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ABSTRACT

This paper provides a broad reexamination of the correlates of faculty age, incorporating several measures of research activity and other related professional achievement variables. The data are derived from a large-scale, nationally representative survey of college and university faculty members; analyses are based on a subsample of all doctorate level teaching faculty in seven major representative scientific areas--physics, biochemistry, earth sciences, chemical engineering, experimental psychology, economics, and sociology. While much of the research focuses either on one discipline or on a broad aggregate of diverse fields, the present study analyzes each discipline separately, consistent with earlier research, which has shown substantial cross-field difference in research-professional activities. Additionally, no single model of aging is proposed a priori. Rather, a series of plausible mathematical models are postulated and tested. The compelling conclusion is that career age (and possibly tenure status) is a poor predictor of research-professional activity. (Author/KE)

CAREER AGE AND RESEARCH-PROFESSIONAL ACTIVITIES OF ACADEMIC SCIENTISTS*

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CAREER AGE AND RESEARCH-PROFESSIONAL
ACTIVITIES OF ACADEMIC SCIENTISTS*

In the shift from the enrollment growth boom of the 1950's and 1960's, American higher education has been compelled to enter a new stage of reexamination of faculty recruitment, retention, and employment practices. There is currently an overproduction of potential new faculty for many fields, and a commensurate decreasing mobility, increased aging, and tenuring-in of large numbers (and proportions) of faculties in many of the nation's colleges and universities.

Albeit a misnomer (Glenny, 1974), the issues implied by these faculty trends are subsumed under the topic of "steady-state staffing" (Furniss, 1973). Questions are raised as to the viability of the conventional tenure systems, the effects of terminating younger untenured faculty and recruiting fewer new junior level faculty members, and the optimal strategies for maintaining faculty 'quality' and heterogeniety through early retirement plans. Implicit in such questions are considerations of age effects, and virtually all discussions at least tangentially address the effects of faculty aging (e.g., see Brown, 1967; Slater, 1972; Mann, 1973; Keast and Macy, 1973; Furniss, 1973; Hopkins, 1974). Indeed, Blackburn's (1972) monograph, entitled Tenure, focuses primarily on research results with respect to faculty age as a means to explore concomitants of the effects of tenure and the tenure system.

Despite the underlying premises regarding the effects of faculty aging to many of the considerations of the contemporary issues in higher education, little direct empirical evidence is available on the relationship between age and academic or scientific performance. Zuckerman and Merton (1973) claim that the field is severely "short on facts." They state:

> The best case that can be made for . . . dealing with age stratification in science is that so little is known about it. In point of fact, systematic research over the years has been devoted to only one problem in this field: the patterns and sources of changes in the productivity of scientists during their life course. Beyond that, just about any methodical research on age, age cohorts, and age structure in science would qualify, through prior default, as a 'new' direction (p. 496).

Nevertheless, there is substantial empirical literature, recently reviewed by Carlsson and Karlsson (1970) and by Bess (1973), which demonstrates many negative effects of aging and is derived from learning theory or research on human development. However, extensions of applications of such theories and results to the scientific and academic professions have not usually been made. Moreover, what few studies which have been undertaken on the correlates of aging within the academic and scientific community have often been based on small nonrepresentative samples, and have been subject to various interpretations. Blackburn (1972), for example, summarizes the findings of studies of aging among college and university faculties as generally reflecting either positive effects on performance or an absence of any direct effects of aging. Bess (1973), in reviewing largely the same literature, shows that, with respect to the effects of faculty aging, there are numerous contradictory study results which report both positive and negative effects. He concludes that there is not yet firm empirical evidence to draw any conclusions as to the effects of age on the careers of faculty members.[1]

This paper provides a broad reexamination of the correlates of faculty age, incorporating several measures of research activity and other related professional achievement variables. The data are derived from a large-scale nationally representative survey of college and university faculty members; analyses are based on a subsample of all doctorate level teaching faculty in seven major representative scientific areas--physics, biochemistry, earth sciences, chemical engineering, experimental psychology, economics, and sociology. While much of the recent research has focused either on one discipline or on a broad aggregate of diverse fields, the present study analyzes each discipline separately, consistent with earlier research which has shown substantial cross-field difference in research-professional activities (Lehman, 1953; Hagstrom, 1965, 1967). Additionally, no single model of aging is proposed *a priori*. Rather, a series of plausable mathematical models are postulated and tested, consistent with the call by Zuckerman and Merton (1973) for further exploratory research in this area.

Aging Curve Functions

In the case where regression equations have been employed in the study of aging effects among college and university faculties, linear models are often adopted for research or illustrative purposes. Blackburn (1972), for example, applies a linear regression model on selected aspects of faculty performance, and reports heteroscedasticity with correlations of "almost exactly zero" (p. 14). This increase in the variance with age is also reported by others with respect to research productivity and professional recognition (Cole and Cole, 1967; Allison and Stewart, 1974). Merton (1968) refers to this as a "Matthew effect," with accumulative advantage by some and decline or eradication of productivity and performance by others.

Linear models of the form $Y = a + bX$, where Y is the dependent variable and X is age, measure only the goodness of fit of the best single straight line relating age to a dependent variable. Such a model, as shown in Figure Ia, implicitly tests merely a cumulative growth hypothesis. If a nonlinear relationship exists, a linear model misspecifies the relationship and underestimates the true relationship. Indeed, a perfect but nonlinear relationship could result in a correlation coefficient of zero by use of linear regression. Consequently, this exploratory paper incorporates several selected nonlinear transformations as well, as described by Bartlett (1947), Blalock (1960), and Johnston (1972). However, there is a virtual infinite variety of nonlinear functions; several alternatives are selected which are consistent with various interpretations of theories of human development and aging. Each function will be tested for goodness of fit for each dependent variable included in the study.

Figures Ib, Ic, and Id illustrate the alternative general nonlinear models employed for testing the results of the relationship between age and the dependent variables. Figure Ib represents the curve for the aging hypothesis of a declining rate of increase. It is expressed by the formula $Y = a + b \log X$. Figure Ic represents the possible plateauing effect with age, or the leveling-out hypothesis. This curve is asymptotic and is expressed by the function $Y = a - b\frac{1}{X}$.

A third nonlinear form, shown in Figure Id, is the equation derived by a second degree polynomial. It is parabolic in shape, and expressed by the equation $Y = a + b_1 X - b_2 X^2$, and is a curve derived from an hypothesis of "burning-out" with age, or an obsolescence function.

