INDIVIDUAL PUBLICATION PRODUCTIVITY AS A SOCIAL POSITION EFFECT IN ACADEMIC AND INDUSTRIAL RESEARCH UNITS[x]

(Revised Version)

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Summary

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. Attempts to explain the higher productivity of higher status scientists by pointing to their greater ease of publication as far as acceptance of their work by journals and publishers is concerned were not supported by the data in some recent studies. If status in general does not confer greater ease of publication the present paper argues that position within a research organization does confer greater ease of author - or coauthorship - and this is the major explanatory variable accounting for productivity differences within research laboratories as far as quantity of articles (and books) is concerned. Upward moves in a laboratory's formal or informal position hierarchy are associated with a change of a scientist's research involvement from goal executing to goal setting functions as well as with an increasing access to scientific manpower and project money. Goal setting tasks provide for a significant reduction of time-expenditures in research necessary to assure that the scientist is identified with the research results; consequently, they allow for an involvement in more research tasks than originally. Equivalently, resources in scientific manpower and project money act as a multiplying element as far as quantity of output is concerned. When group productivity is considered, individual publication productivity and especially supervisory productivity retain a major significance. Additionally, size of the research unit seemingly plays a key role: in the present data set, size tends to be negatively related to per capita group productivity, with most pronounced relationships occuring in academic natural science units.

Productivity and stratification in science

Throughout the development of the sociology of science the study of normal scientific activity has focused on the general stratification and communication system in science. This seems to affect all scientific fields and manifests itself most clearly in the skewed distributions of productivity and rewards for outstanding performance. There have been productivity studies on scientists of a variety of disciplines, including, among others, physiologists (Meltzer 1956), psychologists (Clark 1957), sociologists (Meltzer 1949; Axelson 1959; Babchuk and Bates 1962, Clemente 1974), medical researchers (Ben-David 1960), biologists and political scientists (Crane 1965), psychometricians (Thomasson and Stanley 1966), physicists (Cole and Cole 1967; 1968; Gaston 1969; Cole 1970; Zuckerman and Merton 1971) and chemists (Hagstrom 1971; Blume and Sinclair 1973). Other studies, like that of Pelz and Andrews (1966), covered a wide variety of scientists from different specialties and disciplines.

Although many of the findings reported in this body of literature are, as Kaplan (1964: 967) has noted, ambiguous and often contradictory, there seems to be an emergent consensus that scientific activities are highly stratified and elitist in nature.

For example, as has been known since Lotka (1926), there is only a small and select minority of scientists who produce the bulk of scientific papers published in the literature, and Price (1963) suggested that the square root of the population of scientists produces 50% of scientific discoveries. Merton (1968) proposed the "Matthew effect", which asserts that those who are well known receive more credit for their work than those who are less well known ("unto everyone that has shall be given" according to the

Gospel of St. Matthew, chapter XXV, verse 29). Various aspects of social stratification in the scientific community have recently been examined by the Coles, using citation counts as a measure of the quality of scientific output. Their findings suggest that men located in the top strata of academic science predominantly cite the discoveries produced by other members of the same elite strata, and furthermore, that even members of the lowest strata disproportionally cite the work produced by distinguished scientists, although to a lesser extent than those who are themselves members of the scientific elite (Cole 1970). Additionally, quality of work as measured by citations received and rank of department according to Cole and Cole (1968) account for most of the variance in the "visibility" or reputation of a scientist.

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. Rewards received not so much as a consequence of the individuals' general contribution to science but rather as the results of the preferential citing of the eminent or of the appointment of eminent rather than productive scientists as suggested in the above literature must, as noted by Blume and Sinclair (1973: 134), truely be called unmerited. However, Zuckerman and Merton (1971) found that the formal control mechanisms of science such as reviewing and publication processes are <u>not</u> 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. In addition Hagstrom (1971) claimed that no sociological variables either singularly or in combination account for much of the differences in productivity.

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 (varied for different types of laboratories and education), with a renascence of productivity manifesting itself in a second peak of the age curves about ten to 15 years later. These findings, in addition to standing in distinct contrast to data presented by Lehman (1953; 1958; 1960) as to a continuing decline of major scientific contributions from the late 30's onwards, also do not lend themselves to an easier understanding of productivity differentials. If age and professional experience are the major 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) - raises 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?

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 intraorganizational 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. It is our contention that higher positions - except for the extreme case where the scientist moves out of science altogether - provide for better opportunities of publication, for the simple reason that a scientist's publication capacity is multiplied by the task force he supervises and by the project (and other) money he gains access to (compare Mullins 1975).

