

THE INTERNATIONAL COMPARATIVE STUDY ON THE ORGANIZATION
AND PERFORMANCE OF RESEARCH UNITS:
NATURE OF THE STUDY AND SOME EMPIRICAL RESULTS ON
SOCIAL POSITION, MOTIVATION, AND PRODUCTIVITY*

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A paper presented to the 1976 Joint Meetings of the Society for Social Studies of Science and the Research Committee on the Sociology of Science of the International Sociological Association; Cornell University, Ithaca, New York

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Introduction

This paper presents information about a six-nation research project investigating the organization and performance of research units. The paper consists of three distinct and separate parts.

Part 1 briefly describes the general nature of the project; Parts 2 and 3 provide two examples of empirical results emerging from the data. The first of these, Part 2, explores the extent to which production of publications by individual scientists is related to the social position (i.e., supervisory status) of the individual in the research unit. Part 3 focuses on factors at the unit level and examines the relationship between motivation of the team as a whole and various aspects of its research performance. Parts 2 and 3 of the paper are presented simply as two contrasting examples of the kinds of results emerging from the project. While we believe the results of each are important in their own right, the present report makes no attempts to integrate them.

* S.S. Blume, J. Cole, D. Crane, and E. van Hove provided helpful comments and remarks on the material presented in Part 2 of this paper. R. Kofler, R. Matuschek, and W. Raidl assisted in preparing the manuscript from which Part 2 is derived. Elizabeth Keogh and Marita DiLorenzi helped prepare the analyses described in Part 3. Susan Wood Paz typed the present report. We gratefully acknowledge their contributions.

PART 1. Nature of the project

The International Comparative Study on the Organization and Performance of Research Units is a collaborative multinational research project devoted to an empirical exploration of factors related to the effectiveness of research teams. The project is coordinated by UNESCO's Division of Science and Technology Policies and operates through an International Research Team, which has responsibility for decisions on substantive matters (design, content, etc.). This International Research Team consists of the scientific project director in each of six countries from which data have been collected: Karin Knorr (Austria), Joseph Bonmariage (Belgium), Veronica Stolte-Heiskanen (Finland), Arpad Halasz (Hungary), Salomea Kowalewska (Poland), and Rikard Stankiewicz (Sweden); plus UNESCO representatives (Y. de Hemptinne, or his designates Nicole Visart and/or Gerald Cole) and Frank Andrews (U.S.A.).

The study has been underway for the past five and one half years and has now collected data from samples of about 200 research units in each of the six countries indicated above (1222 units in all). A wide range of disciplines and types of institutions are represented: exact, natural, biological, medical, social, and technological sciences are all included, as are units from academic, industrial, and government-cooperative institutions.

The data were obtained using standardized questionnaires administered to various types of respondents: the unit head, the administrative officer (if any), other professional-level scientists in the unit, technical support staff in the unit, and external evaluators who could rate the performance of the unit. Data from over 10,000 respondents have been coded, cleaned, put on computer files, and archived.¹

The project is, essentially, a study of research units and how their various social and organizational characteristics relate to their scientific productivity.² However, because the basic data come from individual scientists and technical support people, the analyses can also be carried out at the level of the individual person.

¹At the end of September 1976 the original data, suitably anonymized, became available to the world social science community through the Belgian Archives for the Social Sciences (Louvain, Belgium).

²A "research unit" has been defined for the purpose of this international study as a group of scientists which meets the requirement of having specific

Measures of research unit performance include reports of several types of outputs and also more qualitative evaluations. The output measures, available at both the personal and team levels, include various types of publications, patents, prototypes, reports, algorithms, and others. The evaluations of units were made along several dimensions--including general contribution, R&D effectiveness, social effectiveness, training effectiveness, applications effectiveness, and others--by professional-level members of the unit and also by external evaluators.

Organizational variables assessed in the questionnaires include the following: remuneration and advancement, R&D activities, research methods, scientific exchanges and contacts with other units, evaluation methods, choice of research themes and planning of the work, working climate, availability of resources, patterns of influence, supervision, plus various "demographic" characteristics of the unit itself and its members.

To date, a variety of descriptive national reports and more theoretically oriented substantive analyses have been completed. Chapters for a collaborative book of scientific findings from the project are now being developed.

Besides its characteristics as an international research project, the study is intended as an R&D management and information tool for policy-makers at the national, organizational, and research unit levels. It is expected that additional countries will conduct similar surveys on samples of their own research units (e.g., a data collection in India is foreseen shortly). In the light of the experience gained from the first round of data collection, some modifications will be introduced into the questionnaires while an attempt is made to maintain the broad comparability of the data. It is believed that the growing body of cross-cultural research results, combined with a carefully developed and tested methodology for collecting information from and about research units in additional countries,

scientific-technical responsibilities, a distinct life-span, at least one leader and altogether three core members spending at least eight hours per week in the unit. Furthermore, the group must have had an expected life span of at least one year and the individual scientist, in order to be considered as a core member and as eligible for answering the questionnaire, must have been in the unit for at least six months. If a unit included more than three scientists below the leader, a random sample of three staff members was selected for responding to the questionnaire. A similar procedure was used if there were more than three persons in technical support roles.

will represent an important resource for assisting science policy planners and R&D managers to enhance the effectiveness of research efforts.¹

¹ Further information about the operational aspects of the project can be obtained from: The Director, Division of Science and Technology Policies, UNESCO, 7 place de Fontenoy, 75700 Paris, France.

PART 2. Individual publication productivity as a social position effect
in academic research units¹

Studies of stratification in science have increasingly accepted the idea that science is a highly stratified and elitist system with skewed distributions of productivity and rewards (Lotka, 1926; Price, 1963; Cole and Cole, 1968). Those results as well as some of the earlier ones by Crane (1965) as to the high correlation between academic setting and both productivity and recognition seemingly lend themselves to an interpretation which would confer greater ease of publication and hence higher visibility and reputation from individual or academic status. However, Zuckerman and Merton (1971) found that formal control mechanisms of science such as reviewing and publication processes are not affected by status differentials of the authors of papers submitted. The findings of Hargens and Hagstrom (1967) and Hagstrom (1971) support those conclusions: Hargens and Hagstrom showed that status does not affect productivity on the individual level, although it does on the aggregate.

If status does not confer easier access to publication and if ascriptive factors are not primarily relevant for the recognition accorded the like contributions of two unlike scientists, this raises the question as to how the large publication differentials between higher and lower rank scientists can be explained. The above studies provide no simple explanation for this differential productivity. Zuckerman (1970) showed that age is associated with rank and hence with productivity, and Pelz and Andrews (1966) report a continuing increase of productivity with age up to the early or late 40's, with a renaissance of productivity manifesting itself in a second peak of the age curves about ten to 15 years later.

If age and professional experience are important explanatory variables, how does it come about that the average productivity in a unit of time (as measured by the number of written products within the last three or five years and hence adjusted for the accumulating effects of age) rises so steadily not only during the first years of a professional career, where initial lack of research experience alone might provide for an adequate explanation, but rather for 15 to 20 years after graduation?

¹This portion of the paper is an abbreviated version of a chapter by Karen D. Knorr, Roland Mittermier, Georg Ailchholzer, and Georg Waller that will appear in the forthcoming book of scientific reports from the project (see Andrews, in preparation).

This paper attempts to supply some further details as to how productivity differences associated with rank or age can be understood by extending the above research to include intra-organizational variables as a source of explanation. As noted by Whitley (1976), scientists may be affected more by organizational settings and structures than usually emphasized in stratification studies. If one were to take the idea of science as a highly stratified system one step further and apply it to the system of a single organization this would lead one to expect scientific productivity to be associated with the status or position a scientist holds in the formal or informal scientific hierarchy of the organization. The question as to why higher position should confer greater productivity can then be answered by pointing to the differential resources and task structures associated with different levels. Consequently, the relationship between age and productivity found in previous studies would have to be discussed in the light of the association between a scientist's age and the position he has attained in his organizational environment. Since presumably age and the level of supervisory position are highly correlated in bureaucratic organizations (like universities or academies of science) it may well be position and the resources and task structures associated with it--and not so much mere chronological age or professional experience-- which account for most of the variance in productivity.

At this point, sufficient research has been done in the present study to outline the contours of a model which describes intra-organizational position of a scientist as a key element associated with productivity differences. Before describing this model (represented by a structural equation technique), the relationship between age and productivity and the question as to whether age can be considered as a proxy for the position a scientist has attained in a research organization will be explored. Furthermore, the effect of time in research on productivity and the nature of task structures seemingly conducive to high quantity of output will be analyzed.

Measurement of productivity

Despite of the fact that most social scientists working on scientific productivity have agreed on the ideal of a measurement of scientific quality

by peers from within the respective specialty, in practice many have gone on to use a simple counting of published papers as the most viable way of dealing with the problem (e.g., Price, 1963; Coler, 1963; Crane, 1965; Gaston, 1969). In support of those authors, fairly consistent evidence has come up in the literature as to a high or moderate correlation between the sheer volume of a scientist's published papers and their quality as measured by ratings of competence by peers or citation counts (see Meltzer, 1949; Dennis, 1954; Meltzer, 1956; Clark, 1957; Pelz and Andrews, 1966; Thomasson and Stanley, 1966; the Coles, 1967, 1971 and Blume and Sinclair, 1973). The conclusion seems to be that where citation counts are not readily available--as in the case of the present study which includes countries not adequately or not at all represented in the science citation index--publication counts are roughly adequate indicators of the significance of a scientist's work (cf. Cole and Cole, 1971:26).

Following a frequent procedure (e.g., Pelz and Andrews, 1966; Hagstrom, 1967; Gaston, 1969¹), we took as our indicator of "publication productivity" the self-reported number of papers a respondent has published in scientific journals in connection with his or her work in the research unit. In order to eliminate the cumulative effect of sheer professional age, respondents were asked to list only the papers published during the last three years. Where the Lisrel-techniques has been used (below), the number of scientific books published in the same time period has been included in the analysis as a second indicator of publication productivity, justified by a sufficiently high correlation between both kinds of output.²

¹While our data allow for the assessment of the rated quality of the scientific work of our respondents in addition to its quantity, it imposes itself in the case of the present examination to almost exclusively rely on the quantitative measurement of research productivity, for the simple reason that this enables us to more directly relate our results to the findings in the existing literature than it would be the case if results on rated performance measures differing once again from the variety of existing measurement attempts would be used.

²As expected, both measures were highly skewed in that only a small number of scientists proved to be highly productive, while most scientists either had not produced at all or reported only very few papers; accordingly, publication measures were bracketed before further use to reduce skewness.