Figures Ie and If present two additional models which will be employed for testing relationships for selected dependent variables. Each may be viewed as overlaying hypothesized effects of the academic reward system on direct aging effects, incorporating the effects of time to promotion and/or tenure on possible performance variations over time. These curves would also be consistent with previous descriptive analyses of professional performance measures with age which have been described as "saddle shaped" but do not necessarily conform to expected ages for advancement in academia (Pelz and Andrews, 1966; Behymer and Blackburn, 1975). In their study, for example, Pelz and Andrews (1966, pp. 174-199) report a bimodal distribution, with one peak during the "creative years" of the late 30's and 40's and a "renascence" 10 to 15 years later. Figure Ie illustrates a curve derived from a third degree polynomial, by an equation expressed as $Y = a + b_1 X - b_2 X^2 + b_3 X^3$. It is defined as a spurt function and may be tested against the results derived from application of the preceeding equations. Figure If represents the curve derived from a fourth degree polynomial, expressed as $Y = a + b_1 X - b_2 X^2 + b_3 X^3 - b_4 X^4$; it is referred to as a spurt-obsolescence function, and is tested against results suggesting best fit of the other curves.

The Data

Survey Source

In the 1972-73 academic year, the American Council on Education undertook a national general-purpose survey of college and university faculty members. Included was a sample of 108,722 faculty and staff members in a nationally representative sample of 301 higher education institutions, including 78 universities, 181 four-year colleges, and 42 junior or community colleges. A total of 53,034 (48.8 percent) responded. Of the respondents, 42,345 were identified as currently active teaching faculty; data from these faculty members were weighted to adjust for sampling and response bias, and national normative reports were prepared (Bayer, 1973; Bayer, 1974).

A subsample of teaching faculty was drawn from the larger file and included all who reported holding a Ph.D. and were either trained in or recently held an academic appointment in any of seven selected physical science, technological, or social science disciplines. This procedure resulted in a total subsample of 5,079 -- 1,346 in physics, 585 in biochemistry, 607 in earth sciences, 305 in chemical engineering, 324 in experimental psychology, 1,149 in economics, and 763 in sociology.

Variables for Analyses

Unlike most earlier studies which focus on single criterion variables (research quantity, research quality, or scholarly recognition), the present exploratory research examines a broad array of research-professional variables. The primary independent variable is career age, based on the respondents' report in the survey instrument as to the year the highest degree was received. Selected analyses were also run on the basis of tenure status and on chronological age, derived by the respondents' report in the survey instrument as to the year of birth. Because each of the variables is highly interrelated, basically similar results were obtained for each independent variable. Career age was therefore selected as the primary independent variable. Utilization of this variable also accounts for differences in "professional life expectancies" of scientists due to interfield and cross-cohort variations in age at doctorate attainment and for different relative ages of faculty members in various disciplines. Summary descriptive statistics and interrelationships of career age, chronological age, age at doctorate, and tenure status for the sample, by discipline, are shown in Table 1 (data shown are categorized, all regression analyses which will be subsequently reported employ uncategorized single-year measurements for the career age variable).

These data, reported in Table 1, indicate that, for all fields combined, the correlation between career age and chronological age is .87; and by the end of the tenth year beyond the doctorate, more than 9 in 10 are tenured. The average career age ranges from less than 8 years (for experimental psychologists) to more than 12 years (for biochemists). Chronological age ranges from 39 years (for experimental psychologists) to more than 44 years (for economists). These differences in part reflect historical changes in the relative output of various scientific specialties and, in part, reflect changes in age at completion of the doctorate for various cohorts and cross-field differences in age at completion of the doctorate, as shown in the Table. These data, including the interfield differences, are basically consistent with the earlier career pattern studies of science doctorates conducted by the National Academy of Sciences-National Research Council (1965, 1968) and by the National Science Foundation-National Register of Scientific and Technical Personnel (1971).

The array of dependent variables are selected to represent research and broad professional and scholarly "cosmopolitan" roles of academic scientists rather than "local" orientations manifested in lesser professional commitments, greater concern with the goals of the employing institution, and greater focus on an institutional career and teaching roles (Gouldner, 1957; Glaser, 1964).

With the exception of one indicator of research performance discussed below, all dependent variables are derived directly from the survey instrument. A summary description of all variables is provided below; summary statistics are reported in Table 2, showing distributions for the sample on each variable by four selected arbitrary age categories -- the Fledglings (4 years or less experience); the Maturing (five to ten years), the Established (11 to 25 years), and the Patriarchs (over 25 years).[2] Also shown in Table 2 are the number of cases utilized for the analyses of each variable; this varies somewhat because cases with missing data are omitted in the analyses and the amount of missing information for respondents on each questionnaire item varies. The dependent variables, and the coding used for them in the regression analyses, are listed below:

Variable 1: Total number of professional writings published or accepted for publication in last two years (continuous variable, using midpoints of precoded categories).

Variable 2: Total number of published articles in academic or professional journals (continuous variable coded with the same procedure as variable 1).

Variable 3: Total number of published books, manuals, or monographs (continuous variable coded with the same procedure as variable 1).

Variable 4: Number of citations in 1973 to all scholarly works (continuous variable with a range of 0 to 593 for the sample). This measure is derived from the 1973 Science Citation Index or, for the economists and sociologists, from the 1973 Social Science Citation Index. It is a quasi-qualitative index of the impact and recognition of the scientist's work by others. While there are limitations to this variable, it has been shown to be an important independent indicator of research performance and gives less weight than quantitative methods to the "operator" who produces quantity as opposed to the scholar who produces quality (Bayer and Folger, 1966; Cole and Cole, 1967; Chubin, 1973).

Variable 5: Whether currently engaged in pure or basic research and scholarship (dichotomized variable where 2 = yes, 1 = no).

Variable 6: Time spent per week in research and scholarly writing (continuous variable coded with the same procedure as variable 1).

Variable 7: Total number of academic or professional journals to which presently subscribe (continuous variable coded with the same procedure as variable 1).

Variable 8: Whether engaged in any paid consulting outside of current institution during past year (dichotomized variable where 2 = yes, 1 = no).

Method of Analysis

The current data set available for analyses is cross-sectional rather than longitudinal. Indeed, no large-scale data of national scope, and with the broad array of variables we address, presently exists on faculty over a long-term longitudinal basis. Consequently, our method employs a cross-sectional design interpreted, in part, as a quasilongitudinal design.

