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PUBLICATION PRODUCTIVITY, FOCUS ON INSTITUTIONAL, COLLABORATIVE AND COMMUNICATIONAL CORRELATES: A REVIEW OF LITERATURE

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ABSTRACT

Review studies on academic research assessment comprising: the counting of publication output, citation counts, weighting publications, peer ratings, recognition and multiple indicators. Also describes institutional correlates of publication productivity such as funding, library resources and electronic support. Studies on other correlates such as collaboration, information use and dissemination are also described.

Keywords: Publication productivity; Research output; Institutional correlates. Collaboration, Channels of communication; Information use; Dissemination of information; Weighting of publications; Citation counts; Peer rating.

ACADEMIC RESEARCH ASSESSMENT

The Quantity of Publication Output

Published literature have reported a number of studies that used the quantity of publication to assess research productivity. Blackburn, Behymer and Hall (1978) used total articles published over two years, total career publication and total book published from self-reported data to assess the productivity of 1,216 academic staff members from 4-year colleges and 7,484 staff from universities in the United States. The instrument used was the questionnaire. Publication data gathered from self-reported information was found to be a reliable indicator. Allison and Stewart (1974) found that self-reported response from chemists was correlated with publication counts obtained from *Chemical Abstracts* (r = .94). Braun, Glanzel and Schubert (1990) used publication data from the Corporate index files of the Science Citation Index (*SCI*) database for the period 1981-1985, to assess the publication productivity of authors from 10 major OECD countries. Budd (1995) addressed the level of publishing productivity of academic staff members from a number of universities for the years 1991 and 1993 who were also members of the Association of Research Libraries. The publication data was collected from the three citation indexes of the *SCI*. The universities were ranked by the number of publication and per capita publication achieved (total publication by number of academic staff).

Publication counts have not only been used to provide productivity counts but also used to assess research trends in certain disciplines. David, Piip and Haly (1981) used total number of publication counts in textile research to identify trends in specific areas of research and found a decline in basic research at the expense of applied textile research. Reskin (1977) studied a random sample of 238 academic chemists between 1955 and 1961 and found that 7.5% published nothing in the first decade following the receipt of their degree and 11% published 1 article. Although the average rate of publications achieved was low, the variations of publication productivity between the scientists were high (Blume and Sinclair, 1973). Lotka (1926) analysed papers published in physics journal and found the distribution of publication was highly skewed. This indicated that a small minority of scientists produced the bulk of the papers. Price (1963) who studied the growth of scientific literature, went on to generalize that 50% of scientific publications was produced by 6% of the scientific community and that the average scientists published about three papers in his lifetime. In another study, Bottle, et al (1994) compared publication counts produced by chemical professors, readers and senior lecturers in the United Kingdom and those in the United States (1981-1991) and found no significant difference in their publication productivity.

The counting of total or average publications achieved is therefore a common and popular method used to assess research productivity since it is easier to obtain such bibliographic data (Martin, 1996).

The Quality of Publication Output

To measure the quality of publication output is more difficult. Previous studies have attempted a variety of measures. These include citation counts, weighting given to types of output and peer ratings.

(a) Citation Counts

Citation counts are used to gauge the overall impact of a scientists' research output on the scientific community and is generally held to measure quality (Cole and Cole, 1967). An average citation per paper gives an indication of the aggregate level of influence, while highly cited papers reflect the more important contributions to the field. Hence, the importance of a particular paper for later development will influence the number of citations it generally will receive. Citation information is obtainable from the three citation databases produced by the Institute for Scientific Information (ISI), Philadelphia. The databases can be used to retrieve information on the number of citations to a particular paper for a period of years after its publication. The exact period varies from field to field, since the time lag between publication and the maximum number of citations received in a year differs between disciplines. Citation studies in basic research (chemistry, physics and biology) have shown that research institutions producing many papers tended to be more visible (more likely to be cited) than those publishing less (McAllister and Wagner, 1981). The evidence that citation indicates quality is indicated by a number of studies. Garfield (1970) studied the work of Nobel Laureate prize winners and found that they were among the top 0.1% most cited authors. Grynspan and DeMeis (1990) reported that great scientists were generally highly productive. Darwin wrote a total of 119 publications towards the end of his career, while Einstein and Freud wrote 248 and 330 respectively. Finkenstaedt and Fries (1978) found that citation counts correlate highly with other measures of quality such as employment in prestigious universities, listing in important bibliographies of scientists and receiving scientific awards and recognition from colleagues. Other studies have indicated a significant and positive correlation between peer rating of departments and institutions and the citation frequencies to works of their members (Anderson, Narin and McAllister, 1978; Lawani and Bayer, 1983).

A number of studies indicate the relationship between citations and total publications. Cole and Cole (1967) studied 120 eminent American physicists to ascertain the relationship between the quantity of publications and total citations obtained from the *SCI* database. The study found a correlation between the quality and quantity of the research published. The study further identified four types of scholars: (a) type 1, were prolific and achieved high scores for both quantity and quality; (b) type 2, were the mass contributors, publishing a large number of papers of little significance; (c) type 3, were the perfectionists, who published comparatively little but has considerable impact in the field; and (d) type 4, were the silent physicists, who published a few but highly significant papers. Type 1 and 2 were more likely to be those from top rated departments. This situation seems to be similar at the individual level. Zuckerman (1977) found that publication counts, citation counts and peer ratings were inter-correlated. The academic staff members who were prolific writers were also those, whose works were heavily cited and the citations were positively correlated to peer ratings. Lawani (1986) studied citations to reputable articles on cancer research and found that highly rated papers were also cited more. The relations between citation counts and expert ratings was also indicated by Korevaar and Moed (1996).They compared citation scores in the field of mathematics to the opinion of experts concerning the quality of the paper or a journal and concluded that experts' views on the top publications corresponded well to bibliometric indicators on citation counts.

Martin and Irvin (1983) and Martin (1996) indicated that counting citations did impose problems when used on its own and this was related to the shortcomings of the ISI databases. The databases list citations to multi-authored works only once under the first named author. This practice tended to penalise those whose work involved a great deal of collaboration. Also, individuals may be listed under more than one form of their name in the *SCI* and the database did not distinguish authors with the same forename and surname. There were cases where the paper was of high quality but was not cited because it was ahead of its time. Also, poor quality papers may also be frequently cited.

(b) Weighting Publications

A number of studies used weighting of the various types of publication to ascertain quality – that is, giving more weight to publications recognised to be of quality such as refereed types of scholarly publication (Harris, 1989). Glen and Villemez (1970) proposed that a weighting scheme must be discipline specific. The study assigned the following weights: research and theoretical monograph (30), textbooks (15), edited books (10), articles in journals (4-10, depending on the quality of the journal). Lightfield (1971) assigned the following weights to the different types of publication: article (1), edited book (1), and 1 per 100-page book. Linsky and Strauss (1975) combined quantity and quality by awarding points for different types of scholarly output. They assigned 1 for each article, 2 for edited book, 4 for jointly authored book and a 6 for a single-authored book and then added up the values. Finkensteadt and Fries (1978) used the following weights to twelve types of publication: monographs (50), co-author of monograph (40), journal article (10), co-author of journal article (8), editorship (10), co-editorship (8), school text (5), translation of a book (5), short paper (1), book review (1), and dissertation (20). In Indonesia, Wowurunto (1986a, 1986b) used a modified weighting system for his Indonesian publications: research reports (2), printed book (7), edited book (2), chapter in a book (2), article in international professional journal (5), article in Indonesian professional journal (3), publication in mass media (½), unpublished scholarly writing (2½), conference presentation (oral) (2½). This weighting scale was modified from those used by the Indonesian Ministry of Education (Indonesia, 1970). In the Indonesian official version, the ratings adopted were as follows: author of text book (4), co-author of text book (2), adaptation – adapter (2), co-adapter (1), translation (2), editor (2), author of syllabus (2), co-author of syllabus (1), doctoral thesis, cum lauda (25), thesis, non-cum lauda (20), author of scientific book (5-10), article in scientific journal (2-5), article in semi-scientific journal (2), masters thesis (5), research report (2), seminar papers, international level (3), national level (2), working paper, scientific lecture – international (5), national (2) and mass media publication (½). Weighting of publications has not been very widely used in studies on publication output assessment as indicated by the few reported studies in published literature using such indicators.

