skewed with two countries namely Turkey and Iran, each contributed more than 20%. Four countries each contributed share between 5 and 10 % and all remaining countries contributing less than 5%. Turkey, beyond any doubt Islamic world's biggest scientific power has contributed 32.39% in total output of 10 most productive Islamic countries. Next most productive country is Iran with 20.40% share. The three most productive countries (Turkey, Iran and Malaysia) together contributed 64.26% of the total publication of top 10 Islamic countries. Pakistan's share is 6.13 %.

World share of publications

The world share of publications is defined as the number of publications of a country (a region, or an institution) divided by the number of worldwide publications, expressed as a percentage (%). It is the easiest comparable production indicator. The higher the value of this share (between 0 and 100%), the more active is the country in its world scientific production. The world publications share of top 10 productive Islamic countries for two blocks 1996-2003 and 2004-2012 is presented in [Table 1]. Islamic country's relative share of world publications has increased markedly during the last period. Iran has witnessed a phenomenal increase in world share of publication at 638.45%, whereas Tunisia has 183.33% increase in world share, followed by Pakistan with 177.78% increase, Algeria 175.00% and Malaysia 126.67%. All other countries have less than 100% increase in world share of publications. Pakistan ranks 6th amongst the top 10 productive Islamic countries in research publications, with its global publications share of 0.34% as computed from cumulative world publications data for 1996-2012 and global rank of 46th. The share of publications from Pakistan has increased considerably during the last 10 years. In fact

177.78% increase in share is to be considered as a significant rise in the relative contribution to world science. Top three countries Turkey, Iran and Malaysia account for more than 64% of publications. In overall, the global publication shares of the top 10 productive Islamic countries in research publications from 1996-2012 ranged from 0.15% to 1.96%. Turkey tops the list with its global publication share of 1.06% during 1996-2012 and global publication rank of 20th, followed by Iran (1.09%) with global rank of 25th, Egypt (0.60%) with 42nd global publication rank, Malaysia (0.58%) with 40th world rank, Saudi Arabia world share of 0.37% and global rank of 45th and followed far behind are Nigeria, Tunisia, Morocco and Algeria (their publication share ranging 0.15 % to 0.26%).

Relative growth in publications

Table 1 indicates the relative growth in publication activity. The top 10 Islamic countries differ significantly in their publication growth rate as seen from their publications output data during 1996-2012. Pakistan achieved growth rate of 405% from 1996-2003 to 2004-2012. Iran has markedly increased its relative growth in productivity during the last period. Iran showed the growth rate of 1156% from 1996-2003 to 2004-12, the highest amongst top 10 Islamic countries, followed by Malaysia (761%), Algeria (427%), Tunisia (398%). The growth rate of Turkey, Egypt, Saudi Arabia, Nigeria and Morocco is less than 300% [Table 1].

Relative Citation Impact of Pakistan and other productive Islamic countries

The present study assesses quality and impact of published literature by the metric of citations with the help of certain standardized indicators. A wide range of indicators are available in the literature to assess the impact of the research output. To compare the performance based on the scientific activity of countries and institutions two relative indicators of impact are adopted. These are Citation per publication (CPP); and Relative Citation Impact (RCI). Citation per Publication (CPP) is a relative indicator computed as the average number of citation per publication, also called Absolute Citations (ACI). This indicator has been widely used in bibliometric analysis as it normalizes the large disparity in volumes of literature published by different countries for a meaningful comparison of research influence. Another relative indicator that measures both the influence and visibility of a nation's research in global perspective is Relative Citation Impact (RCI). It is defined as the ratio of country's share of world citations to the country's share of world publications (C%/P%). RCI =1 indicates that country's citation rate equal to world citation rate. RCI < 1 indicates a country's citation rate less than world citation rate and also implies that the research efforts are higher than its impact. RCI > 1 indicates a country's higher citation rate than world's citation rate and also imply high impact research in that country.