While the analyses are largely interpreted within the framework of assessing the general process of aging, the results might potentially obtain largely from generational differences. Soddy (1967) and Bess (1973), for example, note that different cultural surroundings accompany the development of each cohort of faculty members at different stages in their professional lives. As a result of these generational differences, groups who differ in age will not all have equivalent experiences and opportunities by the time they reach the same point in life. As Hyman (1972) points out, the aging process and generational differences are "intertwined" in this design and may be jointly responsible for the net effects. Consequently, conclusions in terms of aging must be considered somewhat tentative.[3]

Nevertheless, some of our results would suggest which of the alternative processes have taken place. Consider, for example, lifetime publication productivity. If there are little or no generational effects (i.e., the drive to publish, the emphasis on publishing, and the success in publishing by academic scientists have been constant over time) then the plot of the number of lifetime publications by age for cohort data could not turn downward (but, at a maximum, only plateau) at the upper ages. Conversely, an actual downturn in the lifetime productivity of an older cohort as against a younger cohort would reflect generational effects, regardless of what effects aging itself might have on publication productivity. Aging effects, however, might then be potentially implied by, for example, the results obtain through analyzing the extent of publication productivity for only the past two years.

Additionally, some of our conclusions are more directed toward present policy implications rather than to longer-term effects of faculty aging. As noted above, for example, there is currently a trend toward implementing early retirement policies in higher education institutions. Regardless of how (or why) younger cohorts of academic scientists should turn out when they approach retirement age, the benefits and costs to the present system of early retirement cannot be known until we know how those presently nearing retirement compare to their present younger contemporaries.

Finally, there is no direct methodological resolution to the problem, including the availability of true longitudinal data. If, for example, we were to have available for analysis a sample of academic scientists for whom data were available over a complete span of, say, 25 years, there is still no assurance that we could generalize these findings for predictions regarding where a group of new academic scientists will be in 25 years. Not only might the new academic scientists possibly have different traits at the beginning of their careers than did their predecessors, they will also be subject to different generational influences--different world events, or environmental experiences (e.g., depression or expanding economy, tight money or growing expenditures for scientific R & D, steady state or expanding university enrollments, and so forth).

In summary, the study of aging, as noted by Hyman (1972), opens "a Pandora's box of puzzling problems" (p. 260). These problems may, in part, explain why Zuckerman and Merton (1973) view the existence of studies of age relationships in science as being largely absent by "default." In this paper, we introduce a range of considerations regarding the correlates of career age among American scientists. We introduce new data to the area, albeit exploratory and suggestive, and, of its nature, subject to methodological and interpretative caveats.

Analytical Procedure

In his discussion of age comparisons in cohort analysis, Hyman (1972) states that "a whole series of developmental curves of aging processes could presumably be mapped" (p. 261). As shown above, we have selected a series of such curves, derived from learning theory, previous studies of aging, studies of scientific careers, and from human development models.

For each variable, the linear form model is first employed and tested. The alternative nonlinear models are then assessed for their statistical viability and tested against the linear model and against each other for goodness of fit. That relationship which explains the greatest proportion of variance in the dependent variable is accepted as best depicting the "true," or "best-fit," relationship. Three distinct criteria are employed with regard to the results from each model: (1) the obtained measure of relationship (notated as R) is statistically significant; (2) each of the betas in the equation is statistically significant; and (3) the signs of the betas are consistent with those within the family of each set of possible curves as depicted in Figure I. From among those results which meet the above criteria, the model yielding the highest R^2 is selected as providing the "best fit." In selected cases where a nonlinear model is determined to provide the best fit to the data, the partial derivative with respect to age is also calculated, or $\hat{Y}$ is calculated and plotted for each value of X (career age). This yields further explication of the results through providing estimates of the points of inflection in the curves, of an estimate of the age at which various outcomes would either peak or begin to decay for each nonlinear model which fits each variable.

Results

The results from the analyses of each of the eight dependent variables, by field and for all fields combined, are shown in Table 3. In each case, the zero-order relationship is reported, followed by the specification of the best-fit function which met the criteria for acceptance, and the R obtained by application of this best-fit model. For the purpose of elucidating the method of the paper, presentation of illustrative detailed analytical results are presented for the first variable shown in Table 3; analyses of the remaining variables are presented more concisely.

The first dependent variable is the number of articles published by faculty members in the two years preceding the survey. The descriptive summary statistics, shown in Table 2, suggest a peaking at about 5 to 10 years of career age. At this time period, only 13 percent of Ph.D.'s report no publication activity during the past two years, and 30 percent report publishing 5 or more pieces. During the latter career years (over 25 years), there has been only a slight decline in the proportion of highly productive faculty members, but a substantial proportionate increase in nonproducers. Proportionately, there are as many nonproducers of publications in the patriarch group as there are in the fledglings group. These results support both the "Matthew effect" and prior study results showing virtually no linear relationship between age and productivity as measured by publications over the past two years.

While linear models are clearly not applicable to these data, the fourth degree polynomial (described as "spurt-obsolescence") provides a curve of "best-fit" for all fields combined, and for 5 of the 7 selected disciplines (Table 3). The plots of the $\hat{Y}$'s for each value of career age, derived from the resulting best-fit functions, are shown in Figure II for each field. For biochemistry, the obsolescence curve, peaking at about 20 years of career age, provides the most optimal model among those proposed. For chemical engineering, the third-degree polynomial (described as the "spurt" function) provides the best fit, with a peaking at about 10 years of career age and then a second rise in productivity after 30 years of career age. For the remaining fields, where the spurt-obsolescence function provides the best-fit, the first peak is reached at about the tenth year of career age, followed by a second peaking as the scientists reach retirement age. (The average retirement age period is shown in the shaded portions of Figure II).

Several conclusions are suggested by these data, and are re-emphasized by the subsequent data to be presented. First, application of linear models are especially weak in explaining variance in professional activity with career age. However, even the "best-fit" a priori model for most fields, represented by the fourth-degree polynomial, explains less than 7 percent of the variance even in the case of the field (experimental psychology) with the highest obtained R for prediction of publication output over the past two years. Second, there are major differences across fields in the shape of the curves and in the actual values of the dependent variable at different career points for different fields. Therefore, results of analyses from only a single discipline, or results only from an aggregate of scientists from a broad array of disciplines, may not be appropriately generalized to any other specific discipline. Finally, in most fields a major point of inflection in the curves is obtained almost at the point of expected retirement. The implications of this finding are discussed in the concluding section.