Age, professional experience and productivity

Earlier work referred to above suggested a somewhat curvilinear relationship between a scientist's age and his scientific productivity. Whereas Lehmann's (1953, 1959, 1960) results show a continuous decline of productivity after achievement peaks around the late 30's (depending on discipline), Pelz and Andrews generally report the peak at a later age in the 40's followed by a 10 to 15 year sag with a comeback in the 50's. Our data offer a partial verification of those results: Figure 1 shows the mean production of papers by scientists in different fields and settings for different age categories.

(Place Figure 1 about here)

Stagnation or decline after a certain period of rising productivity, as at least partly verified again in the present data, have met with different attempts of explanation in the literature. The most popular interpretation points to the fact that the more productive scientists are drawn off into teaching, administration, and other work not productive of scientific output. This is supported in our data, for example, by a positive correlation between age and the number of years the scientist has been head of the research unit, a negative correlation between age and the percent of time spent on research and a positive relationship between age and the percent of time spent on administration.¹ However, upon closer examination of the age curves for percent of time in research and administration, one finds a more or less steady decrease (with research) and steady increase (with administration) of the curves from the very beginning of a professional career almost to the end of it (cf. Knorr et al., 1976). Phrased differently, publication productivity is rising sharply (in academic settings) and moderately (in industrial settings) for about the first 20 years of a professional career in spite of the fact that non-research tasks are increasing steadily and time in research is decreasing continuously during all the same time.

¹The Pearson r's between age and years as head of the unit, percent of research and percent of administration are .47 (years as head), -.36 (research) and .44 (administration) in academic natural science settings; .36, -.34 and .37 in academic technological science institutions; and .39, -.14 and .26 for technological scientists in industry.

Age as a proxy for position in the research laboratory

The fact that scientists are drawn off from research and drawn into administrative and other tasks from the very beginning of their career suggests that age--in accordance with our initial thesis--might be considered as a kind of proxy for the degree to which scientists move into various kinds of (informal or formal) supervisory positions.¹ A simple check of such an assumption can be made by asking whether there is any significant direct effect of age and professional experience on productivity over and above the effect which runs through the position a scientist attains in the research unit. If there were such a direct effect it should mean that increasing age stands for rising technical knowledge and competence, which accounts for the increasing productivity more or less independent of the position a scientist holds and the task structure and resources it provides.

By looking at the correlations between age/professional experience and productivity separately for formally acknowledged supervisors like unit heads (which we could differentiate in our data set) and staff scientists of a research unit, the latter including scientists of various supervisory positions below unit heads and non-supervisory researchers (which we could not differentiate), the primary importance of position as opposed to sheer age or experience was underlined. Since in the case of clearly identified supervisory scientists (unit heads), where position was controlled for, the correlation between age/experience and productivity goes down and becomes insignificant, whereas in the case of staff scientists (position not controlled for) it remains significant, this implies that position and not age accounts for productivity differences (compare Table 1).

(Place Table 1 about here)

Another more indirect check of the theoretical priority attributed to position for which age stands as a proxy in the present analysis can be done by pointing to the following relationship: if position as opposed to age is to explain publication differentials, then there should be a positive relationship between a supervisory scientist's access to manpower resources

¹ Examples for such positions might be supervising the work of technicians and graduate students, directing--instead of participating in--projects, and finally becoming head of a laboratory.

and his productivity, for the simple reason that the number of scientists and supportive staff supervised should act as a multiplying factor as far as the supervisor's quantity of output is concerned. If, however, it were age or professional experience and the presumed rise in personal scientific competence to which increasing numbers of publications per unit of time must be attributed, then there should be no such correlation between a supervisor's manpower resources and his productivity.

Again the argument can be checked very simply by looking at the publication productivity of the subgroup of formally acknowledged supervisors, i.e., unit heads, for whom the information as to how many scientists and engineers, technicians, etc., they supervised during the last three years (the period of publication counts) is available. Figure 2 shows how publication productivity in this subgroup rises with the size of scientific manpower resources; Figure 3 documents the equivalent relationship for technical and service staff supervised.¹ Both figures confirm the increase of a supervisory scientist's publication with rising manpower resources.

(Place Figures 2 and 3 about here)

Age, task structure and productivity

If age is acting as a proxy for position with view to productivity in the present data set, then age should also be related to certain characteristics of the task structure associated with supervisory positions. In an earlier paper we have shown that sheer time in research seemingly does not contribute significantly to the publication productivity of a scientist (Knorr et al., 1976).² Then it should be the changing nature of involvement in research associated with attainment of supervisory positions which makes for a difference. Being involved in many projects with a relatively low amount of time mainly at an early (research conceptualization) and late stage

¹Manpower resources in both cases are measured in terms of the average number of man years of a) scientists and engineers (Figure 2), and b) technical and supportive staff (Figure 3) in the unit supervised by the scientists during the last three years.

²This is indicated by Eta² coefficients of .04 between time in research and publication productivity in both academic natural science and industrial technological science units.

(report and paper writing) clearly offers better opportunities for authorship or coauthorship than devoting a large amount of time to actually doing all the tedious work of one research task. Consequently, if the negative relationship between age or experience and time in research, and the lack of a significant correlation between time in research and productivity (except for extreme time involvements), can be supplemented by a positive relationship between age/experience and the degree to which the scientist is charged with goal-setting rather than goal-executing functions (positively related to productivity), this would support our argument that it is the differential advantages associated with supervisory positions which account for much of the productivity differences in research organizations.

To check our argument the following three dimensions have been chosen to represent--to various degrees--a goal-setting task structure: First, the diversity of functions of a scientist, an index based on a simple count of every incidence of a greater than zero percent time-involvement of the scientist in a) research, b) teaching, c) administration, and d) other scientific activities (like consulting work, scientific documentation, etc.).¹ Second, the nature of his involvement in R&D --the degree to which he was involved in goal setting research functions which set the stage for execution by others (like "perception and identification of an area of interest" for the unit) as opposed to genuinely executing tasks (like "collection and production of data" or "literature review.")² The third concept referred to the total number of projects a scientist was involved in, as an indicator of his ability to attract resources in connection with his work in the unit. All three dimensions are thought to mirror the position a scientist held in the unit: the higher he moved in

¹The range of the index accordingly varies from 1-4; the index is based on a general question as to how much of the total work time of the scientist this year was devoted to the above categories, additionally including "routine and control analyses," "design and engineering studies" and "other professional functions" under category d) above.

²Indicators used to measure the volume of goal setting functions are the following: degree of involvement in "perception and identification of an area of interest," in "problem precision: conceptualization, formulation, analysis," in "time-table, administration, organization and economic considerations" and in "formulation and statement of hypothesis"; all items were measured on 5-point Likert scales.

the hierarchy of the research laboratory, the more he would be confronted with a variety of scientific and non-scientific functions in addition to research, and the more the nature of his research involvement should change towards goal setting rather than executing activities, and the more he should be able to attract project money and consequently be involved (as a supervisor or just formally) in more projects within and outside the unit than at the beginning of his career.

A social position model of publication productivity

We have shown so far that age and professional experience are acting as a kind of proxy for the degree to which a scientist holds a supervisory position¹ and that the manpower resources associated with this position relate positively to a scientist's publication productivity. As a final check on our general thesis we now present a path analytic model of the presumed structure of relationships as implied so far, including indices of task structure and ignoring for a moment manpower resources which were only measured for the subgroup of unit heads. The fit of the path analytic model set up to represent this structure has been tested with the help of the Lisrel technique (cf. Joreskog and van Thillo, 1972; Joreskog, 1974).²

¹More specifically one should say that age and experience act as a proxy for position in relation to publication productivity since there seems to be no direct effect of age over and above what is explained by a scientist's supervisory position. However, that age should be associated with position to such a degree in academic settings is in itself interesting, pointing to the fact that advancement in academic bureaucracies is based upon the principle of seniority.

²Lisrel is a computer program for estimating general linear structural equation models with the special advantage of allowing for unmeasured hypothetical constructs or latent variables measured by several indicators each. The method allows for a differentiation between errors in equations (disturbances) indicating the amount of variance explained and errors in the observed variables (measurement error), yielding estimates for both. To check for the measurement assumptions required by Lisrel a test of linearity of bivariate relationships has been made and showed no significant non-linearity in the data. All parameters reported in the models pertain to standardized variables. Linkages between latent dimensions (circles) represent true relationships and are reported as path coefficients, those between observed (rectangles) and unobserved dimensions represent the construct validity of the measures reported as regression coefficients. Arrows pointing to observed variables indicate the amount of measurement error, those pointing to latent dimensions indicate disturbances or residuals. To ensure the identifiability of the model, parameters representing symmetric

As in previous analyses, we chose scientists in academic natural science and technological science units as relevant subgroups for replicating the model. Results for academic natural sciences are shown in Figure 4; the model for academic technological science settings is not included since results are the same as for natural sciences, with an even higher amount of variance explained.¹ The ability of Lisrel to reproduce the input correlations among observed variables was generally good: the mean deviation of the estimated correlations from the observed correlations in the model of Figure 4 was .025; the highest discrepancy was -.134.

(Place Figure 4 about here)

The model suggests that a scientist's age (used as a proxy for the degree to which he holds a supervisory position) is related to his task structure in the research laboratory and that this in turn is related to his or her publication productivity. "Age" is measured by both chronological age and professional experience. Supervisory task structure, as previously, is represented by three dimensions: the diversity of functions, the volume of goal-setting research functions and the number of projects involved in. It is important to note that the pattern of relationships which identifies supervisory position as a major explanatory concept accounting for productivity differences dominated over a wide range of other relationships between organizational variables and publication productivity which were examined.²

linkages between the unobserved dimensions of functions and tasks performed by the scientist were constrained to be equal. Where there was only one observed indicator for a latent dimension (e.g., diversity of functions), the linkage between the two was fixed at 1.0 with a corresponding measurement error of 0 in the observed indicator.

¹The highest residual in this case is -.191, the average residual .032, and the amount of variance explained is 81 percent. Results for technological scientists in industry are reported in Knorr et al., (1976).

²The final version of the model has been checked with the help of the Goodman technique (Goodman, 1972a, b; 1973) which has the advantages of not requiring any of the assumptions of linear regression to be met by the data and of allowing for an explicit inclusion of interaction effects. Results confirmed that there are no significant interactions or non-linearities in the variables; furthermore the model showed an excellent fit in accordance with what we should expect from the Lisrel results (see Waller, 1976).