Table 2 Citation Impact of Pakistan and other productive Islamic countries

	Citations			World share of Citations			Absolute citation impact	Relative citation impact
Country	**1996-2003**	**2004-2012**	**1996-2012**	**1996-2003**	**2004-2012**	**1996-2012**		
Turkey	780009	1155422	1935431	0.45	0.97	0.66	6.31	0.61
Iran	180146	652065	832211	0.10	0.55	0.28	4.10	0.40
Malaysia	11917	237747	356918	0.01	0.20	0.12	3.60	0.35
Egypt	244462	273634	518096	0.14	0.23	0.18	5.79	0.57
S.Arabia	148319	145237	293556	0.09	0.12	0.10	4.99	0.48
Pakistan	77581	166377	243958	0.04	0.14	0.08	4.20	0.42
Nigeria	75074	98928	174002	0.04	0.08	0.06	4.25	0.42
Tunisia	60505	109476	169981	0.03	0.09	0.06	4.43	0.45
Morocco	85994	71225	157219	0.05	0.06	0.05	5.77	0.54
Algeria	36851	69094	105945	0.02	0.06	0.04	4.12	0.41

World Share of Citations

The world share of citations is defined as the sum of citations received by the publications of a country (a region, or an institution) divided by the total number of citations received worldwide, during a given period. The higher the value of the world share of citations for a country (comprised between 0 and 100%) the more visible the publications

of that country in the worldwide scientific production. The citations received by the papers published by each Islamic country during two blocks 1996-2003 and 2004-2012 are given in [Table 2]. Islamic countries have shown a marked increase in the world share of citations. Malaysia's world share of citation has increased 20 times during 2004-2012 compared to 1996-2003, followed by Iran with 450% increase. When we compare the citations received in the first block 1996-2003 with the second block's 2004-2012, Pakistan showed a significant increase in world share of citations at 250%.

Absolute Citation Impact and Relative Citation Impact

In terms of research impact as reflected in absolute citation impact (ACI), Turkey tops the list with citation impact of 6.31 during 1996-2012, indicating the publication of highly cited papers in the Muslim world, followed by Egypt (5.79) at second position and, Morocco (5.77) at 3rd position. The ACI for all other countries except Malaysia is between 4.10 and 4.47. Malaysia has the lowest ACI at 3.60. For all Islamic countries, the value of relative citation impact (RCI) is less than world average, which indicates that the papers published by these countries are poorly cited in the international literature and for them it may be surmised that the research efforts are higher than their visibility and impact. In terms of impact and quality, the absolute citation impact registered by Pakistan's publication output during 1996-2012 was 4.20. Compared to Pakistan, Turkey, Egypt and Morocco registered much higher citation impact during the same period as can be seen from [Table 2].

Table 3 International Collaborative Publications of Pakistan and other productive Islamic Countries

	Number of International Collaborative Publications			% International Collaborative Publications		
Country	**1996-2003**	**2004-2012**	**1996-2012**	**1996-2003**	**2004-2012**	**1996-2012**
Turkey	10901	41072	41072	15.88	17.24	13.38
Iran	3653	34949	38602	24.42	18.61	19.03
Malaysia	3940	28446	32386	38.17	32.01	32.65
Egypt	7054	25673	32727	29.21	39.29	36.57
S.Arabia	4156	23962	28118	27.16	55.04	47.79
Pakistan	2586	15792	18378	26.91	32.55	31.61
Nigeria	2552	7199	9751	29.69	22.25	23.81
Tunisia	2534	13860	16394	39.54	43.41	42.77
Morocco	4646	9156	13802	52.17	49.90	50.64
Algeria	2274	11523	13797	55.44	53.32	53.66

International Collaboration in Pakistan's Publication Output

The share of international co-publications of a country, used to estimate its level of internationalisation, is defined as the total number of international co-publications of that country divided by its total number of publications. The higher the share of international co-publications for a country (comprised between 0 and 100%), the more the country cooperates internationally. Based on the publications' data, the total cumulative collaborative papers of Pakistan during 1996-2012 consisted of 18378 papers, which accounted for a share of 31.61%. Compared to Pakistan, Malaysia's international collaborative papers' share in its cumulative publications' output during 1996-2012 was 32.65% (with 32386 collaborative papers), followed by Egypt with a 36.57% share (with 32727 collaborative papers). Morocco and Algeria have more than 50% international collaborative papers, while Saudi Arabia and Tunisia have more than 40% international share. Pakistan witnessed a substantial increase in the share of its international collaborative papers from 26.91% during 1999-03 to 19.7032.55% during 2004-12. Compared to Pakistan, the international collaborative publications' share of Egypt has increased from 29.21% to 39.29%. Saudi Arabia has doubled its international share from 27.16% in 1996-2003 to 55.04 % in 2004-2012, while Tunisia's share increased from 39.54% to 43.41% during the same period. The share of international collaborative papers for all other countries has decreased during the period under study.