The second dependent variable, total number of published articles during scientists' professional lifetime, is shown to provide a strong (positive) linear relationship with age, consistent with the data in Table 2 which indicate that, among the fledglings, less than 10 percent have published more than 10 articles, whereas more than three-fourths of the patriarchs have done so. However, for each field, a nonlinear function provides a more appropriate representation of the actual relationship. For the total group, and for four of the seven fields, the "spurt" function (third-degree polynomial) provides a best-fit to the data (Table 3). That is, there is a decline in the lifetime article productivity of faculty members presently in mid-career, or at the latter part of their careers, but there is a higher lifetime productivity level for those who are in their retirement years but have not yet left academic employment. With the exception of biochemists, who have a declining rate of increase in lifetime publications across career age, all other fields peak and fall during the course of the career (chemical engineers and economists beyond mid-career show a fall in productivity, with no upswing by those in a later career stage). As noted previously, such curves for total lifetime publications of cohorts could not be obtained solely on the basis of effects of aging. Rather, such relationships would suggest either a generational effect or, alternatively, "selective attrition" from academia of productive scientists at mid-career (to employment in non-faculty roles or to non-academic settings) and early retirement (or non-extension of employment beyond usual retirement age) of prior non-productive scientists. These implications are discussed further in the concluding section of the paper.

Unlike lifetime article publications, lifetime publication of books tends to increase linearly with career age for most fields, with r's ranging from approximately .30 to .50 (Table 3). This result is also consistent with the distribution of book publication by age, shown in Table 2. For chemical engineers, however, there is a relative drop in lifetime book publications by those at mid-career, followed by an increase by those in late career and those still in academia beyond normal retirement age. Unlike all the other fields, the social sciences (economics and sociology) show a relative decline in lifetime productivity of books by those presently at career-end.

Consistent with total lifetime publication of books, the quasi-qualitative measure of professional impact, as assessed through citation counts, shows a different relationship at the tail for the social scientists than for the other disciplines. While none of the proposed models fit the data for earth scientists, the models with obsolescence tails fit the data for economists and sociologists, and the remaining fields either show a declining rate of increase across career ages, or a drop beyond mid-career and a second rise near career's end and through the period of normal retirement.

The next variable shown in Table 3 is a measure of the changing focus of research activity during the course of scientists' careers. For every field, a weak and negative relationship was found between career age and commitment to pure or basic research (as opposed to applied or policy-research). In most cases, none of the other non-linear models adequately fit the data. In two cases (physics and earth sciences), however, the third-degree polynomial provides the best-fit for the data, indicating a decline in the latter part of professional careers, followed by a rise in emphasis on pure or basic research at career end and beyond normal retirement for those still employed in academia. The results for the best-fit equation for all fields combined also illustrates the fallacy of analyzing an aggregate of scientists from an array of fields in combination. In this case the distribution of aggregate data in Table 2 and the resultant best-fit curve for all fields combined (spurt-obsolescence) is not mirrored in any of the seven separate fields which compose the total.

The analyses next summarized in Table 3 regard the variable assessing the amount of time spent in research. It was initially hypothesized that the relationship of career age to this measure would parallel the functions derived previously for measures of research productivity. That is, change in productivity with career age would parallel hypothesized changes in the amount of time required for other academic activities (e.g., administrative) with advancing career experience. However, in 6 of the 7 fields studied, either none of the equations fit the data or only a negative linear function provided statistically significant results, the latter also being consistent with the aggregate descriptive statistics shown in Table 2. Only in the case of experimental psychology did a non-linear function (the third-degree polynomial) fit the data relating career age to time in research, and approximately parallel the courses for some of the research productivity functions analyzed earlier for the field.

A variable utilized as a proxy for scientists' efforts to keep current with the discipline over their career was analyzed next. For this purpose, the measure was the number of current subscriptions to academic and professional journals held by the scientist. While statistically significant results were obtained for each field, no cross-field regularity of results were found. Indeed, among the seven fields analyzed, five of the six hypothesized models emerged as the best-fit at least once. Moreover, if we focus only on the tails of the relationships, there is a steady decline in the number of subscriptions held by scientists beyond mid-career in three fields (physics, experimental psychology, and economics), whereas for the remaining fields there is an increasing rate of journal subscription near the end of the career.

The last dependent variable shown in Table 3 is a measure of the extent to which scientists engage in consulting away from campus over the course of their careers. Consistent with the summary data in Table 2, for all fields combined, and for physics, earth sciences, and chemical engineering, there is a parabolic relationship, with consulting activity increasing into mid-career and thereafter declining regularly throughout the remainder of the career. In two fields (biochemistry and experimental psychology), however, there is a cumulative rise over the entire career age span, while in the two social sciences there is a decline during mid-career and a second rise in consulting activity beyond mid-career.

Discussion

Current changes in the economic position of higher education, coupled with declining enrollment growth rates for the future, have raised anew some of the traditional issues in higher education (e.g. tenure) and introduced new questions to higher education policy (e.g., early retirement programs and faculty layoffs). Many of these issues are subsumed under the general topic of "steady-state staffing" and have given rise to numerous discussions of the relationship of age to faculty members' performance. While some of the literature is based on little empirical research (e.g., Hodgkinson, 1974), others have summarized the existent studies but with resulting different conclusions (cf. Blackburn, 1972, and Bess, 1973). In general, however, little systematic research has been devoted to this area, with the exception of changes in productivity during scientists' careers (Zuckerman and Merton, 1973). Nevertheless, even in this area only few selected criterion measures have been addressed, relatively restrictive sampling has been used, and difficult interpretative problems of methodology have not been surmounted.

The results from the present exploratory analyses, based on a nationally representative sample, introduces preliminary findings of the relationship of career ages of scientists to an array of cosmopolitan professional research activities and related accomplishments, some of which have not heretofore been assessed. While the data and the methodology do not allow the disentangling of alternative explanatory hypotheses, they do establish viable alternative relationships of research-professional activities with career age which have not been previously developed in the body of empirical literature. The results also give doubt to the adequacy and applicability of findings derived from an aggregate of scientists from diverse specialties, or of the utility of generalizing the findings derived from one discipline to that of another.

The primary method of analysis for this paper is the utilization of a series of bivariate relationships, by seven separate scientific disciplines and for eight selected dependent variables. In each case, six alternative models of age relationships, derived from previous research and theory, are tested for goodness of fit. In no case, for each dependent variable, did the same model fit all seven disciplinary fields. Nor were all the results from these cross-sectional data consistent solely with an aging-effects hypothesis. Rather, cohort-effects (generational differences), or possibly selective attrition, appear to be viable alternative explanations of at least some of the observed relationships.

The results of the analyses of total lifetime publications, by career age, indicate potential generational effects for many of the disciplines studied.

If there were little or no generational effects, then the plot of the number of lifetime publications by age cohort would not be expected to turn downward, but at a maximum only plateau in the case were productivity declined with the effects of age. However, for every discipline, the total number of published articles declined for those presently in the cohort beyond mid-career. Similarly, the lifetime total of books and monographs produced by those faculty members beyond mid-career in three disciplines declined, while for the remaining four disciplines there was a regular linear increase throughout the career lifespan.