Control for a scientist's position

As can be seen from an inspection of the model presented so far there remains a relatively high direct effect of age and professional experience on publication productivity in academic settings.¹ We have already shown that the relationship between age/experience and productivity tends to disappear when a scientist's supervisory position is controlled for (see above). In order to check the validity of our previous argument in the case of the multivariate relationships we are now confronted with, we replicated the social position model of individual publication productivity in academic natural science settings for supervisory scientists (unit heads) and staff scientists separately. In accordance with what we have said so far the model would be expected to replicate nicely for staff scientists (since this subgroup includes various kinds of supervisory positions below unit heads), but should, being a social position model, change significantly when unit heads are looked at exclusively. Figures 5 and 6 substantiate these expectations: In the case of staff scientists (Figure 5), the model maintains its significance, with only slight changes in the parameters linking the concepts, and an explained variance in productivity of 65 percent (as compared to an original 67 percent). In the case of unit heads (Figure 6), the quantity of manpower resources at the head's disposal (which was not measured for unit members) was included in the model. The latter variable yields the highest path coefficient in the resulting model, followed by the number of projects in which the supervisor is involved. This suggests that once a supervisory position is attained manpower resources and project tasks account for most of the variance in further productivity differences. In accordance with this, the direct relationship between age/experience and productivity is reduced to .03 from .45 in the global model!), clearly indicating that there is no remaining effect of age once position and what it stands for are taken into account.

(Place Figures 5 and 6 about here)

¹This is indicated by a parameter of .45 in the Lisrel model of academic natural scientists (see Figure 4) and by a parameter of .36 for academic technological scientists (model not included). It is worthwhile noting that this direct effect disappeared in industrial settings (data not shown).

Discussion

Some of the limitations of the preceding analysis can be made apparent by pointing to two different interpretations which can be associated with what we have documented: that individual productivity when analyzed in terms of organizational variables is mainly accounted for by the social position the scientist holds in the scientific hierarchy of his organization.

One interpretation (put forward by us so far) would attribute differences in publication rates to the operation of the stratification system inside organizations. Advancement on the (formal or informal) hierarchy is associated with differential access to resources and with differences in functions and involvement in research, which in turn leads to a higher probability of authorship or coauthorship for the respective scientist. This hypothesis suggests that the status of a scientist significantly affects the quantity of publications he can claim irrespective of his personal innovativeness and productivity. The second interpretation would describe differential productivity associated with position as an outcome of the differential capability and technical competence of a scientist, deriving the higher productivity of higher position scientists from a positive selection of more capable and higher performing researchers into supervisory positions.

The two interpretations do not necessarily contradict each other. If early publication productivity based on personal capacity and dynamic orientation¹ leads to promotion into supervisory status, resources and functions conducive to producing output might then replace or strongly reinforce original capacities. The last mentioned effects are verified in the present data by the significant increase of supervisory productivity obtained with an increase in the size of the scientific and technical staff supervised: it will be remembered that staff size and volume of projects together account for almost all of the variance of head's publication in the Lisrel model.

The present data do not allow for a check of original productivity capacities. They do, however, cast doubt on the view that a scientist's

¹Meltzer (1949) showed a negative association between age at first publication and career productivity and points to the general proposition that the best predictor of an activity is a specimen of past performance in the activity.

productivity suffers as he takes on supervisory duties which involve higher percentages of non-research tasks and hence keep him from pursuing research work. Except for the rarer case where a scientist leaves the scientific hierarchy, he seems to be not drawn off but rather drawn into publication productiveness by advancement in the hierarchy whatever his original production capacities may have been.

The results can be used to shed new light on the meaning of "productivity" as measured by publication counts and on some of the earlier findings relating to it.¹ If what is measured is authorship rather than talent for creating research results, and if--as pointed out by Crane²--in some fields norms allow supervisors to claim authorship for the student's or staff scientist's work whereas in others they don't, we may be more warranted to conceive of "productivity" in terms of higher rank privileges and supervisory efficiency in "productively" organizing the task force supervised than to seek explanations in terms of factors enhancing individual production capacities. Consequently, switching the attention from the notion of (publication) productivity as used in the literature to the notion of authorship as emerging from the present analysis may pave the way for a better understanding of science as a highly stratified and elitist system and of the impact this has on the development of scientific knowledge.

¹The results of Blume and Sinclair (1973), which show that higher rank scientists are more productive in larger groups and that the relationship between group size and individual productivity varies between specialties, can for instance be reinterpreted as showing the advantages higher rank scientists gain from staff size. Equivalently, the results can be held to confirm the relevance of norms specific to single fields in establishing higher rank privileges.

²Comment on this paper.

PART 3. Motivation and the performance of research units¹

Some teams seem dedicated to the work they are doing. For them, the research or development in which they are engaged presents high challenge. They are heavily involved in what they are doing and committed to making the maximum possible progress on the task before them. In these labs the lights are on well after the formal quitting time, and there is hardly time for an extended lunch or coffee break. This portion of the paper will show that motivation varies systematically from team to team (and hence can be considered as a characteristic of the research unit, as well as of the people who are members of the unit), and that where this sense of dedication is high, many kinds of research performance also tend to be high.

The idea that more dedicated scientists might do better research and development work is not a new one. It has obvious links to parallel ideas that high esprit de corps will contribute to the effectiveness of military units, that high morale will help a firm become profitable, or that high commitment is important for political party workers, monks, or bureaucrats. Although the idea is an appealing one, the expected relationship among scientists has been questioned by research results that will be cited shortly, and--so far is now known--has never before been examined as a phenomenon characterizing research units as a whole and related to units' performance.

Some past research on motivation and scientific performance

In 1967 Lodahl and Kejner published an article titled "The definition and measurement of job involvement." They wrote: "Job involvement is the degree to which a person is identified psychologically with his work, or the importance of work in his total self-image [p. 24]." They recommended several items (to be answered on a degree of agreement scale) that could be used to measure workers' sense of job involvement. These included

¹This portion of the paper is an abbreviated version of a chapter by Frank M. Andrews that will appear in the forthcoming book of scientific reports from the project (see Andrews, in preparation).

"The major satisfaction in my life comes from my job," "The most important things that happen to me involve my job," "I live, eat, and breathe my job," and "I am very much involved personally in my work." Their concept of job involvement is essentially identical to what we shall mean by "strength of motivation" or "dedication."

In a more recent article, Lawler and Hall (1970) distinguished between three types of attitudes which workers hold toward their jobs. The three were "job involvement," "satisfaction," and "intrinsic motivation." They accept the Lodahl and Kejner definition which is cited above for job involvement and include the items recommended by Lodahl and Kejner in their questionnaire. The Lawler and Hall article is interesting for two reasons. First, based on a factor analysis of questionnaire data obtained from 291 scientists in 22 R&D laboratories, they conclude that job involvement is a concept statistically separate from both satisfaction and intrinsic motivation. Thus Lawler and Hall plead that a sense of involvement in work not be confused with either satisfaction with work, or a belief that specific rewards will follow from a job well done. Second, they found their measure of job involvement, which consisted of the four items cited above (selected from the earlier work of Lodahl and Kejner), to be uncorrelated ($r = .01$) with self-rated performance! Thus here is one study in which the "obvious" relationship between strength of motivation and a measure of scientific performance did not appear.

The expected relationship also failed to appear in another study reported by Goodman, Rose, and Furcon (1970). Although they found reasonable convergent and discriminant validity for the Lodahl and Kejner measure of job involvement (Goodman, Furcon, and Rose, 1969), they found an essentially zero relationship with four measures of scientific performance (r 's ranged from $+0.10$ to -0.07). Their finding is based on data from 66 employees of a U.S. government research laboratory.

Should we believe--on the basis of these two studies--that a scientist's motivation is unrelated to research performance? This is contrary to what a naive observer would expect. It is also contrary to findings from an earlier and much larger study of scientists by Pelz and Andrews (1966). Working at about the same time as Lodahl and Kejner, but independently from them, Pelz and Andrews incorporated in their questionnaire a set of five items which they used to measure dedication. The items asked scientists to indicate their feelings of involvement and identification with

their work, and to say how challenging, important, and interesting they found their work. Using data from more than 1300 scientists, they found that these items showed significant positive relationships to both ratings of performance and actual outputs of scientific products, for scientists of widely different types and in widely different types of laboratories. Relationships tended not to be very strong (most r 's were .2 or .3), but they were consistent and positive.

When the "job involvement" measure proposed by Lodahl and Kejner, and subsequently administered to scientists by Lawler and Hall, and by Goodman, Rose, and Furcon seems so similar to the concept assessed by Pelz and Andrews, it seems strange that similar relationships to performance did not emerge. The explanation may reside in the relatively weak performance measure employed by Lawler and Hall, and in some idiosyncrasy of the relatively small number of cases investigated by Goodman, Rose and Furcon, but these can be only speculations. Although the Pelz-Andrews data are undoubtedly the more extensive, and their results seem more in accord with expectation, the presence of contrary findings calls for further examination. The data of the present study permit just such an exploration.

Measurement of strength of motivation in the present study

The questionnaires used in the present study included three items tapping strength of motivation. All asked respondents to indicate their answers by picking one of five categories along a scale ranging from "X" to "Y" according to the degree to which the X or Y statements applied.

In the first item, the X and Y statements were as follows: (X) "There is an atmosphere of great dedication to work in the unit"; (Y) "There is a feeling that everyone in the unit only works to make a living." We shall refer to this as the "dedication" item. For the second item, the polar categories were: (X) "I do a great deal of voluntary overtime"; (Y) "I do no voluntary overtime." This is the "voluntary overtime" item. And the third item reads: (X) "The work I do is very interesting"; (Y) "The work I do is not very interesting." We call this the "interest of work" item. Note that in the first item the respondent reports a perception regarding the research unit, while in the latter two the reference is to a feeling or action of the individual person.

All surveyed respondents--unit heads, other scientists, and technical

support staff¹--were asked the first two items; the third item, on interest of work, was not asked of the unit heads. After aggregating answers from the non-staff scientists and from the technical support staff and computing means for each, there were eight "basic" motivation measures: two from the unit head, three from the other scientists, and three from the support staff.

Levels of motivation in different types of respondents and units

Our main interest in motivation is in how it relates to the performance of research units. However, further insight regarding the motivation measures themselves and some interesting background information will come from a brief look at how motivation levels varied for different types of respondents and in different types of units.

Types of respondents and motivation levels. In general levels of motivation were highest for scientists who were heads of units and lowest for people in technical support roles. Staff scientists tended to fall between these two extremes.

The biggest differences appeared with respect to voluntary overtime. On the five-point scale ranging from "I do a great deal of voluntary overtime," to "I do no voluntary overtime," the technical support members tended to put themselves about in the middle. The unit heads, however, tended to put themselves just a half step short of the most extreme "I do a great deal . . ." answer. (Non-supervisory scientists tended to put themselves about one full step short of the extreme answer.) This very same pattern appeared in each of the five types of research units and in each of the six countries from which we have data (not shown).²

¹In the exhibits of this paper, measures based on information obtained from the unit head will carry the designation "SA," those from staff scientists, "SB," and those from technical support staff, "TS."