Peer Ratings

The focus here is on peer review of individual or the group's research performance. These are ratings of scientists' published works by their peers. Ratings reflect the worth of an individual's work. This is the most favoured method of evaluation among scientist (Lindsey, 1980; Martin, 1996). Harmon (1963) attempted to define the bases underlying quality judgement and found that publication quantity was the strongest predictor of evaluation used by the raters. Herring (1968) studied the quality of peer evaluation of published articles in physics. Chase (1970) examined the criteria underlying the quality judgements about scientific work. The study indicated that peer ratings were positively related to other indices of research quality. Hartnett, Clark and Baird (1978) compared data of ratings of the quality of doctoral programmes in chemistry, history and psychology by the Council of Graduates School United States with the ratings carried out by the American Council of Education (ACE) in 1964. The results of the ratings were found to be similar. Jones (1980) analysed raters' assessments of scholarship, and found a correlation between peer reviews and quantitative measures. The ratings were also correlated to other indices of quality (number of articles and book reviews, number of Ph.D. awards, student-faculty ratio). Anderson, Narin and McAllister (1978) found a strong association between the bibliometric measures (publications and citations for the years 1965-1973) with the Roose and Anderson (1970) ratings of 115 US universities. Rushton and Roediger (1978) found that the rankings for 180 psychology departments in Canada, United States and the United Kingdom and the *SCI* citation measures were positively correlated with measures such as journal publications. Four years later, Koenig (1982) observed a high correlation between expert judgement of research performance in pharmaceutical research with articles produced by the companies and citation data to the articles. Irvin (1989) found that peer judgement was strongly related with bibliometric data. Similar results were indicated by Nederhof and Raan (1993) who compared the bibliometric indicators (publications and citations) of six economics research groups with peer ratings. The study found that bibliometric data and peer ratings were complementary and mutually supportive. In a more recent study, Korevaar and Moed (1996) compared citation scores in the field of mathematics to expert opinions concerning the quality of selected papers. The articles that received high rating by experts also received significantly higher citation rate. The results indicated that experts' views on quality, and bibliometric indicators were related. Zhu, Meadows and Mason (1991), however, did not find significant differences between the publication and citation achievements of two chemical engineering departments that received different ratings by the University Funding Committee. Sonnert (1995) not only reviewed peer evaluation studies, but also described his study of six raters who were distinguished faculty members of the biology department from two prestigious universities in the northeast of the USA. The rater evaluated 42 biologists who received postdoctoral fellowship from NSF. Each rater received 42

CVs and bibliographies and evaluated them in private. The independent variables used were publication productivity (annual publication output and annual article output); journal impact score as reported by ISI's *Journal Citation Report* (those unscored but refereed were given a score of 0.10); authorship type (first author, last author); academic rank, and citation measures (annual rate of citations, and average article rate of citation). The study found that the annual publication and citation were strongly correlated with the quality ratings given by raters ($p<0.001$). The study identified the three most powerful predictors; and these were; (a) annual publication productivity; (b) the number of solo authored works and (c) the prestige of the graduate school.

There are problems associated with the use of peer ratings, however, since it is based on perception and the judgement of peers and may be flawed. It is also subjective as peers and colleagues may judge a piece of research differently. Political and social pressures may also affect judgements. Success, therefore, depended on the neutrality of peers (Creswell, 1985). Another problem is the inability of an eminent academic to have sufficient knowledge of all aspects of a researcher's work to make objective judgement (Gillett, 1989). Moed, et al. (1985a, 1985b) found that bibliometric indicators were not correlated to a national rating survey of Dutch chemistry and biology departments. The studies above therefore indicate that there are still contradictory findings regarding the usefulness of peer ratings as an indicator of research performance.

Other Measures of Research Productivity

(a) Recognition Indicators

This includes recognition accorded to scientists through conferment of medals, prizes, and awards. Studies indicated that bibliometric measures, peer ratings and awards were inter-correlated. Cole and Cole (1967) recommended the use of a combination of several indicators such as research and development expenditure, personnel statistics, technological and trade figures. Myers (1970) found that citation output and publication counts were correlated with awards and listings in *Modern men of science*. Clark (1957) studied American psychologists and found correlation between bibliometric output, awards and positions among eminent psychologist.

(b) Multiple Indicators

A number of strategies have been put forward to achieve a more effective and reliable assessment of research output. One of the most discussed in literature was the use of "converging partial indicators" suggested by Martin and Irvin (1981, 1983); Irvin and Martin (1983), and Martin (1996). It is suggested that, since all quantitative measures are only partial indicators, a convergent of various measures should be employed. The researchers have successfully applied these measures in assessing productivity in the fields of radio astronomy observatories, large optical telescopes and electron accelerators. The study proposed the incorporation of the following elements when assessing scientific performance: (a) applying the indicators to research groups rather than individual scientists; (b) using the indicators based on citations to ascertain the impact rather than the quality or importance of research; (3) applying a range of indicators, each focusing on different aspects of a group's performance; and (4) applying the indicators to equally matched groups. Because of the imperfect nature of the indicators only those cases which yield convergent results can be assumed to influence performance. Indicators used include publication per researcher, citation per paper, numbers of highly cited papers and peer evaluation.

At about the same time, research on assessment measures was active at the University of Leiden (Moed and Raan, 1988). The Leiden study presented their micro-scale research performance measurements using quantitative and bibliometric indicators, and experimented its application to the faculties of mathematics, natural sciences and medicine at the University of Leiden. Data used were international publications and citations to these publications. Two concepts played a central role; (a) scientific production or output measured by the number and types of publications; and (b) number of citations received by publications within a period of time (Raan, 1989). Distinctions were made between short-term impact (citation for three years) and long term impact. The study discovered that the second year after publication is the top year for receiving citations, but this again depended on the field under study. For the three disciplines, the number of publications per year was collected for the period 1970 and 1987 and the number of citations received by these publications in the first three years after publication. The number of citation to publications of a research group was compared with the average citation scores of the journals in which the group publish.

The majority of studies of research productivity assessment therefore used a combination of indicators. Hagstrom (1971) used several indicators to assess the outputs of 125 science departments of mathematics, physics, chemistry and biology. These included department size, number of research articles, citations to articles, ease of obtaining information, quality of Ph.D., mean time allocated to research, mean number of researchers and number of post doctoral fellows. Arunachalam and Garg (1985) used both productivity and citation counts to assess Singapore's performance in world's scientific research. The study indicated that Singapore's contribution was mainly in medical research and most works were seldom cited. Zachos (1989, 1991) used publication and citation counts to evaluate the performance of two mathematics departments in Greece. Similarly, Zhang (1995, 1996) also used publication and citation counts to analyse the research performance of key medical universities in China. Zhu, Meadows and Mason (1991) compared the University Funding Committee's (UFC) ratings of two British chemical engineering departments with publications and citation data from the *SCI* database. One of the departments was graded 2 and the other 4, by the UFC. Contrary to other findings that found correlation between bibliometric measures and ratings, the study found no differences between the departments' performance in terms of number of citations and publications.