Generational effects have been largely characterized as emanating from different historical and environmental backgrounds and experiences which occur differentially for different cohorts during their life-course patterns and have sustained effects on subsequent career performance. Others (Ortega y Gasset, 1958; De Solla Price, 1963; Kuhn, 1970; Lovell, 1973) have alluded to periods of "vintage years" in the production of Ph.D.'s who eventually attain an exceptional degree of eminence in their field. The peaks of inflection in the curves previously described may be attributable to the present career ages of the products of "vintage years" in each discipline. With time, therefore, this "vintage" peak should move toward later career ages. While the precise historical comparative data are not available, comparison of the present data for 1972-73 does not show a dozen-year movement of the peak from that reported by Pelz and Andrews (1966) for scientists and researchers of the late 1950's and early 1960's. Consequently, the vintage years hypothesis is not supported although not adequately tested by the presently available data.

Another alternative explanation for the shape of the resultant best-fit functions is a selective attrition hypothesis, one which is not extensively considered in previous substantive or methodological treatments which discuss assessments of age effects with cross-sectional data. Many of the best-fit curves demonstrate a drop in research-professional activities beyond mid-career, and a rise at late-career. Potentially, the more productive scientists may be recruited away from academia, or placed in non-faculty assignments within higher education institutions, during the second half of their careers, to return to faculty positions again at the end of their careers.

Moreover, those in most of the disciplines analyzed who remain in employment beyond usual retirement age show an exceptionally high record of past research and scholarly achievement (lifetime publications of book, monographs, and articles). Nevertheless, they typically exhibit a decay in their recent scholarship (number of publications in last two years) and professional recognition (as assessed by citation frequency). These results suggest that former "stars" are retained in academia beyond regular retirement age, although retention is based more on past performance than on present relatively high rates of research-professional activity.

Finally, the results provide no definitive answer as to the effects of aging (and, by implication, tenure) on the career performance of academic scientists. However, the results do suggest that generational effects, and perhaps "vintage" effects or effects of selective attrition, are overlayed with aging effects in the career-span accomplishments and activities of scientists. The results also clearly demonstrate that any findings based on one discipline may not be applicable to others, and that results based on an aggregate of members from several disciplines may not be applicable to any single field.

Despite the interfield differences, however, the results from the analyses of all seven disciplines would suggest that, within the next decade, a cohort of scientists who may be less productive or eminent in research-professional roles than either their predecessors or successors, for whatever reasons, will be moving into the age of retirement eligibility. The instituting of early retirement programs for some members of this cohort may therefore prove to be a somewhat viable program which would not adversely affect the overall quality of American scientific academic personnel. However, such procedures may be less desirable in the longer run when applied to a future cohort nearing retirement beyond the mid-1980's. Furthermore, the present analyses focus exclusively on the more cosmopolitan roles of research-professional activity. Recent literature (Bayer, 1970; Linsky and Straus, 1975) would suggest that these results may have little or no relationship to the performance of local roles including instructional skills, which might be weighed and deserving of reward and retention in academia as well.

Nevertheless, the compelling conclusion, based on the analysis of seven major physical science, technological, and social science disciplines, and including a number of criterion variables, is that career age (and possibly tenure status) is a poor predictor of research-professional activity. In no case is the amount of variance explained in any criterion variable sufficient to warrant any "standard" educational policy applicable to all members of an age cohort;

nor do additional studies of faculty aging or generational effects on scientific performance hold much promise of yielding robust results with sufficient potential generalizability that they would be amenable to direct translation to higher education policy during a period of "steady-state."

Footnotes

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[1]Clemente (1973) presents a comprehensive review of other related studies of scientific productivity and likewise concludes that the findings have not been cumulative but rather ambiguous and often contradictory.

[2]Later in this paper, in discussing the analytical results, further reference is made to the descriptive statistics shown in Table 2.

[3]Three types of intertwined effects which might be detected in cohort analyses ("cohort effects," "period effects," and "effects of aging") are extensively discussed by Riley, Johnson, and Foner (1972). See especially Chapters 1 and 2, and Appendix.

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Table 1

Summary of Characteristics of the Ag
Structure of Ph.D Faculty in 1972-73, by Selec

Field	Mean Chronological Age	Mean Career Age	Career Age at which Mean Chronological Age>65	Mean Age at Doctorate, by Career Age				
				0-5	6-10	11-15	16-20	21-25
Physics	43.3	11.9	37	29.2	29.0	29.2	29.2	28.8
Biochemistry	43.9	12.7	37	30.1	28.1	29.4	29.0	28.9
Earth Science	44.1	11.3	38	31.4	29.9	30.2	31.3	30.2
Chemical Engineering	43.7	12.1	38	30.1	29.1	29.2	28.4	29.0
Experimental Psychology	39.2	7.8	39	28.9	29.3	29.4	28.6	30.2
Economics	44.4	10.2	37	30.8	31.7	33.3	33.6	32.6
Sociology	43.8	8.9	36	32.5	32.9	33.7	33.2	31.8
Total,all fields	43.5	10.9	38	30.7	30.1	30.8	30.9	30.1

Table 1

mary of Characteristics of the Age
Ph.D Faculty in 1972-73, by Selected Fields

al	Mean Age at Doctorate, by Career Age						Proportion Tenured by Career Age			Zero-Order Correlations		
	0-5	6-10	11-15	16-20	21-25	26+	0-5	6-10	11+	Career Age with Chronological Age	Career Age with Tenure	Chronological Age with Tenure
	29.2	29.0	29.2	29.2	28.8	27.1	20.3	63.6	94.6	.910	.434	.461
	30.1	28.1	29.4	29.0	28.9	27.4	20.4	52.6	89.9	.900	.414	.433
	31.4	29.9	30.2	31.3	30.2	27.8	29.7	74.8	94.6	.895	.413	.422
	30.1	29.1	29.2	28.4	29.0	27.3	34.2	67.4	93.0	.914	.414	.434
	28.9	29.3	29.4	28.6	30.2	27.8	18.4	77.8	91.7	.892	.472	.466
	30.8	31.7	33.3	33.6	32.6	29.3	33.1	80.9	95.9	.858	.459	.499
	32.5	32.9	33.7	33.2	31.8	30.9	27.1	80.9	93.3	.838	.498	.540
	30.7	30.1	30.8	30.9	30.1	28.2	27.0	71.0	93.9	.868	.450	.476

Table 2

Distribution of 1972-73 Faculty Members
on Selected Research/Professional Variables,
by Career Age

(Figures in Table are percentages)