²The five types of research units are:

1. Units engaged in exact and natural sciences and located in academic organizations.
 2. Units engaged in medical and social sciences and located in academic organizations.
 3. Units engaged in applied sciences and located in academic organizations.
 4. Units located in cooperative R&D institutions.
 5. Units engaged in applied sciences and located in industrial organization.
- For a description of the statistical explorations which led to this typology, see Cole, G. (1975).

That unit heads tended to see themselves as spending more voluntary overtime than did others in their units is, of course, no surprise to anyone familiar with the organization of R&D, and, we believe, lends credence to the validity of this measure.

Unit heads were not asked how interesting they found the work, but staff scientists and technical support members were, and here again we found an absolutely consistent difference--in all types of units and in all countries. People in technical support roles tended to judge the work they do less interesting than did the staff scientists for the work that they do. Again, the difference is in accord with what informed observers would expect and supports the validity of the measure.

The smallest differences appeared for the item which asked about dedication in the research unit, and this also is entirely reasonable. Recall that unlike the previous two items, which inquired about personal activities and feelings, this one asked for a judgment about the unit. On this item, support personnel and non-supervisory scientists gave--on the average--the same answer, and unit leaders gave answers which indicated only slightly higher dedication. Ideally, there would have been no differences on this item according to a person's role in the unit since all answers refer to the same thing--the general sense of dedication in the unit. The fact that supervisors saw the unit as more highly dedicated than did the other members may be wishful misperception on their part!

Types of units and levels of motivation. When we compared types of units for levels of motivation, reports of voluntary overtime stood out. There was a clear distinction between academic settings and others: scientists (both team leaders and others) in academic settings tended to report more voluntary overtime than did scientists in either cooperative institutions or voluntary organizations. Interestingly, there was no such difference for people in technical support roles; these people claimed about the same amount of voluntary overtime regardless of the type of unit they were in.

Comments. These very reasonable patterns of differences, as well as being interesting in their own right, help us to have confidence that questionnaire items intended to tap motivation levels are in fact reflecting motivation. It comes as no surprise to find that team leaders seem more motivated than the technical support staff, with the staff scientists

located in between. And to find these differences bigger for the voluntary overtime and interest items than for the dedication item is just what one should expect when one realizes that the first two are descriptions of individual characteristics while the latter asks for perceptions of the team as a whole. While there might be more debate as to what differences should be expected across types of units, our finding that motivation levels, particularly voluntary overtime, were highest in academic settings will match the expectations of many observers.

Strength of motivation as a characteristic of the research unit

Relationships among the eight basic motivation measures are not high, but consistently positive and, in most cases, statistically significant.¹ The correlation between the two items answered by the unit heads is .19; the mean correlation among all possible pairs of the three measures based on answers by the staff scientists is .31 (range: .26 to .39); and the comparable mean for measures from the technical support people is .20 (range: .14 to .29). It follows, then, that items asking about dedication, voluntary overtime, and interest of work do show modest covariation and that this pattern is replicated for all three types of respondents. For the data from staff scientists and technical support staff, where our measures are mean scores from all such respondents in the unit, it is hard to attribute this covariation to anything other than that the items all tap a common phenomenon--the level of motivation within the unit.

Two additional sets of results also suggest that motivation levels vary systematically from unit to unit.

Another way of investigating whether motivation can be regarded as a unit characteristic is to see whether different types of members in the same unit tend to give similar answers regarding the level of motivation in that unit. Hence we looked to see whether there was statistically significant agreement among the answers given by the unit head,

¹When correlations are computed using data from all 1222 research units, conventional tests of statistical significance would show any correlation larger than .07 to be statistically significant beyond the .01 level. Although the sampling design of the present study does not match assumptions built into conventional tests, making proper allowance for these differences would not markedly change the level required for significance.

the average of the answers given by the staff scientists, and the average of the answers from the technical support people. These relationships were all positive and were all significantly different from zero.¹ The fact that members in different roles within the same research unit tended to show at least modest agreement regarding the extent of motivation within the unit is further evidence that motivation level varies systematically from team to team .

In a different approach to this same question, we looked to see how the variation among non-supervisory scientists within the same unit compared with that of non-supervisory scientists in different units. If motivation level can be considered a characteristic of the unit, then the variation within units should be less than that between units. To test this, a "strength of motivation index" was computed for each individual non-supervisory scientist by summing his or her answers to the dedication and voluntary overtime items. Then differences between scientists within the same unit were compared with differences between scientists in different units. (The analysis was done separately in each of the five types of research units so that any motivation differences which might be attributable to type of unit could not influence the results.)

Our expectations were clearly supported. Typically, there was twice as much variation between units as within units, and the same general pattern occurred in each of the five distinctly different types of units (median value = 2.0; range: 1.7 to 2.5).²

We conclude, then, that research teams differ systematically with respect to their members' motivation levels and that it is meaningful to consider strength of motivation as a characteristic of the unit as a whole.

On the basis of the findings reported in this section we constructed a unit-level measure, which we shall call the "Motivation Index," by summing four of the more basic motivation measures--the unit head's answers to the dedication and voluntary overtime items, and the mean

¹ $p < .01$ in all cases

² Statistically experienced readers will recognize this as a one-way analysis of variance in which unit identification was used as the independent variable. The values cited are those of the F statistic. Given the numbers of units having two or more SB scientists (this ranged from 86 to 371 across the five types of units) and the number of SB scientists in units where there were at least two such people (range: 238 to 1057), all F's were statistically significant, most beyond the .001 level.

answers to these items given by the staff scientists in the unit. (Other basic measures could also have been included in a general index but would have proved redundant; data not shown.)

Relationships of motivation strength to research unit performance

We are now ready to see how the general level of motivation within the research units related to their performance. Table 2 provides some of the results. Shown there are correlations (r 's) between the eight basic motivation measures, plus the Motivation index, and ten different measures of performance. (All performance measures have been adjusted to remove variation which could be attributed to differences between types of units.)

(Place Table 2 about here)

Several types of findings emerge in Table 2.

First, the relationship between motivation and performance tend to be positive; the few negative relationships are, without exception, all very small. As a very general statement, then, it appears that research units in which there is a higher sense of commitment are the units in which performance--at least some aspects of it--tend to be higher.

Second, nowhere in Table 2 are the relationships very strong. Differences between units in their members' sense of dedication, voluntary overtime, and interest in the work do not by themselves explain a large part of the differences in units' performance.

Third, some aspects of performance show higher relationships to members' motivation than others. Motivation tends to be most highly related to ratings of R&D effectiveness. It seems clearly unrelated to output of Patents and prototypes and of Reports and algorithms.

Fourth, motivation reported by the scientists in a unit (both the unit head and staff scientists) shows somewhat stronger relationships to performance than does the motivation reported by the technical support people. (Compare the SA and SB columns in Table 2 with the TS columns.) Although this finding might not have been predicted in advance, it does not seem unreasonable. Given that most of the initiative for the work of a research unit comes from its professional members, what may be of

primary importance for the technical support staff is the conscientious application of their technical skills, and this may be possible even in the absence of a high sense of commitment to the particular projects on which the unit is engaged.

Fifth, note that the Motivation index provides a convenient summary of the general patterns just discussed and, in some cases, shows relationships to performance which are somewhat stronger than those indicated by any one of the more basic measures. This is particularly evident for R&D effectiveness and Training effectiveness, but occurs for other aspects of performance as well. We assume this results from the Motivation index being a more broadly based--and hence more valid--indicator of the sense of commitment by scientists within a research unit, and from the likelihood that it is commitment by all scientists which is related to unit performance.

Several checks suggest that the use of Pearson r's and the adjusted performance measures in Table 2 is indeed appropriate. The correlation coefficient r indicates only the linear component of a relationship, but a careful initial exploration showed that these relationships are in fact primarily linear. (Some of the evidence for this will be seen shortly in Figures 7 and 8.)

With respect to the use of adjusted performance measures, we can report that the same general pattern of results also appeared for the unadjusted performance measures. However, by using the adjusted measure we are assured that differences in the focus of a unit's work (e.g., academic units giving relatively more emphasis to training and publications, while industrial units focus more on applications and patents) did not generate spurious relationships with motivation.¹

Having determined that across the full set of research units included in our data motivation showed modest positive relationships to some aspects of performance, it is important to check the generality of this finding.

¹There is no doubt that differences between types of units in both goals and motivation levels did influence the correlations between motivation and some of the unadjusted performance measures: Compared to the figures shown in Table 2, those for the unadjusted measures were somewhat higher for Training effectiveness, Recognition, and Published written output; and were somewhat lower (less positive or more negative) for Applications effectiveness, Output of patents and prototypes, and Output of reports and algorithms.

Relationships similar to those shown in Table 2 were examined separately for each of the five types of research units and for each of the six countries. With remarkable consistency, the same trends emerged. We conclude that the patterns shown in Table 2 occur very generally--in units located in widely different types of organizations, investigating widely different scientific disciplines, and set in widely different national cultures.

Figures 7a to 7e plot the relationship between the Motivation index and three selected performance measures for each of the five types of research units. Figure 8 shows the same results for all units combined.

(Place figures 7 and 8 about here)

Discussion and conclusions on motivation and performance

Four general conclusions have emerged in this part of the paper. First, we have seen that items intended to tap strength of work motivation among members of a research unit relate to one another in expected ways and also show reasonable differences in levels between unit heads, other scientists, and technical support staff. These findings support the validity of the motivation measures.

Second, we have seen that motivation levels show systematic variation across units. There is more variation between units than within, and—within a given unit—people in different roles tend to show somewhat similar motivation levels. It follows that it is reasonable to think of motivation strength as a characteristic of the group of people banded together to conduct a research project: teams, as such, tend to be more or less committed to their work.

Third, we have seen that a team's commitment to its work relates to many (but not all) aspects of its research performance. The strongest relationships appear for ratings of the team's R&D effectiveness; all other ratings of effectiveness show some significant relationship to the team's motivation, and so does output of published written products. The output of patents and prototypes, and of reports and algorithms, however, seem unrelated to the team's motivation. Although the relationships are not strong, they are remarkably general, occurring for units of all types and for units in all six countries.

Fourth, we can report that a relatively simple Motivation index was found to reflect most of the predictive power of the combined measures and that more complicated additive or non-additive indices offered little promise of further gains (data not shown).

Before concluding this section we would briefly consider the strength of the relationships we have observed. How should we interpret the correlations between the Motivation index and performance? Even the strongest--the .36 with R&D effectiveness--is clearly not overwhelming. It seems important to remember two things when looking at results such as these.