Pakistan's Publication Output Profile

The performance of Pakistan is judged and compared on the basis of various quantitative indicators: (a) size of scientific activity measured by volume of production in various types of publications during the period of study, (b) authorship pattern and collaboration of scientific activity measured by co-authorship and the amount of national and international collaboration, and (c) impact of scientific activity measured by the numbers of citations given and citations received during the period of study. These bibliometric techniques constitute a relatively objective indicator for measuring discourse popularity (Ponzi & Michael, 2003). According to the work of Abrahamson (1991, 1996) and Abrahamson & Fairchild (1999), the bibliometric technique of article counting is a reliable approach to beginning an analysis of published literature in order to illuminate and trace the development of a concept**.**

Table 4 Pakistan's Publication output Profile

Year	Publications	Citations	CPP	%ICP	ICP	%World	%Growth	%Total
1996	887	6738	7.60	33.82	300	0.08	-	1.52
1997	987	7978	8.08	32.22	318	0.08	11.27	1.69
1998	1111	9494	8.55	29.88	332	0.10	12.56	1.91
1999	1161	9401	8.10	27.48	319	0.10	4.50	1.99
2000	1146	9197	8.03	25.04	287	0.10	-0.01	1.97
2001	1292	9737	7.54	20.36	263	0.10	12.74	2.22
2002	1427	10218	7.16	2011	287	0.10	10.45	2.45
2003	1599	14818	9.27	30.02	480	0.11	12.05	2.75
2004	1941	16381	8.44	28.44	552	0.12	21.39	3.33
2005	2720	18343	6.74	25.81	702	0.15	40.13	4.67
2006	3389	21249	6.27	29.33	994	0.18	24.60	5.82
2007	4054	25369	6.26	31.06	1259	0.21	19.62	6.97
2008	4949	27756	5.61	32.05	1586	0.24	22.08	8.51
2009	6189	23861	3.86	29.79	1844	0.29	25.06	10.64
2010	7318	18604	2.54	32.41	2372	0.32	18.24	12.58
2011	8723	11734	1.35	33.81	2949	0.36	22.70	15.00
2012	9240	3080	0.33	38.25	3534	0.38	5.93	15.89

The Pakistan's research output, its impact in terms of average citation per paper and the percentage share of international collaborative papers during the 17 years from 1996 to 2012 is presented in [Table 4]. It shows year-wise break-up of papers along with number of contributions that varies year to year. In the year 2012, the highest number of 9240 (15.89%) papers were published and in the year 1996, minimum of 887 (1.53%) were published. The cumulative research output consists of 58133 papers during 1996-2012, with an average number of 3420 papers per year, rising from 887 papers in 1996 to 9240 papers in 2012, showing an annual growth rate of 55.39%. This cumulative Pakistan's publications output received 243958 citations, registering an average of 4.20 citations per paper. The share of international collaborative output accounted for 31.61% share (18378 collaborative papers) in the cumulative research output of Pakistan's during 1996-2012.

Pakistan's Publication output by Field of Science

This section aims to break down the overall publication activity of Pakistan into main subject areas to characterize country's research profile. The count of scientific publications in certain fields of research shows the emergence of national strength in particular areas. Field-wise publications for two blocks 1996-2003 and 2004-2012 along with world share of publications and international collaborative papers are given in [Table 5]. The analysis of data indicates that medicine is by far the largest research field for Pakistan, with around one fifth of all publications belonging to this subject area. Further, Agricultural and Biological Sciences is undoubtedly the second largest research field for Pakistan. Together medicine and Agricultural and Biological Sciences account for 38.76% of the publications. Physics constitutes 9.10% of Pakistan's publications for the period, which makes it the third largest research area in Pakistan when measured in publication output. At a more detailed level [Table 5] also shows that the shares of publications for Biochemistry and Chemistry are somewhat larger compared to remaining fields of

research. The combined publications of 5 major fields is about two-third of the total publications output of Pakistan. Analysis of research output in the context of different subjects revealed that All subject fields witnessed an increase in their world publications share from 1996-2003 to 2004-2012 [Table 5].Share of Biochemistry and Mathematics has increased 500%, followed by Physics with 277.78% increase in world publications. World publication share in all other subjects has increased between 100 and 200%.