Variable Description	Career Age: Fledglings (0-4 years)	Maturing (5-10 years)	Established (11-25 years)	Patriarchs (over 25 years)	Total, all Faculty
Number of published articles in last two years (N=4,959)					
None	25.3	13.0	16.0	24.6	17.3
1-2	38.1	26.5	27.5	27.8	28.8
3-4	22.6	30.1	26.6	20.3	26.5
5+	14.1	30.4	29.9	27.4	27.4
Total number of published articles (N=4,984)					
2 or less	48.1	13.9	8.6	5.8	15.8
3-10	42.6	42.4	21.9	17.9	31.2
11-20	7.3	27.9	21.9	17.4	21.1
21+	2.0	16.8	47.6	58.9	32.0
Total number of published books and monographs (N=4,981)					
None	66.5	61.1	38.4	22.5	48.4
1-2	25.6	27.6	33.7	33.6	30.5
3-4	6.1	7.0	15.5	16.9	11.5
5+	1.8	4.3	13.5	27.0	9.6
Number of citations in 1973 to prior published works (N=5,053)					
None	50.9	26.8	25.7	26.7	30.0
1-5	39.4	50.1	40.4	41.8	43.4
6-10	5.2	13.6	14.3	12.7	12.5
11+	4.6	9.6	19.5	18.8	14.1
Recently engaged in pure or basic research (N=5,053)					
Yes	57.2	68.8	60.1	53.2	61.7
No	42.8	31.2	39.9	46.8	38.3
Average time (hours) in research per week (N=4,831)					
4 or less	20.0	13.3	16.7	21.1	16.5
5-12	35.1	29.0	30.3	34.6	31.0
13-20	27.5	31.7	29.4	27.8	29.7
21+	17.4	26.0	23.6	16.4	22.7
Number of subscriptions to academic/professional journals (N=5,012)					

Number of published articles in last two years (N=4,959)					
None	25.3	13.0	16.0	24.6	17.3
1-2	38.1	26.5	27.5	27.8	28.8
3-4	22.6	30.1	26.6	20.3	26.5
5+	14.1	30.4	29.9	27.4	27.4
Total number of published articles (N=4,984)					
2 or less	48.1	13.9	8.6	5.8	15.8
3-10	42.6	42.4	21.9	17.9	31.2
11-20	7.3	27.9	21.9	17.4	21.1
21+	2.0	16.8	47.6	58.9	32.0
Total number of published books and monographs (N=4,981)					
None	66.5	61.1	38.4	22.5	48.4
1-2	25.6	27.6	33.7	33.6	30.5
3-4	6.1	7.0	15.5	16.9	11.5
5+	1.8	4.3	13.5	27.0	9.6
Number of citations in 1973 to prior published works (N=5,053)					
None	50.9	26.8	25.7	26.7	30.0
1-5	39.4	50.1	40.4	41.8	43.4
6-10	5.2	13.6	14.3	12.7	12.5
11+	4.6	9.6	19.5	18.8	14.1
Recently engaged in pure or basic research (N=5,053)					
Yes	57.2	68.8	60.1	53.2	61.7
No	42.8	31.2	39.9	46.8	38.3
Average time (hours) in research per week (N=4,831)					
4 or less	20.0	13.3	16.7	21.1	16.5
5-12	35.1	29.0	30.3	34.6	31.0
13-20	27.5	31.7	29.4	27.8	29.7
21+	17.4	26.0	23.6	16.4	22.7
Number of subscriptions to academic/professional journals (N=5,012)					
2 or less	28.0	28.4	18.3	9.3	22.1
3-4	37.8	35.1	37.1	30.9	36.0
5-10	31.1	32.8	39.5	48.4	37.0
11+	3.1	3.7	5.1	11.5	5.0
Recently engaged in off-campus paid consulting (N=5,022)					
Yes	39.4	43.1	52.1	49.8	47.1
No	60.6	56.9	47.9	50.2	52.9

Table 3

Summary of "Best-Fit" Curve Functions[a] of Career Age with Research/Professional Variables, by Field

Variable Description	Field: Physics	Bio-Chemistry	Earth Science	Chemical Engineering	Experimental Psychology	Economics	Sociology	Total all Fields
Number of published articles in last two years								
r (linear relationship)	-.016(NS)	.094*	.010(NS)	-.064(NS)	.068(NS)	.005(NS)	.040(NS)	.048**
Best-fit relationship	Sp-Ob	Ob	Sp-Ob	Sp	Sp-Ob	Sp-Ob	Sp-Ob	Sp-Ob
R for best-fit	.146**	.157**	.258**	.217**	.271**	.227**	.145**	.201**
Total number of published articles								
r (linear relationship)	.417**	.539**	.420**	.445**	.564**	.449**	.522**	.474**
Best-fit relationship	Sp	Decl	Sp	Ob	Sp	Ob	Sp	Sp
R for best-fit	.469**	.576**	.494**	.469**	.590**	.461**	.532**	.509**
Total number of published books and monographs								
r (linear relationship)	.343**	.306**	.362**	.398**	.457**	.403**	.500**	.325**
Best fit relationship	Cum	Cum	Cum	Sp	Cum	Sp-Ob	Ob	Cum
R for best-fit	.343**	.306**	.362**	.454**	.457**	.421**	.505**	.325**
Number of citations in 1973 to prior published works								
r (linear relationship)	.089**	.201**	.006(NS)	.141*	.299**	.158**	.265**	.155**
Best-fit relationship	Decl	Decl	(None)	Sp	Sp	Sp-Ob	Ob	Sp
R for best-fit	.111**	.212**	—	.264**	.335**	.184**	.299**	.178**
Recently engaged in pure or basic research								
r (linear relationship)	-.161**	-.169**	-.103*	-.108(NS)	-.056(NS)	-.063*	-.006(NS)	-.067**
Best-fit relationship	Sp	Cum(-)	Sp	(None)	(None)	Cum(-)	(None)	Sp-Ob
R for best-fit	.208**	-.169**	.170**	—	—	-.063**	—	.126**

Table 3 (Con't.)