The first is that these data provide less-than-perfect indicators of the phenomena in which we are interested. Even if a pair of phenomena were highly related, one could obtain only a low correlation between indicators of these phenomena if the indicators included large amounts of random measurement error. Although we do have some empirical estimates of the construct validity and random error components of the performance measures (Andrews, 1975), we have no similar estimates for the motivation measures. If, however, we were to assume that the composition of the Motivation index were identical to that estimated for the R&D effectiveness measure,¹ what would we conclude about the relationship of "true" motivation to "true" R&D effectiveness? An estimated correlation of .49 can be derived. Similarly, the underlying relationship between "true" motivation level and the "true" General contribution of the unit can be estimated at .30.² Thus by applying a set of previously obtained empirical estimates and some admittedly large, but not unreasonable assumptions, we generate results suggesting the motivation level of the unit might explain something in the order of 10 to 20 percent of the variance in those aspects of performance to which motivation is most relevant, after allowing for the invalidities and common biases in the measurements.³

¹The R&D effectiveness measure used in the present chapter has been estimated to consist of 58% valid variance, 4% variance attributable to SA bias/halo, 4% variance attributable to SB bias/halo, 11% variance attributable to EV bias/halo, and 23% random error (Andrews, 1975).

²These values were obtained by applying the formula presented in Appendix B of Andrews, 1975.

³Recall that the square of a correlation shows the percentage of variance in one variable that can be explained by another. Similarly, the square of a multiple correlation shows the percentage of variance in the dependent variable which can be explained by an optimally weighted additive combination of the independent variables.

The second thing to be remembered when considering the strength of the motivation-performance relationships is that one should not expect anything as complex as the performance of a research unit to be fully explained by one factor. Experience and common sense suggest that the level of a unit's performance is determined by a multitude of factors, including such "obvious" factors as the skills and intelligence of its members, and the availability of appropriate methods and materials for the task at hand. Correlations of 1.00 should not be expected in investigations such as this one, and if as much as 10 or 20 percent of the variance in performance can be explained by a single organizational factor we should probably be satisfied.

Finally, we would add a caution about causal assumptions. What the statistical results show is that motivation levels are significantly related to at least some aspects of research unit performance. The results do not prove that higher motivation causes higher performance. Given only these results, one cannot be sure that causality may not operate in the other direction, i.e., that good performance leads to high motivation, or conceivably, that both motivation and performance are the result of some third factor. (However our analyses have explicitly eliminated two of the most likely "third" factors: the relationships persist even when the performance measures are adjusted for differences between types of units; and the possibility of the results being due to a simple response bias has been eliminated.) With the data presently available it is not possible to determine the extent of causal priority (or reciprocity) between motivation and performance. For the present, we must be satisfied at having demonstrated the existence and generality of the relationship and at having obtained some approximate estimates of its strength.

References

- Andrews, F.M. (1975) Estimating the construct validity and correlated error components of the rated effectiveness measures. (Unpublished document prepared for International Comparative Study on the Organization and Performance of Research Units, Division of Science and Technology Policies, UNESCO). Paris, UNESCO
- Andrews, F.M. (ed.) (In preparation) Scientific productivity: Research units in six countries.
- Blume, S.S. and Sinclair, R. (1973) Chemists in British universities: A study of the reward system in science. American Soc. Review, 38: 126-138.
- Blume, S.S. and Sinclair, R. (1973) Research environment and performance in British university chemistry, London, Science Policy Studies No. 6 HMSO.
- Clark, Kenneth (1957) America's psychologists. Washington, D.C., American Psychological Association.
- Crane, D. (1965) Scientists at major and minor universities: A study of productivity and recognition. American Soc. Review, 30: 699-714.
- Cole, G. (1975) Development of a performance typology for research units in the first round data: A preliminary analysis report. Unpublished document STP/525, Paris, UNESCO.
- Cole, J. (1970) Patterns of intellectual influence in scientific research. Sociology of Education, 43: 377-403.
- Cole, S. and Cole, J.R. (1967) Scientific output and recognition: A study in the reward system in science. American Soc. Review, 32: 377-90.
- Cole, S. and Cole, J.R. (1968) Visibility and the structure bases of awareness of scientific research. American Soc. Review, 33: 397-413.
- Cole, S. and Cole, J.R. (1971) Measuring the quality of sociological research: Problems in the use of the Science Citation Index. American Sociologist, 6: 23-29.
- Coler, M.B. (ed.) (1963) Essays on creativity in the sciences. New York: University Press.
- Dennis, W. (1954) The bibliographies of eminent scientists. Scientific Monthly, 79: 180-183.
- Gaston, J.C. (1969) Big science in Britain: A sociological study of the high energy physics community. Ph.D. thesis, Yale University, New Haven, Connecticut.
- Goodman, L.A. (1972a) A modified multiple regression approach to the analysis of dichotomous variables. American Soc. Review, 37: 28-46.

- Goodman, L.A. (1972b) A general model for the analysis of surveys. American Journal of Sociology, 78: 1035-86.
- Goodman, L.A. (1973a) Causal analysis of data from panel studies and other kinds of surveys. American Journal of Sociology, 78: 1135-91.
- Goodman, P.S., Furcon, J.E., and Rose, J.H. (1969) Examination of some measures of creative ability by the multitrait-multimethod matrix. Journal of Applied Psychology, 53: 240-243.
- Goodman, P.S., Rose, J.H. and Furcon, J.E. (1970) Comparison of the motivational antecedents of the work performance of scientists and engineers. Journal of Applied Psychology, 54: 491-495.
- Hargens, L.L. and Hagstrom, W.O. (1967) Sponsored and contest mobility of American academic scientists. Sociology of Education, 40: 24-38.
- Hagstrom, W.O. (1967) Competition and teamwork in science. mimeo, University of Wisconsin Department of Sociology, Madison, Wisconsin.
- Hagstrom, W.O. (1971) Inputs, outputs and the prestige of university science departments. Sociology of Education, 44: 375-97.
- Joreskog, K.G. and Thillo van, M. (1972) Lisrel: A general computer program for estimating a linear structural equation system involving multiple indicators of unmeasured variables. Unpublished research bulletin, RB-R-26, Educational Testing Service, Princeton, N.Y.
- Joreskog, K.G. (1974) Analyzing psychological data by structural analysis of covariance matrices. In Contemporary Developments in Mathematical Psychology, vol. III, D.H. Krantz, R.D. Luce, R.C. Atkinson and P. Suppe (Eds.) San Francisco: W.H. Freeman and Company.
- Knorr, K., Mittermeir, R., Aichholzer, G. and Waller, G. (1976) Individual publication productivity as a social position effect in academic and industrial research units. Paper presented at the Parez-IAS colloquium on "The Role of Research Organizations in Orienting Scientific Activities," Vienna, July 5-6, 1976.
- Lawler, E.E. III and Hall, D.T. (1970) Relationships of job characteristics to job involvement, satisfaction, and intrinsic motivation. Journal of Applied Psychology, 54: 305-312.
- Lehmann, M.C. (1953) Age and achievement. Princeton, N.J.: Princeton University Press.
- Lehmann, M.C. (1958) The chemists most creative years. Science, 127: 1213-1222.
- Lehmann, M.C. (1960) The age decrement in scientific creativity. American Psychologist, 15: 128-134.
- Lodhal, T.M. and Kejner, M. (1965) The definition and measurement of job involvement. Journal of Applied Psychology, 49: 24-33.
- Lotka, A.Y. (1926) The frequency distribution of scientific productivity. Journal of the Washington Academy of Sciences, 16: 317-323.

- Merton, R.K. (1968) The Matthew effect in science. Science, 59: 56-63.
- Meltzer, B.M. (1949) The productivity of social scientists. American Journal of Sociology, 55: 25-29.
- Meltzer, L. (1956) Scientific productivity in organizational settings. Journal of Social Issues, 12: 32-40.
- Pelz, D.C. and Andrews, F.M. (1966) Scientists in organizations: Productive climates for research and development. New York: John Wiley and Sons.
- Price, D.J. de Solla (1963) Little science, big science. New York: Columbia University Press.
- Thomasson, P. and Stanley, J. (1966) Exploratory study of productivity and 'creativity' of prominent psychometricians. Unpublished manuscript, University of Wisconsin.
- Waller, G. (1976) Individuelle produktivität in akademischen forschungsorganisationen: Eine Goodman analyses, Wien, Institut für Höhere Studien.
- Whitley, R. (1976) Types of science: Organizational strategies and patterns of work in research laboratories in different scientific fields. Paper presented at Parex-IAS Colloquium, Vienna, Institute for Advanced Studies.
- Zuckerman, H.A. (1970) Stratification in American science. Sociological Inquiry, 40: 235-257.
- Zuckerman, H. and Merton, R.K. (1971) Patterns of evaluation in science, institutionalization, structure and functions of the referee system. Minerva, 9: 66-100

Table 1: Pearson r's between age/experience and publication productivity for different subgroups of academic scientists

	Pearson r of productivity with	
	chronological age	professional experience
Unit heads		
natural scientists	.05	.13
technological scientists	.00	.13
Unit members		
natural scientists	.34**	.43**
technological scientists	.32**	.44**
Academic natural scientists (total)	.46**	.51**
Academic technol.scientists	.43**	.50**

** significance $\geq .001$

Table 2

Relationships of Motivation Strength to 10 Measures of Research Unit Performance

Performance Measures ^a	Motivation Measures						Motivation Index
	Dedication			Voluntary Overtime		Interest of Work	
	SA	SB	TS	SA	SB		
<u>Rated Effectiveness</u>							
General contribution	.21	.18	.06	.09	.07	.02	.15
Recognition	.20	.15	.08	.12	.10	-.02	.08
R & D effectiveness	.25	.30	.11	.15	.19	.08	.12
Training effectiveness	.18	.14	.06	.14	.14	.02	.08
Social effectiveness	.08	.15	-.02	.10	.09	.06	.06
Application effectiveness	.11	.18	.09	.04	.10	.12	-.01
Administrative effectiveness	.17	.13	.07	-.00	-.01	.01	.09
<u>Output</u>							
Published written output	.07	-.03	.03	.12	.04	-.05	.04
Patents and prototypes	-.05	-.02	-.03	.05	.02	-.01	.07
Reports and algorithms	-.03	-.03	-.00	.06	-.01	.05	.01

NOTE: Coefficients are Pearson r's.

^aAll performance measures have been adjusted to remove differences attributable to type of unit.

Figure 1: Mean publication productivity and chronological age for scientists in academic natural and technological sciences as well as for scientists in industrial units.