Table 5 Pakistan's Publication output by Field of Science

	Publication output			World Share of Publication			International Collaborative Publication		
Field	**1996-2003**	**2004-2012**	**1996-2012**	**1996-2003**	**2004-2012**	**1996-2012**	**1996-2003**	**2004-2012**	**1996-2012**
Agricultural	1641	7833	9474	0.23	0.63	o.40	512	212	2624
Biochemistry	527	4506	5033	0.04	0.24	0.16	280	2282	2562
Chemistry	1199	4062	5261	0.17	0.35	0.28	276	1489	1765
Earth Sci	204	678	882	0.05	0.10	0.08	215	1473	1688
Engineering	753	3383	4136	0.06	0.16	0.12	138	446	584
Microbiology	270	1091	1361	0.08	0.21	0.16	139	484	623
Mathematics	179	2435	2614	0.05	0.31	0.24	107	1300	1407
Medicine	3482	13057	16539	0.12	0.28	0.22	501	2590	3091
Toxicology	301	1313	1614	0.11	0.28	0.21	107	450	557
Physics	691	4602	5293	0.09	0.34	0.25	333	2589	2922

Citation Impact of Pakistan's Publication output by Field of Science

The quantity and quality of publications by a country indicates its contribution towards scientific development. The significant and visibility of published scientific articles is usually evaluated by the number of citations the article receives in the years following publication. The number of citations can be seen as a direct measure of the resonance or impact that a publication has on the scientific community. Average citations per articles by an institution or a country assess the visibility of these articles.

Table 6 Citation Impact of Pakistan's Publication output by Field of Science

	Citations			World Share			Absolute Citation Impact		
Field	**1996-2003**	**2004-2012**	**1996-2012**	**1996-2003**	**2004-2012**	**1996-2012**	**1996-2003**	**2004-2012**	**1996-2012**
Agricultural	14386	28350	42736	0.11	0.31	0.19	8.77	3.62	4.51
Biochemistry	10326	21675	32001	0.03	0.09	0.05	19.59	4.81	6.36
Chemistry	8943	16803	25746	0.06	0.14	0.10	7.46	4.14	4.89
Earth Sci	3086	3522	6608	0.04	0.07	0.05	15.13	5.19	7.49
Engineering	3855	14695	18550	0.04	0.18	0.10	5.12	4.34	4.49
Microbiology	5555	9569	15124	0.05	0.15	0.09	20.57	8.77	11.11
Mathematics	1619	10217	11836	0.04	0.32	0.16	9.04	4.20	4.53
Medicine	22558	41825	64383	0.05	0.12	0.08	6.48	3.20	3.89
Toxicology	3753	7589	11342	0.08	0.20	0.13	12.47	5.78	7.03
Physics	7698	23144	30842	0.06	0.23	0.13	11.14	5.03	5.83
Total	81779	177389	259168	0.56	1.81	1.08	115.77	49.08	60.13

Considering the citation impact and quality, the research output under immunology and microbiology registered the highest impact of 11.11 citations per paper, followed by Earth Sciences (7.49%), pharmacology, toxicology and

pharmaceutics (7.03 citations per paper), Physics (5.83 citations per paper), biochemistry, genetics and molecular biology (6.63 citations per paper), medicine (2.85 citations per paper) and agricultural and biological sciences (1.44 citations per paper).