Bieber and Blackburn (1993) applied the constant units of measure to assess research productivity. The economic concept of real or constant units of measure was used to assess the rate of inflation or deflation of opportunity for publication between 1972 and 1988 for the disciplines of biology, psychology and English. The *Ulrich's International Periodical's Directory* and *Annual Bibliography of the English Language and Literature* were used to determine the level of supply of articles for these disciplines. The basic strategy was to identify a sample in which at least 20% of the contributions comprised US contributions, which gave an estimated total usable journal. For each subject 30 journals were picked. The level of demand for space was estimated by multiplying the average department size as determined, by the sample of total institutions within each discipline. The average number of publications for two years was collected. The results indicated that an inflation rate of 103% is needed for biology, 85% for psychology and 45% for English. It was estimated that academic staff members had to produce 14.65 publications for biology, 5.05 for psychology and 1.18 for English in the two years prior to 1988 to be rated as productive in real articles as they were in the two years prior to1972. Herbstein (1993) investigated the publication output of a university chemistry department in Israel. The indicators used were total publication, total citation, total co-authorship pattern (self-citation is subtracted) and the length of the publication. The results obtained were skewed, that is a few members (less than 20%) produced more than half the publications and received more than half of the citations of the group as a whole. The use of indicators such as the length of pages of articles published by academics from a department, the joint authorship pattern (located within the same department or outside) was also used by Johnes (1988) when surveying the research output of the economics departments in British universities. Cozens (1995) disclosed recent developments in research assessment in the United States. At the institutional level, stress was put on peer expert assessment, bibliometric measures (which includes patent counts) and customer satisfaction ratings. In the United States, all agencies are required to set quantitative performance targets and report annually on their progress. Fonseca et al (1997) concentrated on identifying the influencing factors of highly productive Brazilian scientists. Indicators used were scientists' total numbers of published papers and sum impact of the journals in which the articles are published. These two scores were plotted along the years of each scientist's career.

The use of multiple indicators in the assessment of basic research was aptly summarised by Martin (1996) who surveyed the methods used by articles submitted to 12 issues of *Scientometrics* (volumes 31-34) between 1994 and 1995 compared with articles published in another 12 issues in the same journal between 1988 and

1989. Martin found that the most common indicator used was publication counts (60%, 72 out of 121 papers), followed by citation counts (32%, 38). Academics who were approached, favoured peer review (86%), publication counts (64%) and weighting publications (70%) according to the status of the journals in which they appear. Overall, the majority favoured a combined approach. Martin suggested that publication and citation counts continue to be popular because it is comparatively cheaper to carry out than the peer review process.

Published literature have, therefore, indicated the use of a variety of measures to assess scientific performance. However, the two major indicators are based on publication and citation counts. Most of the studies take the form of raw counts or averages while some have devised weighting schemes to enhance both raw publication and citation counts. A major strength of these quantitative measures of scientific quality is their reliability, and their weakness lies in their validity (do they really measure what they intend to measure?). However, since publication is the standard way of communicating research findings, it is widely considered an appropriate measurable instrument of a scientist's performance (Sonnert, 1995).

Previous studies which related personal, academic and departmental correlates and publication productivity was dealt with by Zainab (1999). A further analysis of published literature has indicated other possible correlates. These are institutional-related correlates, and correlates related to the collaborative and communication behaviour of academic researchers. Descriptions of literature on such studies follow.

INSTITUTIONAL CORRELATES OF PRODUCTIVITY

Institutional correlates within the academic context refer to support provided by university management. These include funding for equipment and material; adequate library resources and electronic support. These supports are exogenous in nature, that is, they are beyond the control of the individual academic staff. As a result previous researchers have focused mainly on academic staffs perception of the adequacy of institutional support available to them for research and related this to their achieved publication productivity.

(a) Financial Support

Funding is considered an important determinant of research productivity. Implicit in the research fund allocation process is the assumption that bigger funding would results in higher productivity. The adequacy of funds is also regarded as an important issue. Folger and Gordon (1962) and Salisbury (1980) found a positive relationship between adequate amounts of financial support for research and publication productivity. As early as 1970, the UK Science Research Council expressed the need to support research more selectively given its limited resources (Johnston, 1994). Institutions have used different guidelines for funding and they basically fall into three criteria (Wakefield, 1978): (a) Impact of the research – findings of the research project are expected to have impact nationally and form the basis for further research; (b) Existing knowledge gap in the research area – research is undertaken to fill gaps which may arise because of little work in the area of research or previous findings have been inconclusive; and (c) Researchable area – judgements is made on the quality of the proposal as well as the likelihood that the research would advance knowledge, based on the qualification of the researchers, the soundness of the design, and the potential asset. In relation to grants, Warner, Lewis and Gregorio (1981) found that social scientists have not fallen behind the natural scientists in the mean number of grants received. However, the amount of grants received has resulted in greater article productivity for the natural scientists. In the same year, MacAllister and Wagner (1981) in their US sample found a positive and linear relationship between research and development expenditures and the number of papers published in journals.

Rushton and Meltzer (1981) compared the publication counts of 169 universities in Britain, Canada and the United States with institutional correlates such as revenue of the university, age of the university, number of journal subscriptions, the number of bound volumes in the library, the number of both graduate and postgraduate students. The study concluded that revenue was a principal factor, as from the number of millions of dollars the university earns, it was possible to predict all other variables. The US sample showed a correlation between the number of publications by faculty members and the university's income. In an earlier study, Meltzer (1956) indicated that the adequacy of funds must be accompanied by the freedom of its use in research organizations. Freedom was the extra boost, which provided sufficient impetus for faculty to be more productive.

In an Australian study of factors influencing research performance of academic staff, funding was regarded as extremely important, especially for scientists (Woods, 1990). A particular problem was the increasing difficulty of justifying some applications in terms of support for technical, secretarial and computer facilities. A related concern was not being able to attract and retain high calibre technical and research assistance. The choice of research topic became increasingly influenced by the opportunity to attract outside funding. Liebert (1977) raised similar claims that funds were needed to get costly equipment and to cover travelling expenses.

Johnston (1994) surveyed research productivity studies and found strong evidence from the existing literature that the scale and continuity of funding helped higher-level research activity, especially in areas strategically targeted with a higher risk but promised greater achievements. He concluded that large, well-funded, well-led research groups produced more publications of higher impact and received higher international recognition than smaller groups. In a study of 50 highly productive scientists, Fonseca (1997) found that material conditions such as adequate facilities and sufficient funds to purchase chemicals, helped improve publication productivity.

Financial awards are often allocated based on previous research income accrued by the researcher and are peer reviewed. Hartmann and Neidhardt (1990) and Gillett (1991) outlined the pitfalls in assessing research performance based on grant income achieved by a researcher. They pointed out that income based measures were deficient for the following reasons: (a) total research income did not measure output (it was an input measure) and such measure would award scores for those who obtained a grant even if they produce no research output at all; and (b) income awarded did not indicate the cost effectiveness of the research (whether value for money was obtained). The validity of peer grant-review is also flawed since it is based on the forecast of possible achievements of future work; limited amount of information provided and are biased towards those who have better publication records or who have received previous awards regardless of the quality of the research output and outcome. Gillett (1991) pointed out that using income to measure performance could lead to a situation in which inefficient departments are rewarded and cost effective departments are penalised.