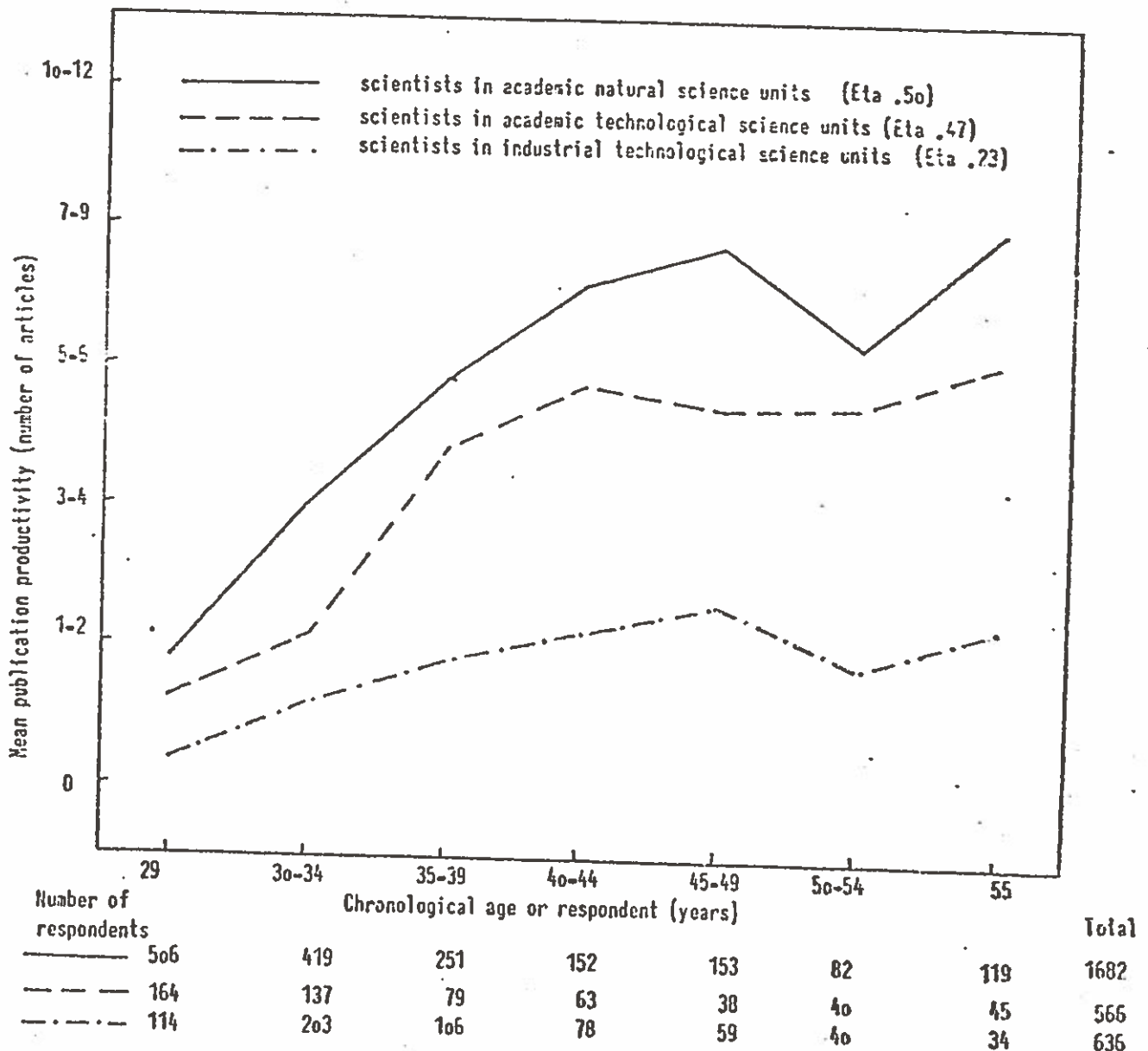


Figure 2: Mean publication productivity of supervisory scientists for different manpower resources of scientists and engineers at their disposal in academic natural and technological science units and in industrial settings

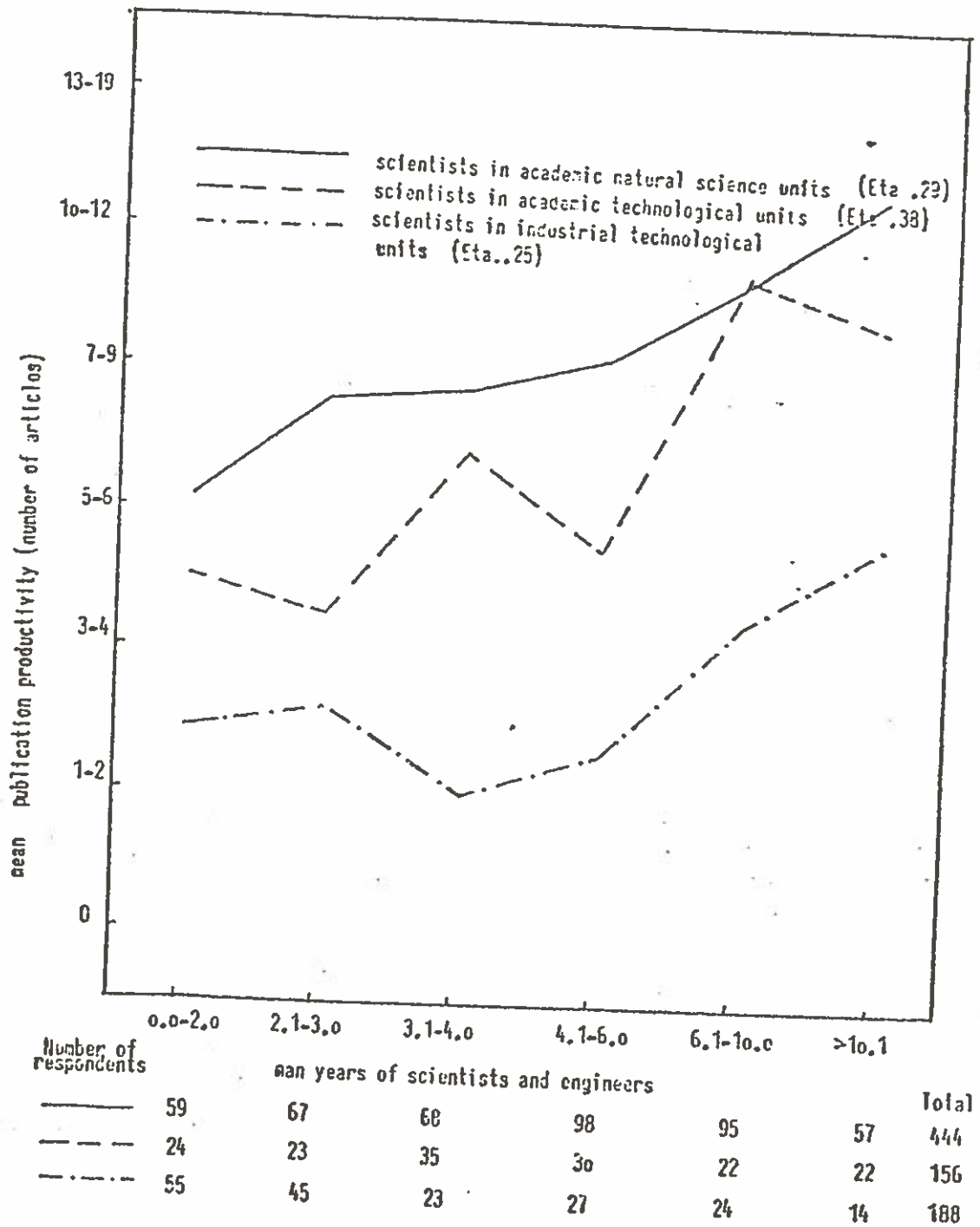


Figure 3: Mean publication productivity of supervisory scientists for different manpower resources of technical and service staff at their disposal in academic natural and technological science units and in industrial settings