More explicitely, one could reason that status in general might not confer greater ease of publication in the simple sence of intriguing referees and publishing companies towards publication of whatever is submitted by a high status scientist, but status may well confer greater ease of production through opening up channels of resources not accessible to those in low positions. The relationship between age and productivity found in previous studies would then have to be discussed in the light of the association between a scientists age and the position he has attained in his organizational environment. Since presumedly 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 structure 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 intraorganizational 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. Finally, the social position model of individual publication productivity will be supplemented by some details as to how group productivity is related to individual productivity and what additional factors have to be taken into account if group output is looked at.

Data

The data presented in this paper are drawn from an international comparative study on the organization and performance of research units done in 6 European countries (Austria, Belgium, Finland, Hungary, Poland and Sweden). In each country, a sample of 150-250 research units stratified according to type of organization and scientific field has been taken; the final data set comprises 1222 research units and 4057 scientists mainly working in the natural and technological sciences[1)] in academic settings, in cooperative

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[1)] For selection of scientific fields the Unesco "Proposed International Standard Nomenclature for Fields of Science and Technology" has been used. The international data set includes the following disciplines by number of scientific institutes and in industrial enterprizes.[1)] In order for a scientist to be included in the population of which the sample was taken, he must have been attached to a "research unit";[2)] hence individual scientists not belonging to a group of researchers were excluded from the universe. Data were collected in 1974 by means of 5 different questionnaires (based on a pretest of 150 research units in three countries) from unit heads (personal interview), individual scientists of the unit (self administered questionnaires)[3)], the technical and service staff of the unit (self administered questionnaires) and external evaluators of the work of the

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respondents: Physics (280); Chemistry (825); Life Sciences (708); Earth and Space Sciences (228); Agricultural Sciences (331); Medical Sciences (189); Technological Sciences (1176); Social Sciences (258); and others such as Mathematics, Astronomy etc. (62).

1) The category "academic settings" comprises, beyond universities, institutes attached to universities and academies of science. The category "cooperative institutes" comprises those research units which belong to institutions wholly or partly serving a branch of industry and/or to government institutions. In the international data set, the academic sector is overrepresented; it comprises 2566 respondents as compared to 744 in cooperative institutes and 657 in industrial enterprizes.

2) A "research unit" has been defined for the purpose of this international study as a group of scientists which meets the requirement of having specific scientific-technical responsibilities, a distinct life-span, at least one leader and altogether 3 core members spending at least 8 hours/week in the unit. Furthermore, the group must have had an expected life time 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 6 months.

3) If a unit comprised more than three core members, in general a random sample of 3 scientists of the unit was taken for filling in the questionnaires.

unit (personal and self administered). The response rate varied between 70 and 85 percent (depending on countries and fields of study) with no indication of a serious response bias by rank of respondent, field or type of organization. The international combined data set is, however, not representative for either type of organization or scientific field in each of the participating countries because of the different sampling frames that have been used on a national basis.

Measurement of productivity

In order to empirically examine scientific productivity in relation to stratification or organizational variables a variety of approaches to the construction of operational indicators of performance have been used in the literature. As noted by Blume and Sinclair (1973), the only valid assessment of a contribution to science must come from within the respective specialty, for only members of a specialty are competent enough to judge the significance of a scientific contribution to their field. Despite of the fact that most social scientists working on scientific productivity have agreed on the ideal of such a measurement of scientific quality, 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). Meltzer and Salter (1962: 354) note some of the a priori objections which might be raised against such a productivity measure; a co-author is given the same amount of credit as a full author, a short paper is counted the same as a long one, no distinction is made between poor and excellent products, no difference can be distinguished between highly original work and the repetition of old ideas, and the benefits of having written the product may be attributed to those who only exploited the ideas or research work of others.

Despite of the plausibility of those arguments 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 its 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).[1] The conclusion seems to be that where citation counts are not readily available - as in the case of a study including 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).

While our data allow for the assessment of the rated quality[2] of the scientific work of our respondents in addition to its quantity, they do not include a measure of citation counts for the reason mentioned above. Hence it imposes itself in the case of the present examination

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[1] To cite but a few examples, Blume and Sinclair obtained a Goodman-Kruskal correlation coefficient of .63 between peer group assessment of the work of a scientist and number of published papers; Cole and Cole (1967) found a Pearson correlation of .60 between citation and paper count and a correlation of .72 between number of papers and number of citations to the three most frequently cited contributions of the scientist (a measure that cannot be an artefact of the quantity of publications); and Pelz and Andrews (1966) report a Pearson correlation coefficient near .40 between ratings of a scientist's contribution to technical or scientific knowledge in the field by members of the same laboratory and number of papers published in professional journals within the past five years.

[2] The quality of scientific work of a researcher was measured by peer- and supervisory ratings of his group from within and outside the unit on several dimensions. See Knorr et al. 1975 for an example of the use of those measures.

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.