Variable Description	Field: Physics	Bio-Chemistry	Earth Science	Chemical Engineering	Experimental Psychology	Economics	Sociology	Total all Fields
Average time in research per week								
r (linear relationship)	-.084**	-.195**	-.017(NS)	-.078(NS)	-.047(NS)	-.114**	-.007(NS)	-.042**
Best-fit relationship	Cum(-)	Cum(-)	(None)	(None)	Sp	Cum(-)	(None)	Sp
R for best-fit	-.084**	-.195**	--	--	.191*	-.114**	--	.105**
Number of subscriptions to academic/professional journals								
r (linear relationship)	.281**	.355**	.212**	.400**	.179**	.115**	.059(NS)	.168**
Best-fit relationship	Ob	Cum	Sp	Cum	Ob	Sp-Ob	Decl	Cum
R for best-fit	.287**	.355**	.238**	.400*	.230**	.159**	.072*	.168**
Recently engaged in off-campus paid consulting								
r (linear relationship)	.158**	.183**	.113**	.050(NS)	.138*	.053(NS)	.085*	.090**
Best-fit relationship	Ob	Cum	Ob	Ob	Cum	Sp	Sp-Ob	Ob
R for best-fit	.175**	.183**	.154**	.146**	.138*	.156**	.182**	.109**

[a]Abbreviated in body of table as follows:

Cum: cumulative growth function; $Y = a + bX$ (Figure Ia).

Decl: declining rate of increase; $Y = a + b \log X$ (Figure Ib)

Lev: leveling out function; $Y = a - b \frac{1}{X}$ (Figure Ic).

Ob: obsolescence function; $Y = a + b_1X + b_2X^2$ (Figure Id).

Sp: spurt function; $Y = a + b_1 X - b_2 X^2 + b_3 X^3$ (Figure Ie).

Sp-Ob: spurt-obsolescence function; $Y = a + b_1 X - b_2 X^2 + b_3 X^3 - b_4 X^4$ (Figure If).