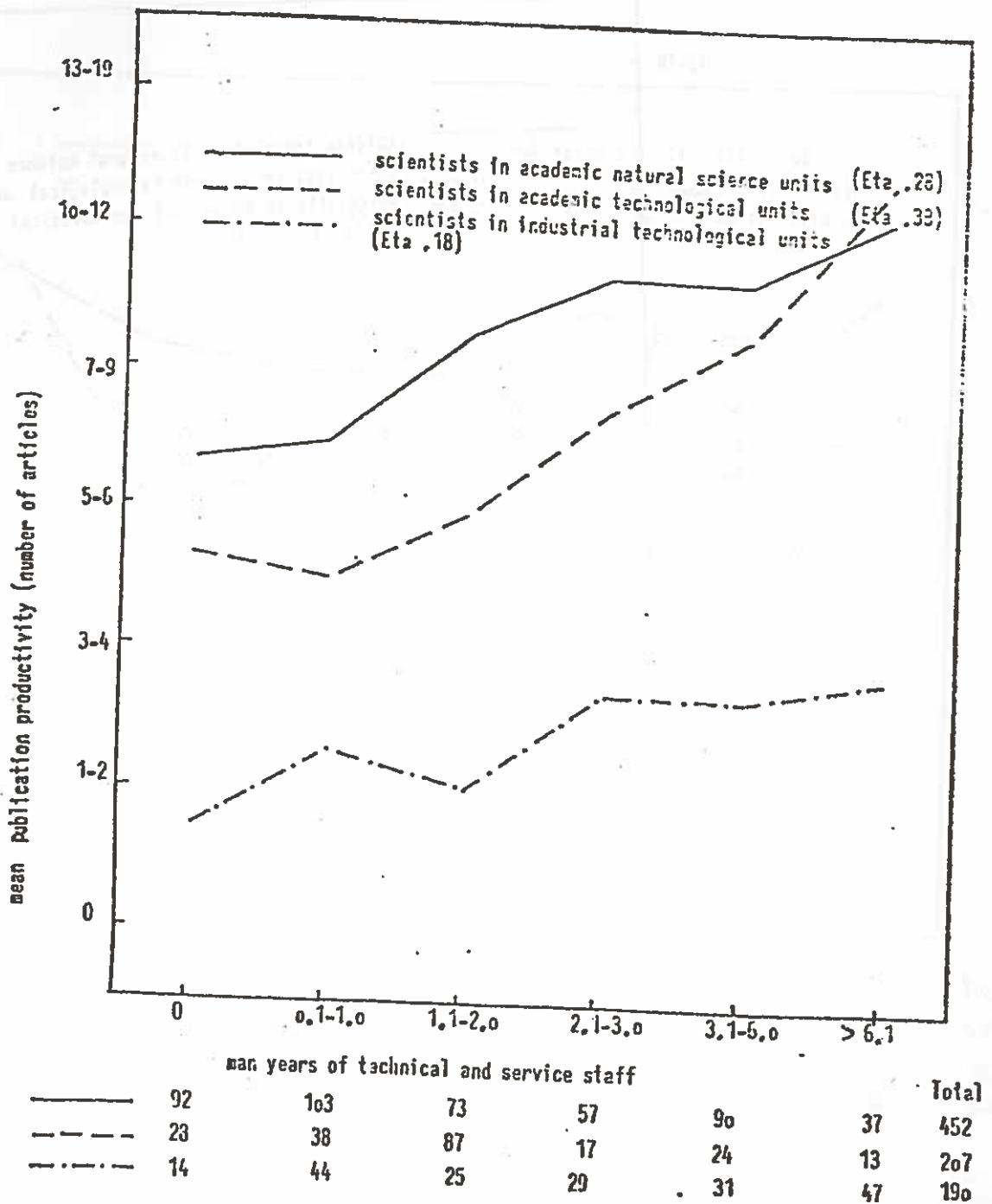
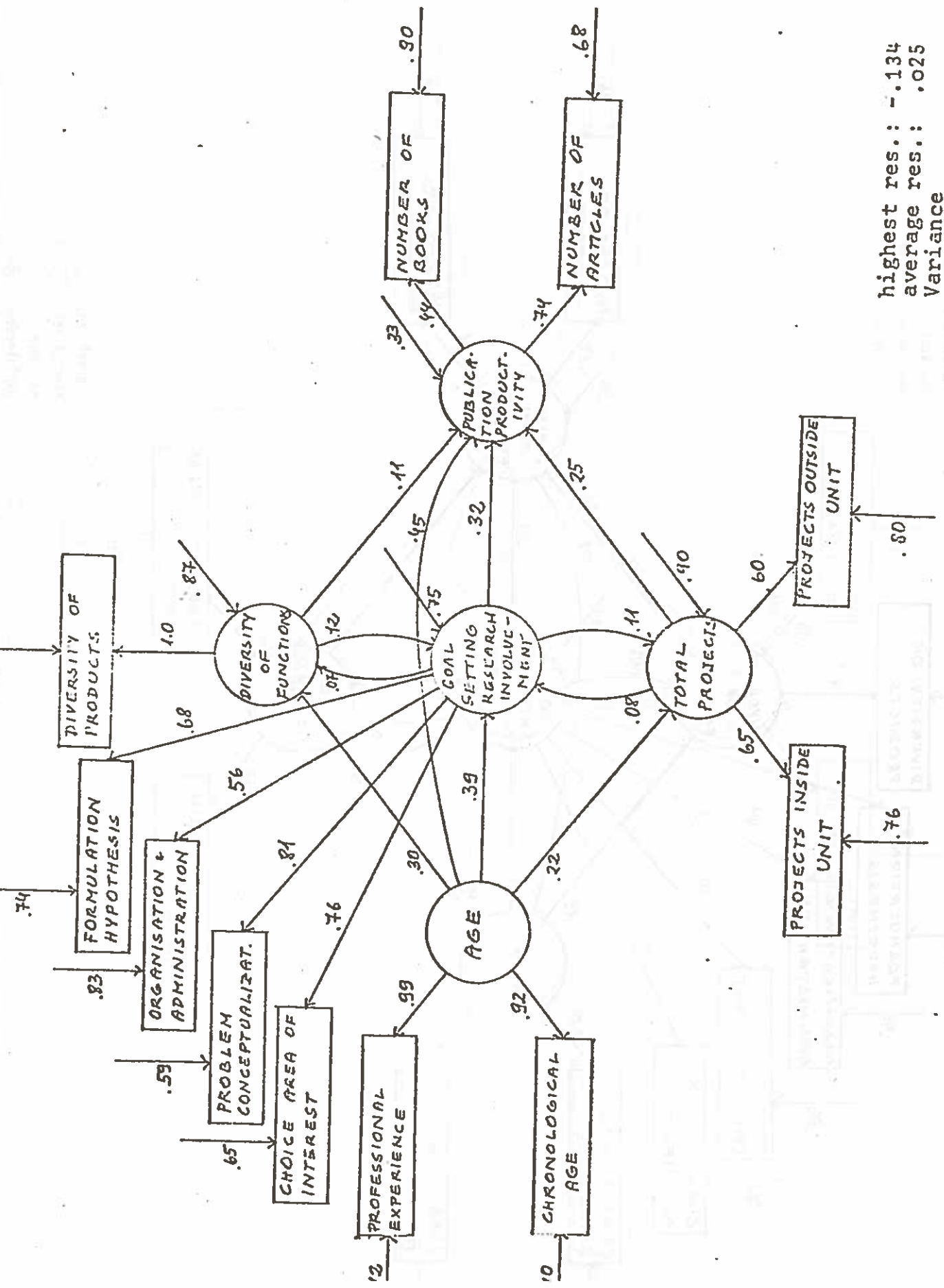
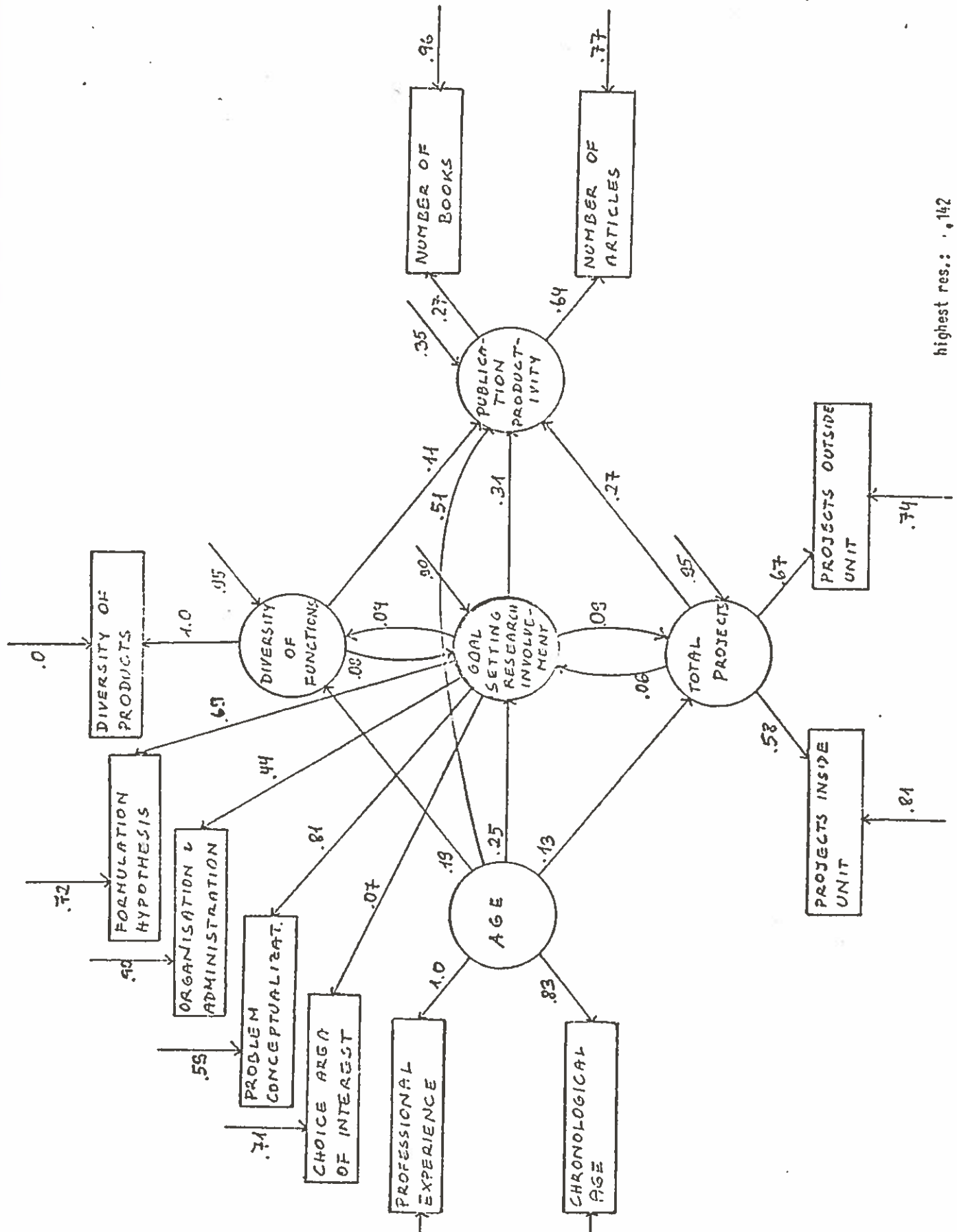


Figure 4: Lisrel model of individual publication productivity as a social position effect for scientists in academic natural science units



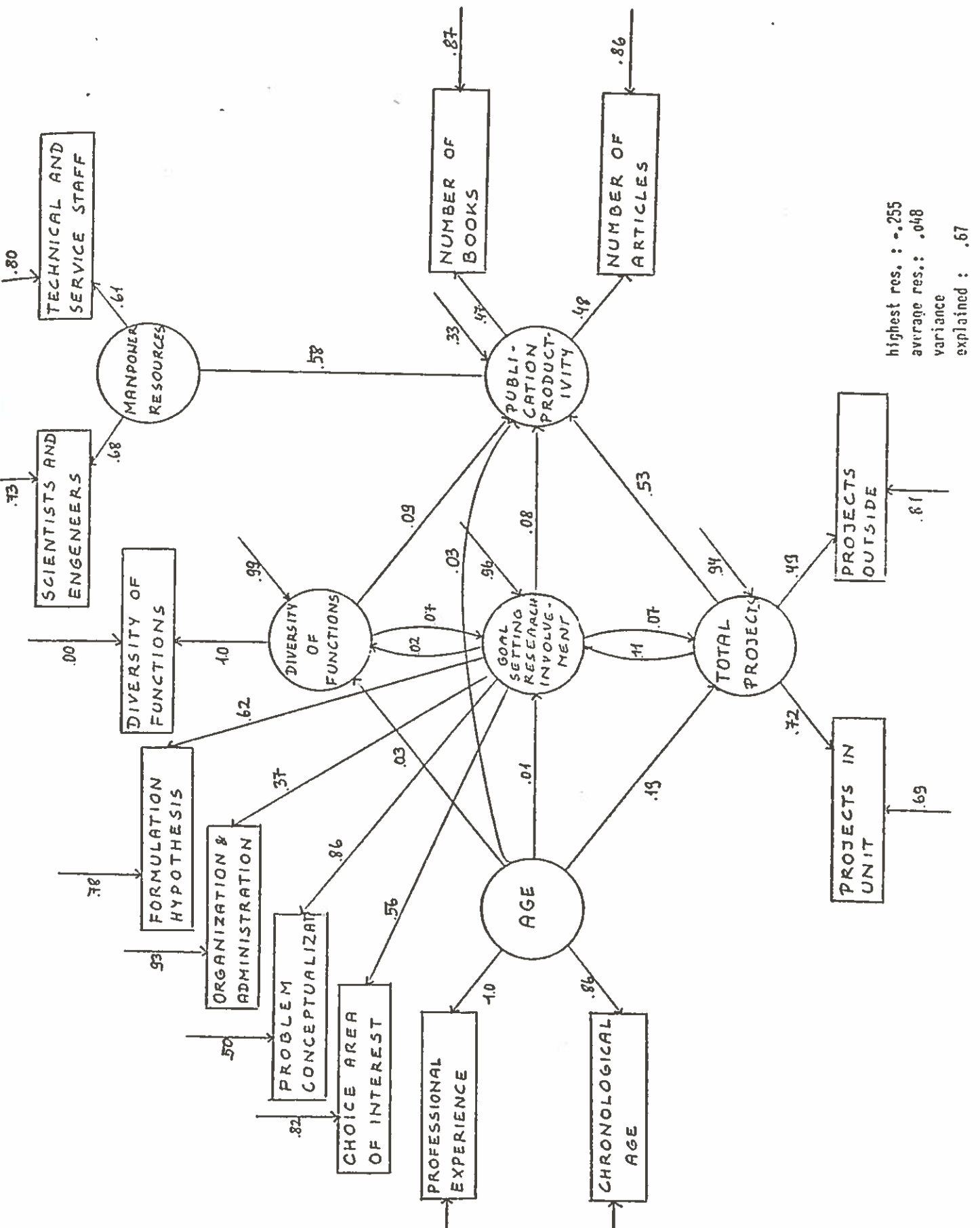
highest res.: -.134
 average res.: .025
 Variance explained: .67