Following a frequent procedure (e.g. Pelz and Andrews 1966; Hagstrom 1967; Gaston 1969) we took as our indicator of "publication productivity" the self-reported number of papers a respondent had 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-technique (see p.28 ff.) has been used, 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.[1)]

In general, academic natural science settings, academic technological science research[2)] and industrial settings (technological research) were chosen as relevant subgroups for which all analyses were conducted separately. This

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[1)] As expected, both measures were highly skewed in that only a small number of scientists prooved 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.

[2)] Technological sciences as defined by the Unesco Nomenclature basically comprise all applied branches of natural science disciplines (such as chemical technology and engineering or nuclear technology), in addition to such inherently technological fields as motor vehicle technology or materials technology.

decision was based upon a typological analysis of quantitative and qualitative performance measures in different disciplines and types of institutions in the present data set (Cole 1975), which showed that performance differs markedly in the above settings whereas no significant gain was made by looking more specifically at single disciplines (e.g. academic chemistry).

Age, professional experience and productivity

Earlier work to which we have referred above suggested a somewhat curvilinear relationship between a scientist's age and his scientific productivity. Whereas Lehmans' 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 years 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, and figure 2 gives the equivalent productivity curves for what we have called professional experience, that is the number of years of R&D experience of a scientist. The latter concept has been introduced in addition to chronological age in order to adjust for differential disadvantages of those scientists who for various reasons were not continuously involved in scientific work or who started their career at a somewhat later age. As age and professional experience were highly correlated,[1] productivity curves turned out to be of similar shape for both measures.

