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IMPACT OF PROFESSIONAL AND CHRONOLOGCAL AGE ON THE PRODUCTIVITY OF SCIENTISTS IN ENGINEERING SCIENCE LABORATORIES OF CSIR

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ABSTRACT

Examines the two types of research output of scientists varying in chronological and professional age of engineering sciences in India. The mathematical models of aging derived from the earlier studies have been tested in the two types of scientific and technical output in order to determine the linear and non-linear trends and the productivity rate for each interval

Keywords: Scientific productivity; Scientists; R & D laboratories; Professional age; Chronological age.

INTRODUCTION

The changing scientific and technological policies and differing socio-economic environments have generated renewed interest in the productivity of scientific community worldwide. One such concern is that whether the aging of scientific community will affect the nation's rate of scientific advances and scientific productivity of researchers.

The scientific productivity of an individual scientist is generally measured in terms of various scientific and technical outputs. The scientific output is reflected mainly in the number of papers published, number of technical reports written, number of books published, and others. The technical output is generally reflected in the number of processes under utilisation. The research output of individual scientist is also affected by various factors such as social, psychological and economic, which are interrelated in a complex manner. Relation with age and productivity also depends on the research involvement of institutional setting, reward system, and generally socio-economic environment of a given country.

Keeping in view the above considerations, the present study examines the two types of research output of scientists varying in chronological and professional age working in Council of Scientific Research (CSIR) in the field of engineering sciences in India. The mathematical models of aging derived from the earlier studies have been tested in each type of scientific output in order to determine the linear and non-linear trends and the productivity rate for each interval.

LITERATURE REVIEW

Adams (1946) for the first time established that the most outstanding scientific contributions are by young scientists. Since then, many studies have appeared in the literature, exploring the relationship between the age of scientists and the quality/quantity of their research output. One of the earlier works in this direction, was carried out by Lehman (1958) who established an inverse relationship between age and scientific productivity. He found that the majority of the scientific discoveries have been made by younger scientists and the number of contributions are found to decrease with age. Other studies by Alison and Steward (1974) and Zuckerman (1972) have stressed on the existence of a linear relationship between the age and research output in which the mean of publications increases at a steady rate throughout scientist's academic life. By contrast, the result of Diamond (1986) based on scientist's working in natural and social sciences, reveal that quality and quantity of current output decline with age.

DATA AND METHODOLOGY

The data used in this study has been derived from one of the six volumes of the *Directory of CSIR Scientists*, exclusively devoted to 13 engineering science laboratories, published in 1996, covering information up to 1994. The directory covers a wide range of self-reported achievements. The directory contains information on the age (date of birth); academic qualifications (name, place, and year); experience and hierarchical level in the organisation; the field of specialisation; scientific and technical outputs, and others. Age was considered in terms of professional or career age (PA) and chronological or biological age (CA). The former is the time elapsed since the researcher finished his/her post-graduate degree, and was represented in seven age ranges from 0-5 years to 36 and more years. Chronological age or self-reported year of birth was introduced, in addition to professional experience to adjust for differential advantages of those scientists who started their careers late in the laboratory. Nine groups were considered, from 20-24 years to 55-60 years.

ANALYSIS AND RESULTS

The total sample consists of 1,912 scientists, of which 1,798 are males and 114 females. In terms of contribution, only 73.57% (1,406 scientists) of the total scientists have written at least one research paper and 21.49% (411 scientists) of the total scientists have been granted at least one patent. The distribution of the scientists, by chronological age and type of research output is given in Table 1.