Figure 5: Lisrel model of individual publication productivity as a social position effect for academic natural sciences (excluding unit heads) -38-

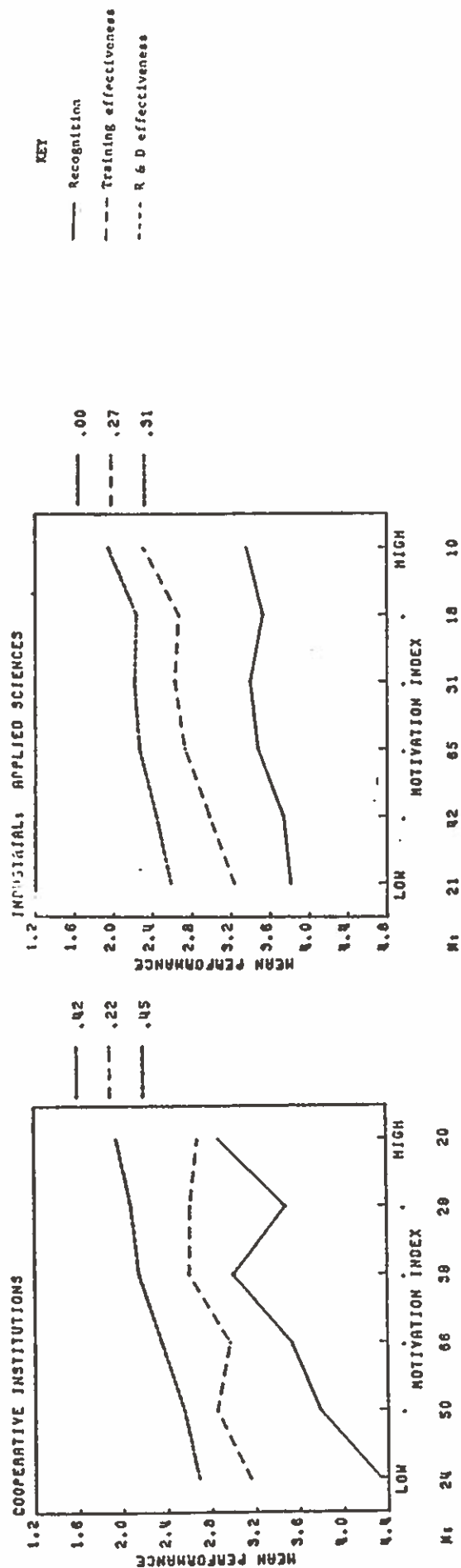
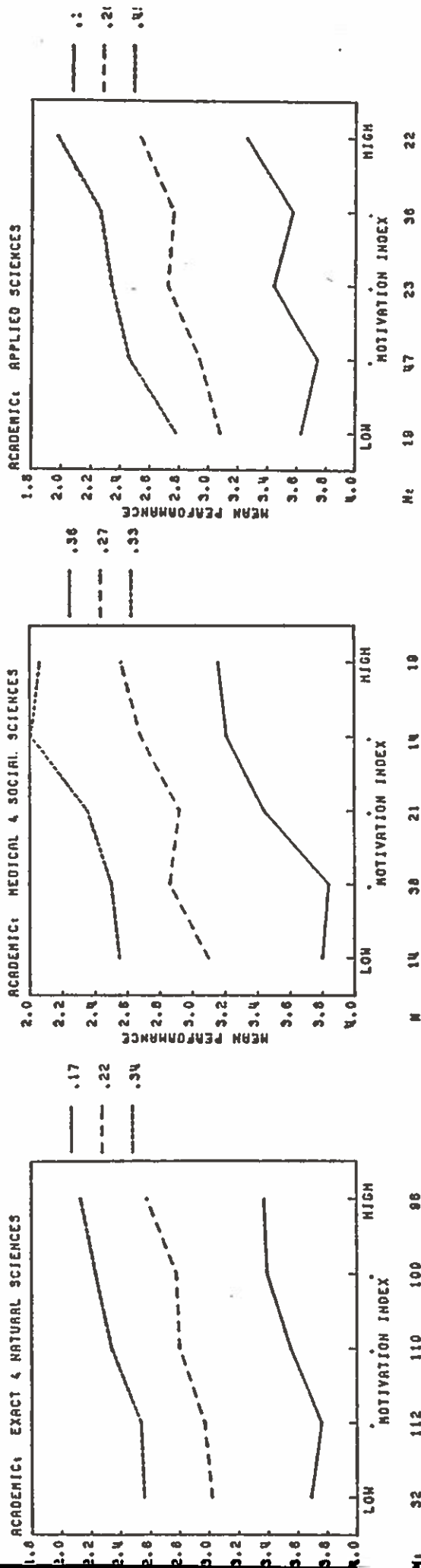


highest res.: .142
average res.: .019
variance explained: .65

Figure 6 : Lisrel model of individual publication productivity for supervisory scientists (unit heads) in academic natural science settings



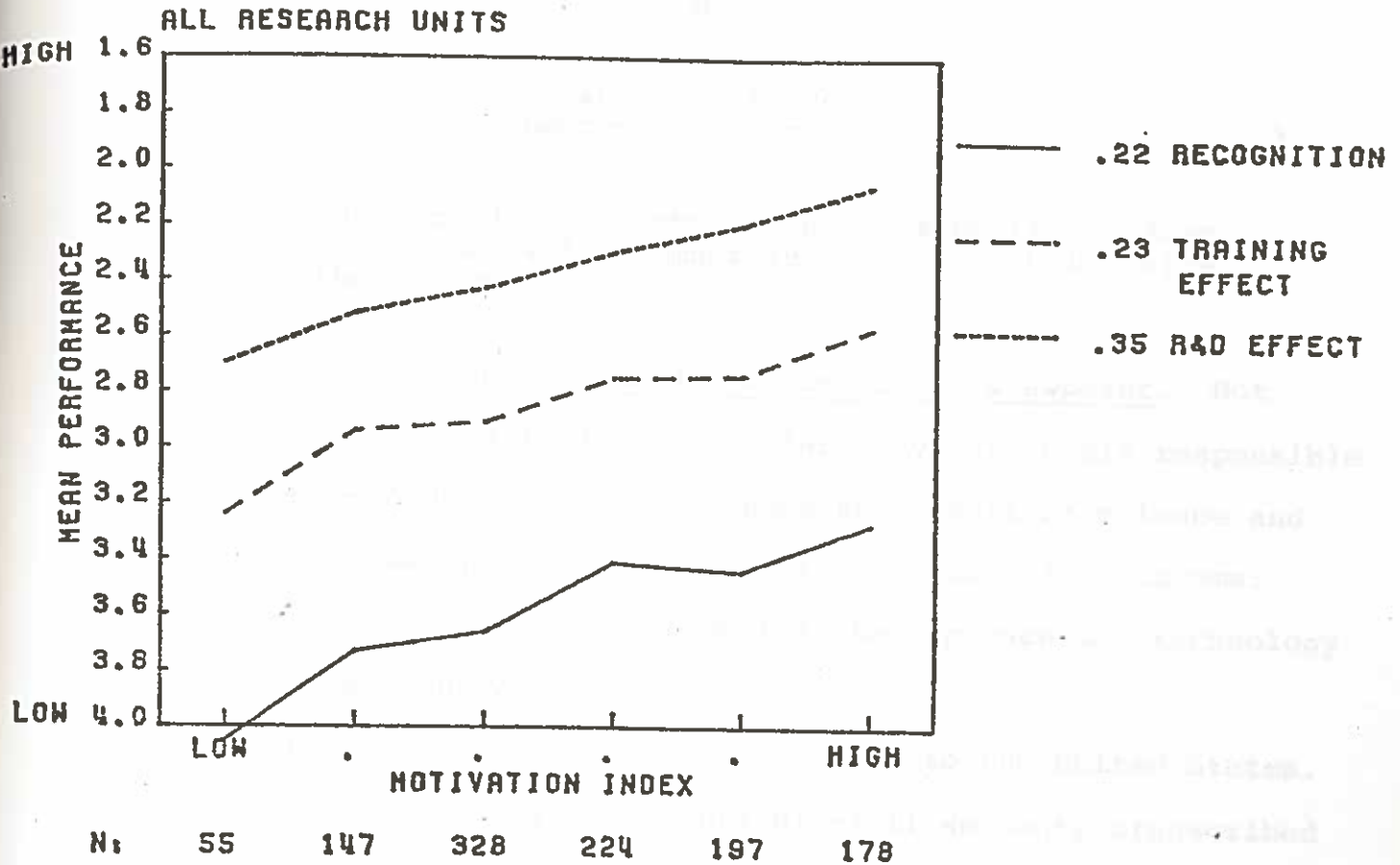
Mean performance by motivation in designated types of research units
(Statistics show adjusted etas)



NOTE: ALL PERFORMANCE MEASURES HAVE BEEN ADJUSTED TO REMOVE DIFFERENCES ATTRIBUTABLE TO TYPE OF UNIT.

FIGURE 8

Mean performance by motivation
(Statistics show adjusted etas)



Note: All performance measures have been adjusted to remove differences attributable to type of unit.