Pakistan's Publication Output and Impact Indicators by Field of Science

Publication output Indicators

Activity Index

The analysis by fields gives a more detailed insight in the national publication activity. The activity index is defined as the ratio of the country's share of the world publication output in a given field to the country's share of the world publication output in all science fields. An activity index of one indicates that the country's research output in the given field corresponds to the world average; an indicator larger than one reflects a higher than average emphasis in the field and vice versa. The value of one is taken as the index of the average activity in the country in the field. The value of AI above 1 indicates that the publications activity in the given field is above the country average. For example, in case the activity index for field is greater than 1, say , 1.31, it shows that activity index of the country in this particular field is 31% greater than the average publications activity. The values of activity index have been calculated for two periods 1996-2003 and 2004-2012 to examine the shift in emphasis during 2004-2012 compared to 1996-2003. The results of the activity index are given in [Table 7]. The activity index for all fields except Earth Sciences and Chemistry moved into the fields of revealed priorities that are over emphasised in the country (activity index above one). The country witnessed rise in activity index for all fields. The rise was very significant for agriculture and Biological Sciences and activity index for this field was 215% above the country average activity index during 2004-2012. Although in chemistry, the activity index was below the country's average during 1996-2003, but it rose 75% above index the country average activity index in the second block. During the corresponding period, the activity index for Physics rose 70% above the country's average activity index. In mathematics, the activity index for the country was below the country's average in 1996-2003, but rose 55% above the country's average activity index in 2004-2012. Whereas the activity index for Toxicology and Medicine were below the country's average during 1996-2003, but increased 40% above the country's average activity index for both fields 2004-2012. The activity index also showed increase in Earth Sciences and Engineering but were low productivity areas as their activity index were less than county's average activity index during 1996-2003 to 2004-2012.

Table 7 Activity Index, Relative Specialization index, Activity Transformative Index

	Activity Index		**Relative Specialization Index**		**Activity Transformative Index**	
Field	**1996-2003**	**2004-2012**	**1996-2003**	**2004-2012**	**1996-2003**	**2004-2012**
Agricultural	1.15	3.15	0.07	0.52	0.96	1.01
Biochemistry	0.2	1.2	-0.67	0.09	0.58	1.09
Chemistry	0.85	1.75	-0.08	0.27	1.27	0.94
Earth Sci	0.25	0.50	-0.60	-0.33	1.28	0.94
Engineering	0.30	0.80	-0.54	-0.11	1.01	1.0
Microbiology	0.40	1.05	-0.43	0.02	1.10	0.98
Mathematics	0.25	1.55	-0.60	0.22	0.38	1.14
Medicine	0.60	1.40	-0.25	0.17	1.17	0.96
Toxicology	0.55	1.40	-0.29	0.17	1.04	0.99
Physics	0.45	1.70	-0.38	0.26	0.73	1.06

Activity Transformative Index (AAI)

In order to study the change in output in the two blocks, use of Transformative Activity Index (TAI) suggested by Guan and Ma has been made. A glance at TAI for different fields indicates that the publication activity has

decreased considerably for Chemistry, Earth Sciences, Physics, Engineering, Microbiology, Medicine and Toxicology [Table 7]. In case of Chemistry and Earth Sciences, the decrease is the highest. For other fields there is an increase in the publication activity as reflected by the vales of TAI. The increase is highest for Mathematics followed by Biochemistry, Physics and Agricultural and Biological Sciences. The growth of research activity in Mathematics was outstanding. TAI of Mathematics increased from 0.38 during 1996-2003 to 1.14 during 2004-2012. Likewise, the TAI of Biochemistry has increased by 0.51 points.

Relative Specialization Index (RSI)

The publication output of Pakistan for various fields of science has been expressed by the Relative Specialization Index (RSI). This measure indicates whether a country has a relatively higher or lower share in world publications in a particular field of science than its overall share in world total publications. The Relative Specialization Index is defined as RSI = [(AI-1)/(AI+1)]. From its definition follows that RSI can take vales in the range [-1, 1]. RSI= -1 indicates a completely idle research field, RSI = 1 if the country is active in no other than the given field. RSI < 0 indicates a lower than average, RSI. 0 a higher than average activity; RSI =0 reflects a completely balanced, average situation. RSI = 0 for all fields corresponds to the world standard. RSI for various subject areas have been calculated [Table 7]. Pakistan has positive RSI values in all research fields studied here but are less than one. It indicates a low than average activity.

Citation Impact Indicators

Table 8 provides information about various impact indicators, such as relative impact index, attractivity index and publication effective index.

Table 8 Table Relative Impact, Index Attractivity, Index Publication Effective Index