Abrams (1991) suggested that evaluating previously published work might be a better means of predicting the quality of future work than evaluating research proposals. A study by Sonnert (1995) on the consistency of peer judgement of scientific performance, indicated a variance in evaluator's judgments of about 40%. Reasons were laid out as to why such a situation came about but pointed out that this measure alone cannot be used. The National Science Foundation Survey (Great Britain) in 1988 also revealed a significant pool of dissatisfaction (38%) with the process (Kruytbosch, 1989). The five most cited reasons for dissatisfaction were: (a) reviewers or panelists were not expert in the field (18%); (b) reviews were perfunctory, cursory and non-substantive (17%); (c) reviews were conflicting (12%); (d) "cronyism", politics, old boys network prevailed (12%); and (e) decisions made were unclear or inconsistent with reviews (10%).

(b) Library Support

Library resources in this context refer to electronic bibliographic databases and library collections. Few libraries maintain databases and produce bibliographies of their institution's staff publications. Vieira and Faraino (1997) proposed that such a service puts the library in a strategic place in providing faculty members with a qualitative analysis of where and how their research is cited and its impact in their fields of research. *Journal Citation Report (JCR)* provides information on citations appearing in the largest, most frequently cited journals. The library, therefore, has a role in providing information about academic staff's publications.

Libraries can also promote the use of information databases by either providing search services or allowing their users access to such databases. The availability of electronic networks provide connections and access to online catalogues and databases from the academic's own desk. In this area, a number of libraries and information personnel conduct studies to ascertain the extent of use academics make of these electronic resources. Bonzi (1992) in a study of senior faculty's perception of research productivity found that access to databases and computer support facilitated the faculty research productivity. A study carried out by the SUNY library of their academic staff's use of electronic information resources (Adams and Bonk, 1995) revealed that non-use occurs is due to a lack of knowledge about available resources. Zhang (1998) surveyed the use of electronic resources by academic staff from Rollins College in the United States and indicated that 69% search for information from the Olin online catalogue, 53% use UMI's *Pro Quest* direct online database, 35% use the OCLC *FirstSearch* package and 30% use the ProQuest CD-ROM system. Those who did not use electronic databases indicated lack of time, too busy, no current need to use the library as some of the reasons for non-use.

Wood, Wallingford and Siegal (1997) indicated that in the field of medicine, librarians and information professionals represent one-fifth of customers who frequently access the NLM database. As such the library's professional staff seemed the most appropriate personnel to provide an efficient search services.

Curtis, Weller and Hurd (1997) investigated the use of new information technologies by health sciences faculty. The survey was administered to all faculty members in medicine, nursing and pharmacy at the University of Illinois at Chicago, and the results indicated that the use of printed *Index Medicus* among faculty was about 30.5%, while 68% accessed *MEDLINE* through electronic means. Academic staff therefore preferred to access electronic databases from their offices than doing so in the library. Health sciences academic staff members used a wide variety of databases in addition to *MEDLINE* to fulfill their information needs. Most faculties did not participate in the in-house or electronic training sessions offered by librarians.

An Indian study by Srichandra (1970) showed that a large number of his respondents indicated being hampered in their work due to lack of library facilities. Babu and Singh (1998) explored about 200 variables influencing research productivity in India. Resource adequacy in the Indian context was characterised by adequate equipment with maintenance provisions, adequate funding for research, access to literature and adequate library resources in order to keep abreast with relevant literature in the field. On the whole, very few studies have related information searching skills to research productivity.

(c) Electronic Support

A growing number of studies have explored the impact of electronic support on academics' communication behaviour for research, teaching and also their publication productivity. Academics' connectivity, specifically the nature and level of Internet use is expected to somewhat change the traditional productivity model. The previous studies mainly explored the use of electronic support systems (stand-alone or networked computers) among various groups of academic staff and focused on the Internet use.

It is in academia that the study of computer use is most active. The current concern is whether academic staff are fully utilising the electronic networks available to them. Irvin and Martin (1985) compared scientific performance of basic research between the East and West Europe in high energy accelerators. They concluded that the scientific output in the Eastern bloc were small in comparison with the West because of inferior facilities in terms of scientific instruments and computers.

In 1988, Schaefermeyer and Sewell surveyed the use of e-mail by academic staff. The study found that an increase in accessibility had resulted in an increase in the use of electronic networks to communicate and seek others with similar interests, regardless of their geographical location. "Proponents of computer and network technology claimed that this technology would improve scholarly productivity, increase technology transfer, and widen information access" (Cohen, 1996, p.41). Cohen referred to the use of electronic resources as "computer mediated communication" and proposed that the impact of its use on communication is due to its nature which is informal, convenient, and geographically borderless, and allows rapid transmission of information. Brown (1994) estimated that only 10% of academics at institutions with access to the Internet actually used it. He suggested that 30% of the users only use it for e-mail. Possible reasons for this lack of use were unawareness of available information sources on the Net and the lack of skills in locating the information needed. Adams and Bonk (1995) and Applebee, Clayton and Pacoe (1997) attributed barriers to use amongst academics to the lack of time, and lack of training on how to use. As observed by Lazinger, Barllan and Peritz (1997), most of the studies on Internet use by academics only focused on the users, leaving the reasons for non-use unexplored. Lazinger, Barllan and Peritz reported about 80.3% (371 out of 462) of academic staff members from the University of Jerusalem were Internet users. Similarly, White (1995) and Zhang (1998) found that between 72% and 73% of the academics sampled consulted the Internet for their information needs.

Milne (1992) reported a mixed response of the effect on the use of the Internet. This was an expected result in the early years of electronic networks when the interface was not so user- friendly. Bruce (1994, 1995) surveyed 79 respondents at

13 tertiary institutions throughout Australia and indicated that the services which academics accessed through AARNET, helped to enhance the efficiency, quality and productivity of their academic work. Cohen (1996) indicated that academic staff's main use of CMC (Computer mediated communications) is for the e-mail facilities to and from other faculties, both on- and off-campus.

Other usages of the Internet include, FTP (File transfer protocol), Telnet and Gopher. The study also found low use of the electronic journals. In the United States, McClure, et al. (1996) reported on the impact of networking on the academic institution. Abel, Liebscher and Denman (1996) and Lazinger, Barlian and Peritz (1997) reported on academic scientists and engineers' use of electronic networks mainly for e-mails, electronic discussion groups, access to databases, running programs and file transfer. Lazinger, Barllan and Peritz found that 362 out of 371 respondents used the Internet for e-mail and most e-mail correspondences were research related. Kaminer and Braunstein (1998) in their study of academic staff at the University of California, Berkeley and the College of Natural Resources, found that 94% of respondents use the e-mail. Other types of use include telnet (62%), WWW (44%), gopher (37%), listserver (35%), FTP (24%), and e-journal (9%).