(a) Research Papers

From the analysis of data presented in Tables 1 and 2, it is observed that the lifetime productivity of the scientists in terms of research papers increases in all professional ages from 0.5 years up to 26-30 years of professional age, and then declines. When the least squares regression analysis of the data was carried out, it revealed a cubic relationship between lifetime production and professional age (R^2 = 0.975, F= 51.19, significant at 0.01 level). The scientists on an average

Table 1: Distribution of CSIR Scientists Working in Engineering Laboratories by Chronological Age and Types of Research Output

Chronological Age	Research Papers		Patents	
	NS	NP	NS	NPT
20-94	-	-	-	-
25-29	12	18	10	20
30-34	77	358	52	232
35-39	142	1,244	108	830
40-44	193	2,430	171	1,476
45-49	285	4,326	244	3,220
50-54	336	5,662	292	4,328
55-60	361	7,053	309	5,621
Total	1,406	21,091	1,186	15,727

NS=Number of scientists ; NP=Number of papers; NPT=Number of patents

Table 2: Distribution of CSIR Scientists Working in Engineering Laboratories by Professional Age and Types of Research Output

Professional Age	Research Papers		Patents	
	NS	NP	NS	NPT
0-5	32	200	27	289
6-10	106	779	91	697
11-15	180	1,719	133	1,055
16-20	236	3,405	203	2,522
21-25	276	4,635	231	3,082
26-30	237	4,563	207	3,243
31-35	228	3,942	203	3,246
36-40	108	1,848	86	1,595
Total	1,406	21,0091	1,181	15,729

NS=Number of scientists ; NP=Number of papers; NPT=Number of patents

contributed one research paper approximately every 15 months during their career.

The quadratic relationship was also found to be significant (R^2=0.925, F=30.84, p<0.002), and better than the least squares regression line. The fitted polynomial function (Y) shows a fall in productivity at an upper age. The first derivative (Y) of the second degree polynomial curve gave us productivity index for each age interval.

The scientists at the beginning of their career have an estimated productivity of one research paper for every two and a half years of experience. Those whose professional age ranges from 6 up to about 20 years, produced one paper on average approximately every one and half year, while researchers with more than 20 years of R & D contributed one research paper every two years.

A similar conclusion can be drawn from the study of productivity in terms of research paper per author in relation to chronological age. When the least squares regression analysis of the data was carried out, it gave a slope 1.8 (R^2=0.996. F= 164.58, significant at the 0.001 level).

An improvement of the fit was obtained with the cubic model (R^2 =0.0998). The fitted function (Y) indicates that productivity increases with age. The estimated productivity of the scientists in their 20's is one research paper for every 10 years, the group in the 30s contributes one research paper every three years, while those from 40 years onwards scientists produce just one paper every two years.

(b) Patents

The study of the mean lifetime productivity distribution of patents produced by CSIR scientists taking into consideration the professional experience is also considered. The average contribution of those patent holders who have worked in R & D for five or fewer years is 2 patents per scientist. The scientists at the next age range show a decline in productivity, i.e. 1.67 patents per scientist. Thereafter, the number of patents per scientist increased, reaching a peak of 4.26 patents at 36-40 years of carrier age, with the exception of carrier age group 31-35 years indicating a decline.

The least squares-regression line indicates a curvilnear relationship between career age and patent productivity (R^2=0.73, F=3.70, significant at 0.001 level of significance). It is estimated that the scientists on an average produce one patent every nine years of experience.

When the lifetime productivity is of patents per scientist is studied in terms of chronological age, it is revealed that the average research output increases steadily among scientists up to 55-59 years of age range, except a slight drop in the productivity in the age range of 40-44 years.

CONCLUSION

The trends derived from the analysis of scientific and technical productivity of the scientist as per their professional and chronological age emerge as follows:

In all the cases, and when the entire range of age is considered, a non-linear relationship between lifetime productivity of CSIR scientists and professional and chronological age emerges. While in the case of patents, lifetime productivity and achievement increases with age, but in the case of research papers it falls at the last slab. The productivity of the scientists in the beginning of their career is slow in the case of patents, compared to the research papers. The productivity of the scientists in case of research papers reaches its peak between 26-30 years of experience, when researchers are in their late 50's the age of greatest attainment and then it tapers off. While in case of patents, the life time productivity of CSIR scientists continue to increase with professional age. This finding is in contrast to an earlier study by

Lemoine (1991), where he found that lifetime productivity decreases in the case of patents in the last slab of their career, and maintain a high level in the case of research papers even in the last slab.

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