	Relative Impact Index			Attractivity Index			Publication Effective Index		
	1996-2003	2004-2012	1996-2012	1996-2003	2004-2012	1996-2012	1996-2003	2004-2012	1996-2012
Agricultural	0.48	0.49	0.48	2.75	2.21	2.38	1.11	0.94	0.97
Biochemistry	0.75	0.38	0.31	0.75	0.64	0.63	0.95	0.47	0.49
Chemistry	0.35	0.22	0.36	1.5	1.0	1.25	0.83	0.81	0.91
Earth Sci	0.8	0.70	0.63	1.0	0.5	0.63	3.23	2.44	2.76
Engineering	0.67	1.13	0.83	1.0	1.29	1.25	0.88	1.52	1.65
Microbiology	0.63	0.71	0.56	1.25	1.07	1.13	3.07	3.32	2.71
Mathematics	0.80	1.03	0.67	1.0	2.29	2.0	3.74	3.11	2.96
Medicine	0.42	0.43	0.36	1.25	0.86	1.0	0.24	0.22	0.23
Toxicology	0.73	0.71	0.62	2.0	1.43	1.63	4.33	3.58	3.87
Physics	0.67	0.68	0.52	1.5	1.64	1.63	1.43	1.15	1.19
Total	6.3	6.48	5.34	14	12.93	13.53	19.81	17.56	17.74

Relative Impact Index

Table 8 shows the relative impact index (an indicator of research quality) of various fields for the periods 1996-2003 and 2004-2012. The values of RII have increased for all fields except Chemistry and Earth Sciences from 1996-2003 to 2004-2012. A relative impact index (RII) above one indicates that the country's publications in the particular field attract more than average citations and an index of less than one indicates that the field attracts fewer citations. The citation rates vary considerably. By far, the highest relative impact index is obtained in Engineering during 2004-2012. In this field the research publications are cited 13% more than the world average. In Mathematics the impact index is also above the average. The lowest citation rate is found in Chemistry. In this field the papers only obtained 22% of the world citation rate of the field. The RII are slightly higher in Toxicology, Microbiology and Earth

Sciences, but still significantly lower than world average and cited 30-35% below in the world average. in the field of Physics the articles are poorly cited.

Attractivity Index (AAI)

Attractivity profile of Pakistan has been examined by using Attractivity Index (AAI). Like the absolute publication output, the absolute impact is also confounded by the size of the country and size of the field. Hence, Attractivity Index, also suggested by Schubert and Braun has been used. AAI characterizes the relative impact, the publications of a country make in a given discipline as reflected by the citations they attract. AAI =1 indicates that country's citation impact in the given field corresponds precisely to the world's average, AAI > 1 reflects higher than average, and AAI < 1 lower than average. The values of AAI for different disciplines are given in [Table 8]. From the values of AAI given in [Table 8], it is observed that Agricultural and Biological Sciences has the highest value of AAI in 2004-2012. The value of AAI is also high for Mathematics during the same period. Similarly, like the AI, the highest values of AAI for all other fields are above the world average except Biochemistry and Earth Sciences as values of AAI can be seen from [Table 8].

Publication Effective Index (PEI)

Publication effective index indicates whether the impact of publications of a country as a discipline commensurate with the publication effort devoted to it. A value of PER>1 indicates that impact of publications is more than the research effort and vice versa. The values of PEI are highest for toxicology, Mathematics, Earth Sciences and Microbiology. Other fields for which the value of PEI>1 are Engineering and Physics [Table 8]. It implies that these fields earn more impact than that is commensurate with their publication effort. The values of PEI<1 for Agricultural and Biological Sciences, Chemistry, Medicine and Toxicology indicates that in these disciplines the impact of the research is not commensurate with the publication effort.

Co- Publications Indicators

This indicator measures interactions and scientific relationships between networks, reams, institutions and countries. A co-publication is the result of co-operation between representatives of each entity and each country taking part in a particular join research programme. Such research forges links between the parties (scientists, laboratories, institutions, countries, etc.) that have worked together to produce a scientific paper. The total number of links instituted by particular participants can be defined, depicted and measured by co-authorship. Using an indicator of co-authorship, it is therefore possible to outline these relationships. This indicator can identify the main partners in research endeavours and provide a description of scientific networks.