Other factors related to computer use include personal correlates such as gender and age. The factor "age" as a predictor of computer use was explored by the diffusion theory of Rogers (1986) who observed that early adopters of new technology tended to be younger. Chu (1994) observed a negative correlation between age and the use of e-mail. White (1995) found that the younger academic staff tended to use the Internet more than those older. A reason for this may be that, the former group participated in electronic discussion groups and were less dominated by those higher in status. Cohen (1996) investigated the use of computer networks by 888 academic staff, and found higher use of the computer networks by younger academics. Applebee, Clayton and Pascoe (1997), however, did not find age a significant factor in the use of the Internet and proposed that 'older' academics have 'caught on' the use of computers in their work. The effect of age on computer use, therefore is inconclusive, especially in the current situations where all academics regardless of age are dependent on the computers for their teaching, research and administrative work.

The effect of gender on computer use has also been investigated. A study by Ruth and Gouet (1993) found greater number of female academics using the computer networks. White (1995) discovered that female academic staff make significantly higher use of the Internet than their male counterparts. In contrast, Applebee, Clayton and Pascoe (1997) found a higher number of male academics from the University of Canberra used the e-mail than the women. Cohen's study (1996) also indicated a greater proportion of females using the network than males. The effect of personal factors such as gender on computer use, therefore, is inconclusive.

The effect of academic rank was studied by Cohen (1996), who found that assistant professors use the network more than both the associate professors and professors. Llazinger, Barllan and Peritz (1997) discovered an inverse relationship between rank and the Internet use among faculty members from both the humanities and social sciences.

Other studies have focused on Internet use among users of different disciplines. Chu (1994) reported that more of her respondents (faculties at two US universities) from the sciences used the e-mail than those in the humanities and social sciences. Chu's study, however, focused only on e-mail use and did not reflect overall computer or network use. Cohen (1996) found that the proportion of users in the humanities discipline was lower than the social science and the sciences. Lazinger, Barllan and Peritz (1997) indicated higher number of users among those in the sciences and agriculture than the humanities and social sciences. However, the result must be taken with caution because both studies did not consider whether all departments had equal access to the Internet. In other words, the level of connectivity may differ among the disciplines. Also there are variations in use even among the scientists, where the use may be high among a particular group (such as the chemists) compared to the other science disciplines.

A number of studies explored how academic staff use the Internet for teaching. Bruce (1995) studied academic staff from 13 Australian universities and found that the academics felt that the Internet helped remote institutions gain access to useful information resources and ease the delivery of lectures. Cohen (1996) found that the computer mediated communication users were more likely to be engaged in research. Lazinger, Barllan and Peritz (1997) found that more than half (57%) of the 273 respondents used the Internet to conduct research with distant colleagues, more so among the scientists than the other disciplines. About 83% of the respondents indicated that the Internet has influenced them by increasing their cooperation with colleagues. The results of studies indicate that the Internet has changed the way academics conduct their professional life since a great deal of correspondence and finding of resources are being done by themselves instead of by information mediators.

Most studies that linked computer use and scholarly productivity focused on the scientists and engineers. A Chilean study by Ruth and Gouet (1993) surveyed scientists' use of computer networks and found that those who used the network were more productive, measured by the number of publications produced. Hesse, et al (1993) studied network use by oceanographers and found high frequency network users published more articles in refereed journals, and received higher peer recognition. Bruce (1994) found that 81% of Australian academic staff believed that network access benefited them in conducting research and 63% believed that it helped to increase their publication. Cohen (1996) investigated the relationship between academics' use of computers and scholarly productivity (measured by publications, receipt of awards, service on national or regional committee of professional organization, service on an editorial board of a refereed journal, and role in funded projects). The study found that those who frequently use computer-mediated communication performed significantly in publication rates. Overall, academic staff believed that e-mail and network access benefited their productivity. The benefits mentioned were time, access to information, to new tools for research, to new kinds of information, enhances contact with faculties from other institutions, and better ability to collaborate with faculties at other institutions. Abel, Liebscher and Denman (1996) found that the majority of network users used the electronic services for teaching and predominantly for research. A recent study by Kaminer and Braunstein (1998) compared bibliometric data of scholarly productivity to Internet use. The study explored the nature and level of Internet use and its possible effects on scholarly output. Data were obtained from three sources: a publication count derived from bio-bibliographies maintained by the Academic Personnel Office at the University of California at Berkeley and from the College of Natural Resources. Data on actual use of the Internet were obtained from the computer logs maintained by the university's UNIX system. Data on the respondent's personal, academic and institutional environment were compiled from a questionnaire and the 1995/96 edition of *American Men and Women of Science*. The results indicated that an increase in Internet usage had an effect on productivity. The study of Internet use therefore, help explain the changing traditional mode of scholarly productivity.

COLLABORATION BEHAVIOUR

Communication among scientists is often discussed in terms of "interaction" or "collaboration", and is becoming increasingly common in scientific research. The research process includes active communication with scientists talking to each other, sharing ideas or equipment, writing and reading papers and letters, communicating research results or information, co-producing and co-reporting research results. In short, members of a group communicate and collaborate (Melin and Persson, 1996).

(a) Types of Collaboration

Academic collaboration occurs in a variety of settings and takes different forms, depending on the nature of the collaborative team and the goals of its members. Essentially, faculty collaboration is a cooperative endeavour that involves common goals, coordinated effort, and outcomes or products for which the collaborators share responsibility and credit (Austin and Baldwin, 1992).

Fundamentally, academic collaboration occurs in research and teaching. This section will focus on the relationship between collaboration and academic research productivity.

The results of collaboration can be measured in terms of co-authored works. A scientific document is co-authored if it has more than one author. It is institutionally co-authored if it has more than one author address. Other types of outputs as a result of collaboration are patents and personal contacts. Data on co-authored articles can be obtained from bibliographic database especially the *Science Citation Index* and *Social Science Citation Index*. The types of analysis usually comprise aggregating co-authored works based on countries, cities, organizations, individuals or groups (Melin and Persson, 1996).

The degree of collaboration was found to be discipline based. Stankiewicz (1976) observed that the propensity to work in groups seems to reflect the intrinsic requirements of the research process for Swedish scientists. Stankiewicz's study indicated the frequency of group membership was highest in the rapidly developing fields such as physics, chemistry and molecular biology. In these fields, more than 90% of the scientists were group members. Group frequency was lower in fields such as biology, geography and engineering. Smart and Bayer (1983) and Bayer and Smart (1988) similarly proposed that collaboration is most common in "data disciplines" such as physics or chemistry. Collaboration is less widely practised in "word disciplines" such as sociology or political science and is rare in fields such as philosophy or literature.

A thorough review of scientific collaboration, the origin of co-authorship, its effect on research productivity, visibility and the history of modern scientific co-authorship has been undertaken by Beaver and Rosen (1978, 1979a, 1979b). The study revealed that cooperative activities first began in France during the Napoleonic years of the 17^{th} and 18^{th} centuries, and claimed that after the Second World War collaboration in published works grew exponentially until it formed the majority of work in most scientific fields.