* significant at .05 level

** significant at least at .01 level

Figure I

Alternative Models of Aging Functions

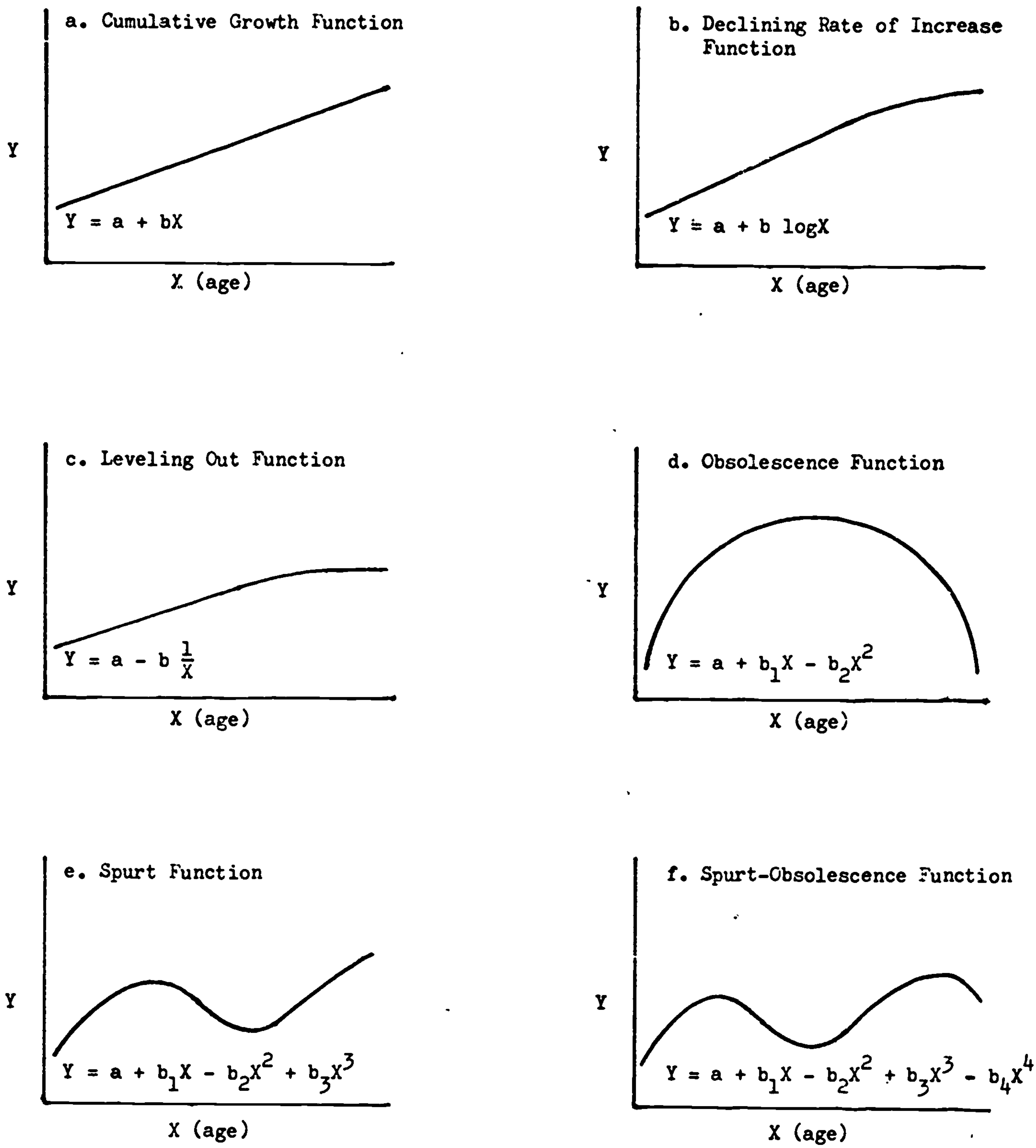
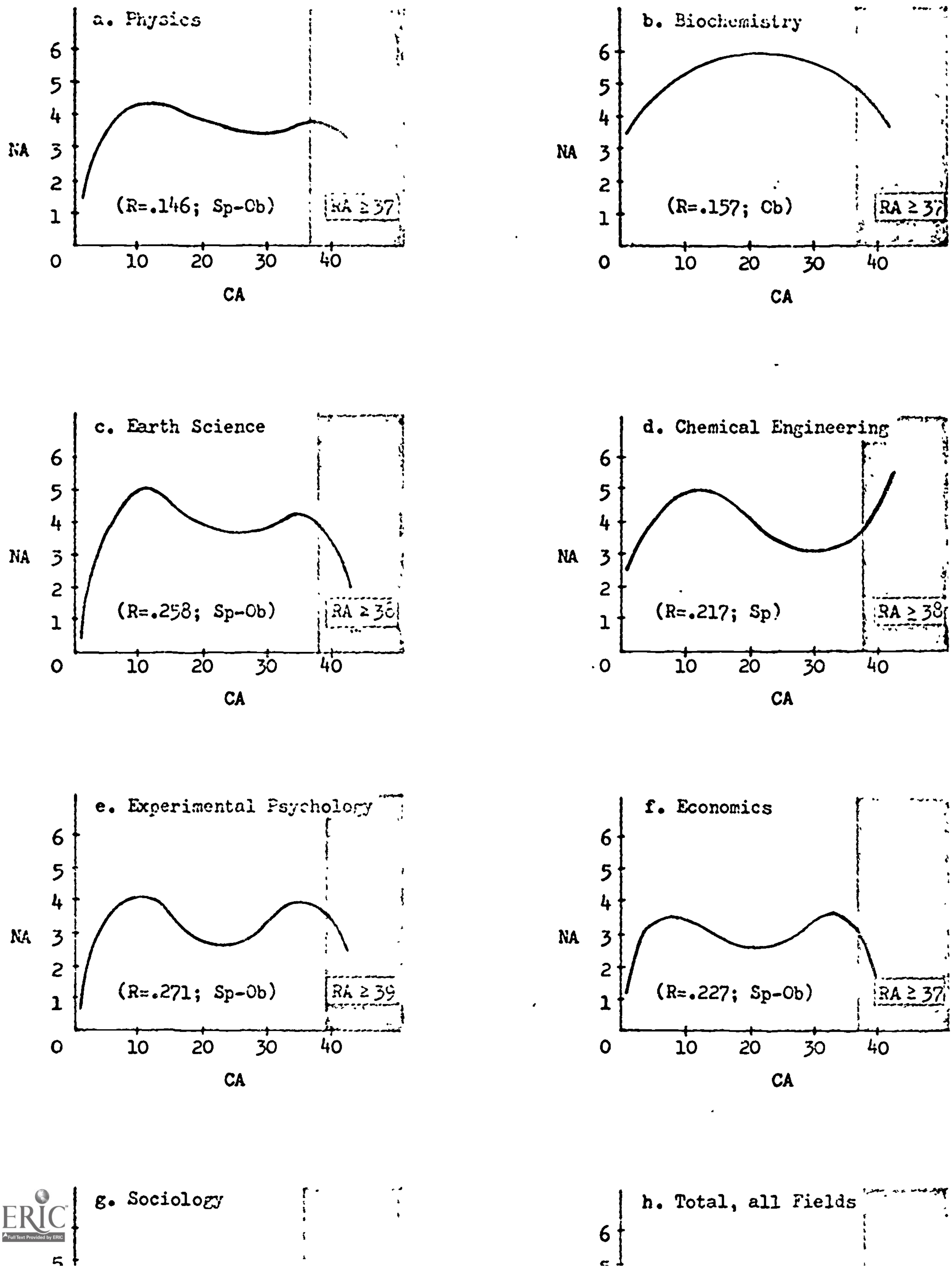
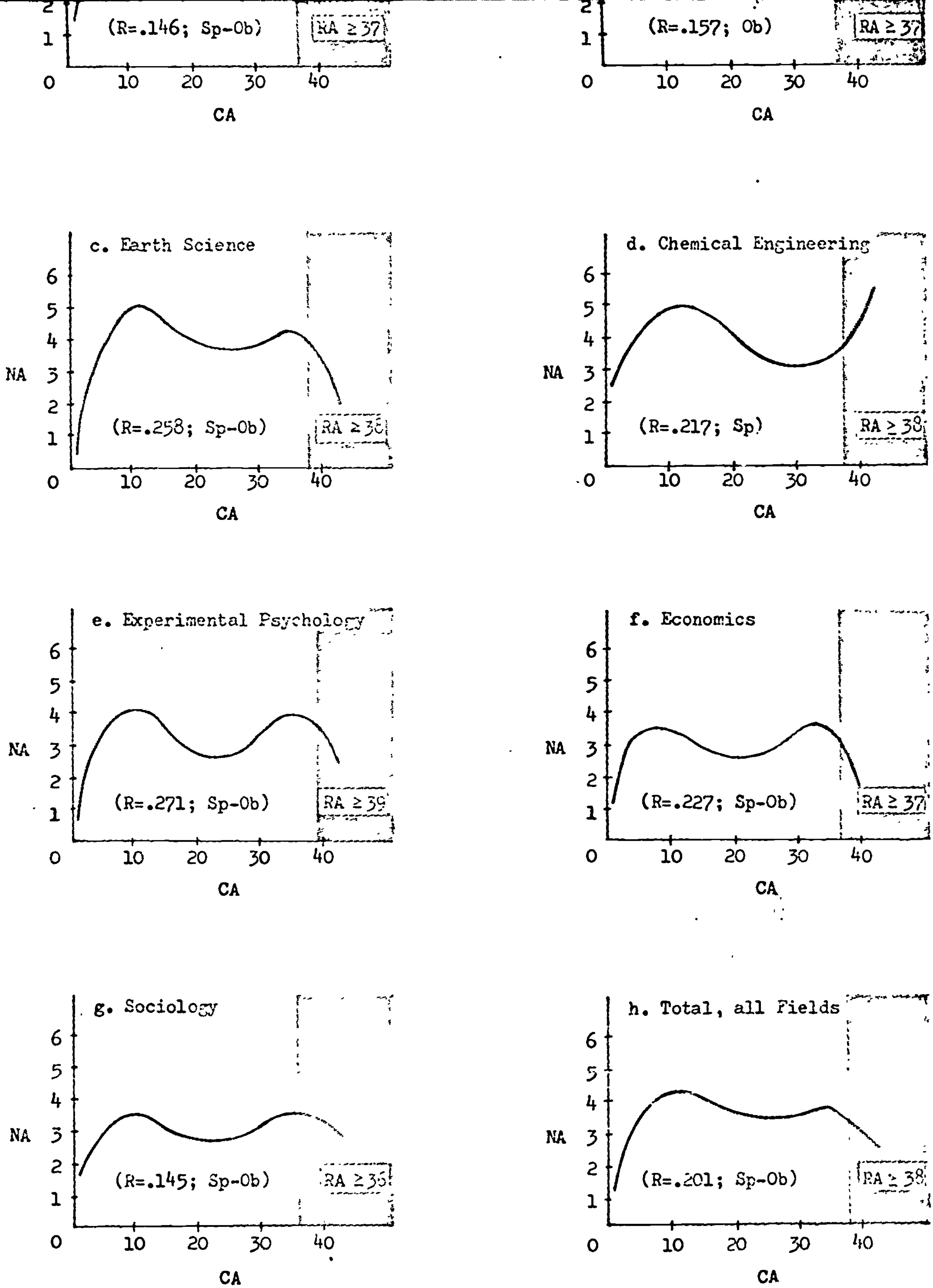


Figure 11

Plots of Best-Fit Model of Career Age with Number of Published Articles in Last Two Years, by Field





Notes: NA = number of articles published in last two years
CA = career age
RA = career age at which retirement is expected (from Table 1)