Table 9 International Collaborative Index (ICI)

	International Collaborative Publications			**International Collaborative Index**		
	1996-2003	**2004-2012**	**1996-2012**	**1996-2003**	**2004-2012**	**1996-2012**
Agricultural	512	2112	2624	1.02	0.88	0.9
Biochemistry	280	2282	2562	1.73	1.65	1.66
Chemistry	308	1457	1765	0.84	1.17	1.09
Earth Sci	215	1473	1688	0.93	1.42	1.33
Engineering	138	446	584	0.68	2.14	2.16
Microbiology	139	484	623	1.68	1.45	1.49
Mathematics	107	1300	1407	1.95	1.74	1.75
Medicine	501	2590	3091	0.47	0.65	0.61
Toxicology	107	450	557	1.16	1.12	1.12
Physics	333	2589	2922	1.57	1.83	1.8
Total	2640	15183	17823	12.03	14.05	13.91

International Collaborative Index

The duality of the co-authorship/co-operation relationship has long been discussed in the bibliometric literature (e.g., Katz and Martin 1997; Laudel 2002). At the level of individual authorship (Laudel) or at the institutional level (Katz and Martin), co-authorship does not depict research collaboration entirely, or might be distorted by scientists' multiple affiliations. Nonetheless, co-authorship proved a good proxy for 'higher-level' research collaboration between institutions, regions, and countries. Above all, international collaboration is usually well acknowledged in the published literature, and therefore a good indicator of co-operation at this level as well (Glänzel and Schubert 2004). The international collaborative index calculated for the block periods 1996-2003 and 2004-2012 is given in [Table 9]. The international collaborative index for Chemistry, Earth sciences, Engineering and Physics has increased from 1996-2003 to 2004-2012.

Affinity Index

Except quantitative and qualitative analysis of scientific output, the international collaboration analysis in S&T or simply co-publication analysis, another important facet of bibliometrics, has been discussed here. The co-publication activity of Pakistan with different countries for the period 1996-2012 is shown in [Table 10]. Pakistan's scientific research publication activity is heavily associated with international cooperation. The scientists in Pakistan co-authored publications with their colleagues mostly from the USA (23.61%), UK (20.23%) and the except these two heavy-weight research partners, the co-publications are growing with scientists from Germany (9.75%), China (9.02%), Canada (6.69%), Japan (5.62%), Saudi Arabia (5.44%) and South Korea (5.30%).

Table 10 Affinity Index

Country	No. of Collaborative papers			Affinity Index		
	2001-05	2006-10	2001-10	2001-05	2006-10	2001-10
USA	636	1607	2243	29.87	21.80	23.61
UK	518	1404	1922	24.33	19.04	20.23
Germany	211	715	926	9.91	9.70	9.75
China	78	779	857	3.66	10.57	9.02
Canada	147	489	636	6.90	6.63	6.69
Japan	159	375	534	7.47	5.09	5.62
Saudi Arabia	101	416	517	4.74	5.64	5.44
South Korea	68	436	504	3.19	5.91	5.30
India	86	300	386	4.04	4.07	4.06
Australia	87	277	364	4.09	3.76	3.83
others	38	575	613	7.79	6.79	6.45
Total	2129	7373	9502	100.00	100.00	100.00

Conclusions

It is concluded that Pakistan had published 58133 papers during 1996-20012and registered an average citation per paper of 4.20. The cumulative Pakistan's papers witnessed a growth rate of 55.39% for the papers from 1996-2003 to 2004-2012. Pakistan ranks 46th position with its global publication share of 0.34% and international collaborative publications share of 31.61%. To examine the quality of research irrespective of the volume, performance indicators Absolute Citation indicators Impact (ACI) and Relative Citation Impact (RCI) were adopted. Through these indicators it is construed that Pakistan with only 0.34% of world's output, is publishing low quality research attracting low citations with ACI of 4.20% and RCI of 0.42 which are well below world's average. The Pakistan's research output under different subjects shows that the highest research output was from medicine and Agricultural Sciences with 38.76% publications share in cumulative Pakistan's publications output during 1996-2012. In terms of

impact, the field of immunology and microbiology registered the highest citation impact of 11.11 citations per paper during the same period.

It is concluded that the existing Pakistan's research output is quite low in the global context as reflected from its total publication output and its world publication share. In addition, the impact and quality of Pakistan's research is low compared to that of Turkey, Egypt, Morocco and Saudi Arabia. Pakistan is far behind Turkey and Iran in terms of publication output, citation quality and share of international papers in publications. If Pakistan has to catch up these counties, it has to evolve strong and effective strategies to achieve higher publications growth rate. There is an urgent need for substantial increase in research and development investments. For catalyzing S&T activity, new programmes need to be initiated in the country to encourage greater institutional participation, grater collaboration in research at national and international level, attract young talent into science, organize in-service training of staff in creative and innovation ideas, and set up sophisticated instrument facilities for S&T education and research in the country.

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