An increase in joint-authored works was indicated in various fields. Clarke (1964) studied the authorship trends in biomedical sciences for the period 1934-1969 and indicated that the average number of authors per paper has remained stable at 2.3. Price (1963) and Price and Beaver (1966) also indicated this pattern of growth and noted an increase in the proportion of multi-authored papers since the beginning of the 20^{th} century. Price predicted that the trend in single authorship would slowly decline and the change in the size of authorship has been associated with a transition from little to big science. Other studies have also echoed this finding. Gupta (1993) studied collaborative trends in geophysics. Data were collected from the *Cumulative Index of Geophysics* for the period 1936-1985. A total of 3,417 publications from *Geophysics* and 1,318 publications *in Geophysics prospecting* comprised the database. The study indicated that 56.2% of the publications were single authored but the number continued to decline from 1936 to 1985 indicating that like other disciplines in the sciences, collaboration in exploration geophysics research was increasing. In Europe, Luukkonen, Persson and Sivertsen (1992) studied the international pattern of scientific collaboration and the results indicated that collaboration between research institutions increased in most research fields and internationally co-authored articles doubled during the previous 10 to 15 years. Melin (1996) studied staff's publications (1,572 papers) from the Umea University in Sweden, between 1991 and 1993 and found that a total of 1,446 papers were co-authored of which 40% was local, 26% national and 34% international collaboration. Most of the collaboration was in the field of medical sciences. Meneghini (1996) studied 48,335 bibliographic records of the Brazilian published papers retrieved from the ISI database for the years 1981 to 1993. The study indicated that solo works remained steady but the growth of collaborative publication increased (especially international collaboration). Sen (1997) introduced the term mega-authored works, which comprised papers authored by 10 or more authors. In his study of 1,294 papers published in the *Proceedings of the National Academy of Sciences of the United States of America*, about 5% of this sample were mega-authored. The study indicated that the number of multi-authored works has grown, especially, those by 10 or more authors.

Trends in recent studies on collaborated works at institutional level indicate an increase in international collaboration, especially between smaller and bigger nations. Plaza, Martin and Rey (1996) studied Spanish publications and found that the percentage of bi-laterally co-authored papers was 43.8% and the number of multilateral co-authored papers was 56.2%. Poland and Russia were the countries with the highest number of collaborated papers with Spain. However, the flow from Spain to other countries was small. The study also showed both international and domestic collaboration were correlated with productivity, and that publishing with a foreign partner enhanced the scientist's visibility by achieving publication in high impact journals.

Persson et al (1997) analysed 2000 articles produced by 22 Nordic universities in 1993. The results indicated that internal scientific collaboration was active in all universities, and the amount of collaboration varied across fields, highest among physics and medicine where international collaboration occurs. The study proposed that international contacts were governed by research specialisation. Melin and Persson (1998) investigated the collaboration pattern of co-authored articles produced by academics in European universities retrieved from the *SCI*. The results indicated that there were no major differences between universities of the various sizes in terms of their output of national or international co-authored works. The study did find some country variations and a negative correlation between country size and proportion of international collaboration. It is suggested that scientists from smaller countries should look for foreign partners for collaboration. They described the university functioning as a "cosmopolitan hotel" housing nodes of a scientific network that are becoming increasingly international.

At the institutional level, collaboration can take the following form (Melin and Persson, 1998): (a) internal collaboration among departments within the same university; (b) national collaboration among one or more institutions within the same country; (c) international collaboration among one or more institutions in other countries and (d) mixed national and international collaboration with one or more institutions in other countries including one or more national institutes.

Bayer and Smart (1991) studied longitudinal data of published works of 150 male university chemists in the United States. The study provided a typology of publication pattern and collaborative styles based on long-term publication profiles of a sample of academic scientists. Overall, collaborative styles indicated that the proportion of single- and two-authored papers decline over the scientist's career. Multi-authored works were also frequent in the two years after their Ph.D. career, dropped substantially after two years and increased regularly over the rest of their career, sometimes exceeding one half the number of all published papers.

(b) Collaboration and Productivity

Collaboration has often been associated with higher productivity (number of publications) or quality (citations) of published works. Pelz and Andrews (1966) studied scientists in laboratories to identify productive climates for research, and found that the effective scientists were not only self-directed but also interacted vigorously with colleagues. In summary, the study found that the output of papers by scientists with a Ph.D. were highest when they contacted colleagues weekly. Conversely, scientists who exchanged information with fewer people outside their group tended to have low performance. In effective older groups, the members interacted actively and preferred each other as collaborators, yet, each felt free to disagree on technical strategies. Blackburn, Behymer and Hall (1978) sampled tenured academic staff from 303 institutions and found that the highly productive staff frequently communicated with scholars in their disciplines or at other institutions and actively stay abreast of current research published in academic journals. Gordon (1980) and Presser (1980) found a positive correlation between the number of authors of a paper and probability of acceptance for publication. Abt (1984) found a positive correlation between the number of authors and the number of citations in astronomical journals. Beaver (1986) indicated that co-authored works in Physics tended to be of higher quality than single authored works. In the same year, Waworuntu (1986a, 1986b) indicated that Indonesian academics who are actively involved with their colleagues in research activities are the ones who wrote more.

Bayer and Smart (1991) studied the relationship between patterns of publications and collaborative style amongst American chemists. The study proposed that it is not enough to differentiate between single or multi-authored works and that distinction must also be made between two and multi-authored works. The study provided seven types of collaborative pattern: (a) the low producers – those who published 10 or less total number of publications during the entire 25 years of their academic career (this group authored a high degree of single or dual works and the average publications declined over time); (b) the burnouts – those belonging to the smallest group who had no publication over the recent 6 years and achieved an overall average publication productivity (most of their works are multi-authored and their publications declined after tenure); (c) the singletons – those who seldom collaborated and the majority of their work were single authored; (d) the team leaders – those who achieved consistently high rate of productivity over their career and were also active collaborators (usually named first) (members of this group are relatively infrequent producers of single authored works); (e) the team players – those in this group achieved low single authored works and high level of multi-authored works throughout their career, and this increased regularly over time(those in this group were seldom named as first authors) ; (f) the doubleton – those who had a high proportion of single authored works both as first authors or named second throughout their career; (g) the rank and file – those in this group formed the largest cluster (76-150), who achieved a below average productivity throughout their career. They achieved a mixed balanced between single and collaborative works. On the whole, the study found no significant difference among the seven groups in terms of the number of years since obtaining their Ph.D. and promotion to associate professorship. However, there was a significant difference among the seven groups in terms of promotion to full professorship ($p>0.001$). Low producers and singletons were unlikely to have advanced to full professorship, the doubletons and team leaders and team players had attained full professorship by the time they had been a quarter decade into their Ph.D. Also, team leaders and doubletons have an average of more than 100 papers published during the first decade of their career and had significantly more total number of publications. These results were consistent with those of Hammel (1980) who found that productivity among those in their sample did not decline but rather leveled off with increasing age. Bibliometric analysis on impact and visibility of scientific publications as a result of scientific collaboration also seems to support the idea that it pays to cooperate (Moed, et al, 1991; Narin, Stevens and Whitlow, 1991).

Crase and Rosato (1992) proposed that collaboration can be expected to result in higher quality work due to the collective experience and pre-submission refereeing that normally take place in joint works. Crow, Levine and Nager (1992) indicated that among physicists, the co-authored works tended to be of higher quality than single authored works based on citation counts. Austin and Baldwin (1992) proposed that collaboration and engagement in a community of scholars is instrumental to scholarly productivity, particularly among prolific scholars who sustain a commitment to scholarly research and writing over the course of many years. Prpic (1996a, 1996b), who studied the characteristics of eminent scientists, indicated that the scientific productivity of eminent researchers indicated a more intensive scientific collaboration. Babu and Singh (1998) revealed 11 determinants of productivity with eigen values of 1.0 or more (significant). One of the determinant was "external orientation", that is, those who have adequate contact with superior scientists would be enhanced by professional exposure and were more likely to be involved in seminars and conferences in terms of collaborative work.

The relationship between productivity and the collaboration pattern between married academics was also the concern of a study by Creamer (1999). The study sampled 21 collaborative pairs comprising tenured faculty members at the rank of associate or full professors. Answers were transcribed and coded into the qualitative software NUDIST. The study identified three types of collaboration: (a) Short term collaboration – which described pairs working on a single project where their research briefly intersected. In most cases this type of collaboration occurred early in one or both of their careers. Participants in this type of relationship supply specialist role knowledge such as a foreign language. Most of participants in this group did not see this type of collaboration as any different from their collaboration with the others; (b) Intermittent collaboration – which described partners working together to produce scholarly publications on more than one project with gaps of more than 5 years between those publications. The couples in this group often stop collaborating because of the pressure to establish distinct scholarly identity but often planned to resume co-authorship when their reputation as scholars is secure enough; (c) Long term collaboration – which described partners collaborating consistently on scholarly publications. The collaboration was sustained because of a continued interest in a topic. The impact on scholarly productivity of an academic partner is varied by the pattern of co-authorship. The first two types of collaboration seldom view the partnership with their spouse as special or contributive to their overall career productivity. The reverse is the case in long term collaboration where partners are more likely to view these relationships as impacting either on the quality or quantity of their scholarship. The advantages of these types of collaboration are feedback about ideas and response to draft of manuscripts.

Not all studies found a positive relationship between collaboration and research productivity. Oromaner (1975) found no significant difference between citation rates for single authored works and multiple authored papers in sociology. The study concluded that collaborative works were not necessarily of better quality.

Lindsay (1978) failed to find any significant difference between citation rates across six disciplines. The study also failed to find a significant difference in terms of quality between single and multi-authored works. A study by Avkiran (1997) reported an empirical comparison of the quality of collaborative research with the quality of individual research. The quality of a paper was measured by the citations received over four years following the year of publication. The study found no significant difference between the quality of collaborative and individual research and proposed that decision makers should hesitate interpreting collaborative research as a criterion or sign of an ability to produce better quality research results.

Generally, the reasons and advantages attributed to collaboration are many. Fox and Faver (1984) listed the advantages of collaboration as: saving time as a result of work division, the generation of a larger pool of ideas on research topics; enhanced motivation as a result of team discussion and improve chances of publishing the final product. Austin and Baldwin (1992) believed that collaboration increases productivity, maintains motivation, stimulates creativity, and risk taking, maximises the use of limited resources and enhances the quality of teaching, research and the ability to solve complex problems. They proposed that administrative support can help to promote collaborative ventures by recognising and rewarding collaborative achievements and the frequently accepted idea that single authored publications are more valuable than co-authored works should be re-examined. Price (1963), Patel (1972), Heffner (1981), and Hart et al (1990) found a significant relationship between co-authorship and funded research. Pao (1995) showed that increased co-authorship in schistosomiasis was associated with research funding and the data supported the theory that scientific collaboration served as a means to advance research as well as a mechanism to increase the visibility of the highly productive. Qin, Lancaster and Allen (1997) proposed that people collaborate to cope with the multi-disciplinary nature of the subject, while Creamer (1999) found that respondents attributed the advantages of collaboration to feedback about ideas and responses to draft manuscripts. When collaboration is undertaken internationally, it helps to promote the spread of scientific ideas, increases the progress and success of research (Dobrov and Kocherovers, 1979) and allows access to a wider variety of assets and skills (especially in new areas of research) (Persson, et al,1997).

RESEARCH COMMUNICATION BEHAVIOUR

Communication correlates refer to the use and transmission of information for research purposes. This includes academic staff's use of formal and informal channels to obtain information, to keep current and their behaviour in disseminating research results. Hagstrom (1971) in his study of 125 science departments, found that scientists in high prestige departments engaged in significantly more informal scientific communication compared to other scientists.

They were also centrally located with regard to scientific communication: not only did they publish more but they engaged more frequently in the informal circulation of manuscripts and obtained information indirectly through service on various advisory committees. They also obtained substantial information from face to face contacts with others.

(a) Channels Used to Obtain Information for Research

A number of studies have attempted to ascertain the types of information channels and sources used by scientists and engineers. These were especially undertaken by librarians and information providers in order to formulate strategies to promote higher use of information sources for teaching and research. Most of the studies indicated that scientists rely more on informal channels such as communication with colleagues, attendance at conferences than on formal sources such as journals, indexing and abstracting sources (Meadows, 1974; Styvendaele, 1977). Through a survey of use of information sources in science, technology and social science at Antwerp State University, Styvendale found that the main sources of reference are citations found at the end of articles in periodicals and books (54.3%), papers listed in *Current Contents* (21.1%), items listed in indexing, abstracting journals (15.3%), personal recommendations, theses and catalogues (9.3%). Focus was on the use by academic staff of bibliographic databases mounted on campus network. Crawford, Halbrook and Igielnik (1986) investigated the use of *Current Contents* database. by four medical school departments at Washington University. They found strong preferences for the online databases over the hard copy equivalents for reasons of convenience and enhanced access. Academic staff appreciated the facility for downloading references. Clark and Gomez (1990) also conducted a survey of academic staff at Texas A & M University to find out the extent of use of databases provided. They found that 21% of staff searched the databases from outside the library, particularly from their homes. Hurd, Weller and Curtis (1992) surveyed the use of *Current Contents* and *Science Citation Index* by science and engineering faculties at the University of Illinois, Chicago. They observed a higher percentage of use of *Current Contents* by scientists (30% to 44.8%) than by the engineers (16.3%). Similarly, a higher percentage (between 65% to 100%) of academics in the sciences (except for mathematics) used the *Science Citation Index* compared with the engineers (41.8%).

A number of studies have focused on the engineers, in an attempt to investigate their information seeking behaviour and use of information sources. One of the earliest studies was by Herner (1954) who interviewed 600 scientific and technical personnel at John Hopkins University. This study pointed out the differences in information seeking behaviour of academics, who made greater use of the library for published material while at the same time maintaining contacts outside the organisation. Those who were involved in applied or industrial research made greater use of informal channels such as personal collections and colleagues. The 1970s saw several similar studies such as those by Rosenboom and Wolek (1970), and Allen (1977). The former reported three differences in information use behaviour between engineers and scientists: (a) engineers tended to make greater use of sources within the organisations compared to the scientists; (b) scientists make greater use of formal literature; and (c) scientists were more likely to acquire information as a consequence of activities directed toward general competence rather than a specific task. The latter study by Allen reported on the different philosophies and habits regarding the use of technical literature in terms of generating new ideas and solving problems in research. Allen indicated that engineers seldom use technical literature to generate new ideas but rely more on personal contacts, discussion with colleagues, and gatekeepers. In the 1980s, a number of information seeking behaviour studies were undertaken (Kremer; 1980; Shuchman, 1981; Kaufman, 1963). Kremer studied the use of technical information among engineers in a design company and found that colleagues within the company was the most frequently used channel, followed by colleagues outside the company. Libraries were not rated as an important source of information and are seldom used by the engineers. Kaufman's sample indicated engineers consulted their personal collection first, followed by colleagues and subsequently literature sources. The formal literature preferred were technical reports, textbooks and technical handbooks. As indicated by Anthony, East and Slater (1969), engineers have psychological traits that predisposed them to solve problems alone or seek help from colleagues rather than find answers in published literature. This is because their work is oriented towards product design and production (Taylor, 1986). A summary of studies about engineers is well documented by Pinelli et al (1993).

Very few studies have connected the use of information sources preference to research productivity. Blackburn, Behymer and Hall (1978) found that academic staff's use of formal journals, professional associations and exchange networks, correlates highly with productivity. Wowuruntu (1986) found that among his Indonesian academics those who subscribed to foreign journals achieved higher productivity. The competency in obtaining and seeking information is regarded as an important criteria in ensuring research successes especially in the early literature gathering stage.

Generally, two models have been put forward to indicate why certain channels of information were chosen (Hardy, 1982). One model proposed that the researcher makes an assessment of the expected benefits and costs of using an information channel and selects an information channel on that basis. The second model was the least-effort model. It proposed that users opt for the least amount of effort when searching for information. In other words, users will choose to use information sources, which have the least psychological and financial cost in its use. Hardy proposed a third model, that is the model of marginal utility. When the marginal utility of the search equals the marginal cost of the search, searching will stop. This is similar to Orr's (1970) observation that scientists will try to obtain information through experimentation and observation or they can obtain it from other people, or archival sources. The channels they approach will depend on their estimation of the likelihood of success in providing the desired information. The scientists make decisions on which channel to select on the basis of both cost and expected outcome. The "least effort factor", was also pointed out by Allen (1977) in his sample of engineers in research and development firms. Allen found that accessibility was highly related to frequency of use rather than to technical quality. Engineers used the most accessible sources as their first channel of information and that accessibility determines the frequency of use of information channels. Studies seem to indicate that researchers minimise the cost of obtaining information while sacrificing the quality of information received. Hardy (1982) studied the use of scientific and technical information of Forest Service personnel in the United States, examining the sources they use and the reasons for using them. The study found that accessibility factor had greater weight in determining frequency of use than did content.

(b) Channels Used to Communicate Research Results

A number of methods are used to communicate or disseminate scientific communication. Allen (1991) groups them into: (a) oral (telephone conversation, face to face conversation, conferences, seminars), (b) written (refereed articles, preprints, monographs, popular journals, conference proceedings, technical reports, dissertations, newsletters and abstracting journals) and (c) electronic communication (video conferencing, facsimiles, electronic mail, electronic journals, electronic newsletters, bulletin boards, electronic discussion groups).

A widely used model of the evolution of scientific literature begins with research and development and progresses through a series of increasingly formal modes of dissemination; such as correspondence, letters, conference proceedings and finally the journal article (Drott, 1995). The journal article is said to be the most important bibliographic unit (Subramaniam, 1981a, 1981b). Poland (1993), related the proposal by Walker and Hurt (1990), that journal articles are the basis of formal scientific communication which serve four main functions: (a) they act as quality control through the review process; (b) they assign priority to an idea or concept; (c) they disseminate information; (d) and they archive the article in a permanent, unchangeable format. Conference papers are valued because of their currency but act as an intermediate stage to a fully constructed scientific article. As such, they are often regarded as preliminary material, a product in an incomplete stage. This understanding evolved as a result of previous research pioneered by Willian D Garvey, Nan Lim, Carrot Nelson and Belver Griffith (Garvey, 1979). Their studies between 1966 and 1971, found that nearly half of all conference papers were eventually published as journal articles, usually within two years or less. Papers in science and engineering achieve publication more rapidly and in greater proportion than those in the social sciences. However, this situation may not be true for all disciplines. Drott (1995) found that conference papers in information science are less likely to lead to journal articles. Drott followed up papers presented at the 1987 Annual Meeting of the American Society of Information Science. The sample consisted of 32 papers and out of these, 5 were followed by at least one additional publication on the same topic. In two cases there were two follow-up publications and in one case there were three. The study observed a 13% rate of journal article follow-up compared to 50% in Garvey's studies. The author attributed this low rate of follow-up to (a) the small sample size and (b) to the possibility that information science as a field is simply less publication oriented than the fields studied by Garvey and others (Garvey, 1979). Even though conference papers do not match journal articles in terms of citations, they do function as the final product in some fields. Conference papers may report details of the application of information science techniques rather than experiments or new discoveries, and the field allows for a small amount of information to be reported for others to replicate a finding. Drott (1995) therefore proposed a remodeling of the knowledge communication cycle to include new forms of communication such as conference proceedings and "group monographs" (collected works).

Another important medium of communication (especially among the engineers) is the technical report. Benning (1976) identified the following types of report: (a) private communication (sent only to selected individual); (b) reports with restricted distribution (not generally available in the interest of the organisation which commissions the work); (c) reports containing valuable knowledge (available at a price); and (d) unlimited reports (freely available from the writer, frequently sent for international or national distribution).

The language used to communicate research results as well as the channels used to publish, influence the degree of visibility of published works. Lofthouse (1974) observed that journals provide the major outlet for academic publishing in the sense that more academics will produce an article than a book. Academics also see journals as an important source of information for keeping in touch with current and recent work.

Nederhof, et al, (1993a, 1993b) assessed the quantity and the citedness of published works by academics in an agricultural university in the Netherlands, retrieved from the ISI database between 1976 and 1987. The study found that more of the recent articles were cited. The 1976 publications were cited 180 times between 1976 and1978 and those from 1987 were cited 973 times. The sciences tend to orientate their publication to an international audience since the percentage in the Dutch language was small compared to those from the social science department. About 80% of the total number of citations were for publications in the sciences. Document type also seemed to affect a work's impact. Publications in ISI journals received more citations than the non-ISI publications; books and theses were relatively well cited but contributions to conferences received low citations and research reports were hardly cited at all.

Luukkonen (1992) studied scientists' publishing behaviour and found that scientists were reward oriented and attempted to publish in prestigious channel, especially journals with high impact factor. This is because of their need to gain prominence from publishing in important journals. The study also found that chemists used a large number of journals to publish. British chemists published in a wider variety of journals (344) than their American counterparts (255). The most popular was *Journal of the Chemical Society* (800 papers) and the *Journal of the American Chemical Society* (600 papers). Country of origin of the journals was important to the researchers. Over 70% of the American chemists have chosen to publish in journals originating in the USA, and similarly the British chemists preferred European journals.

Ashhoor and Chaudhry (1993) found that Asian scientists prefer to publish in journals from US and UK. The ranking of journals used indicate a wide scattering of journals. Prpic (1996a, 1996b) studied the characteristics and determinants of 385 eminent scientist's productivity, and found that they were generally more productive than the average population and published more abroad (four times more than average population). They also collaborated more as reflected by their total co-authored publications.

As a communication channel, computer networks have a democratizing effect on the way researchers communicate with each other (Spears and Lea, 1994). Studies in the use of computers have found that: (a) those who used computers maintained regular communication with contacts; (b) computers promoted interaction among people who would not otherwise interact; (c) computers increased the opportunity to maintain contacts with those in other countries; and (d) computers decreased inhibition among those who communicate.

CONCLUSION

The literature reported in this paper indicates that studies on research output assessment and its determinants have been undertaken since the early 1940s, especially in European countries and the United States, and continue into the 1990s. A variety of methods were used to assess the quantity and quality of research output. Publication and citation counts proved to be the frequently used indicators. The focus of this paper is on three broad correlates of publication productivity reported in the published literature: institutional correlates (which include variables such as funding, library and electronic support), collaboration and communication behaviour of academic staff members. Previous studies have not conclusively explained the existence of variations in research output among some academics given similar situations and conditions. A variety of correlates could therefore be considered when making evaluations since no single determinant can be studied in isolation to explain the situation. In developing countries, such studies are extremely lacking and these remain much to be researched.

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