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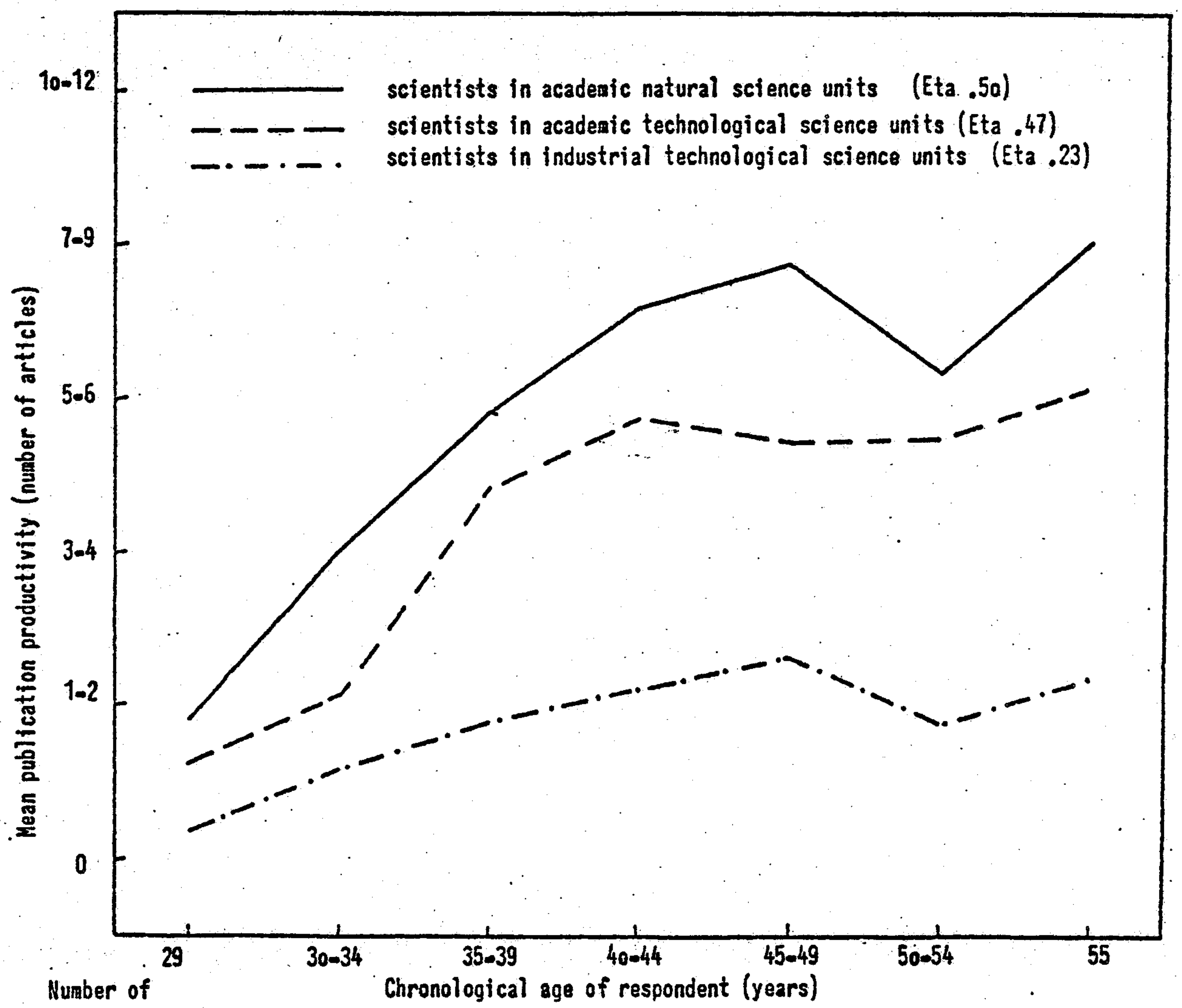
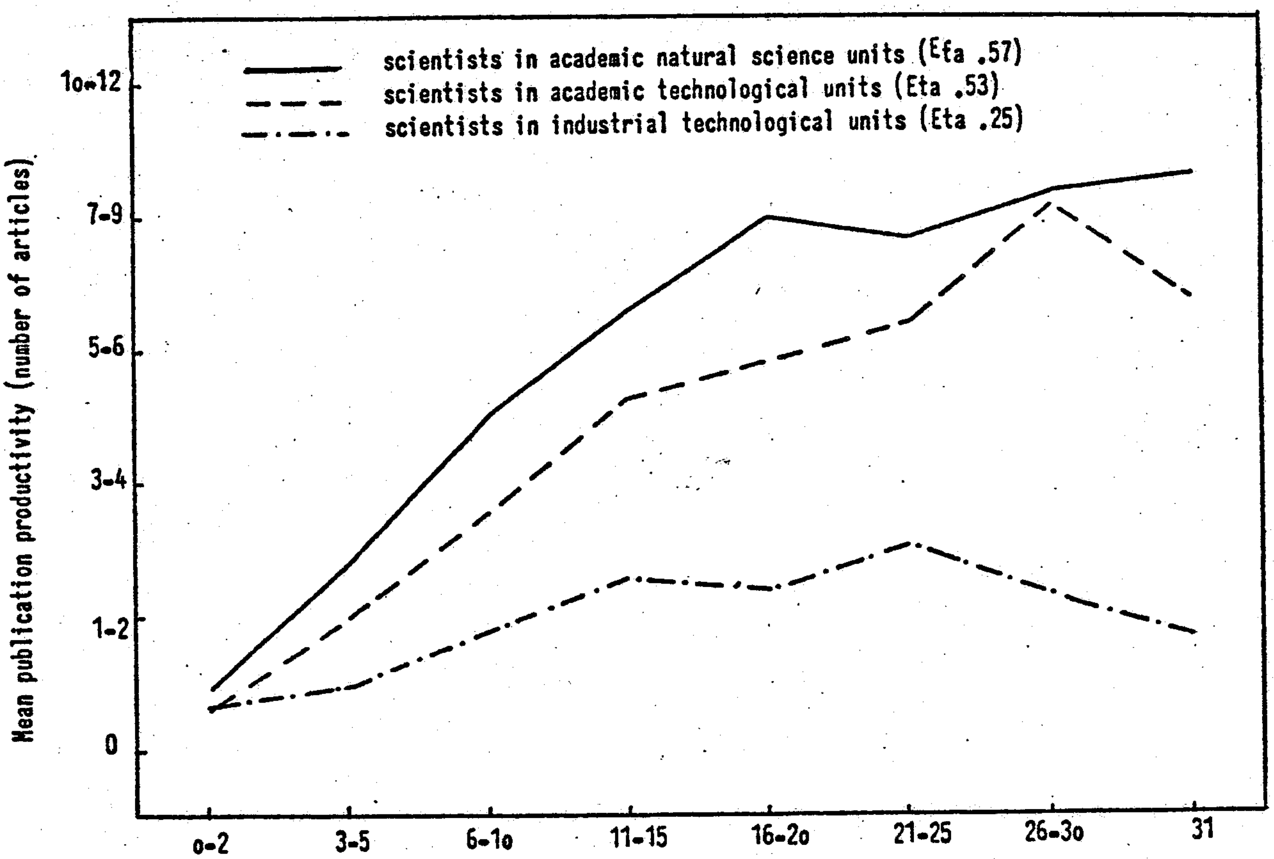
[1] The Pearson'r between age and professional experience for academic natural scientists, for technological scientists in academic settings and in industrial settings is .85, .83, .76 in the above order.

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



Number of respondents	29	3o-34	35-39	4o-44	45-49	5o-54	55	Total
———	5o6	419	251	152	153	82	119	1682
— — —	164	137	79	63	38	4o	45	566
—·—·—	114	2o3	1o6	78	59	4o	34	636

Figure 2: Mean publication productivity and professional age for scientists in academic natural and technological sciences as well as for scientists in industrial units



Professional experience of respondent (years)

Number of respondents									Total
———	264	423	374	2o1	155	127	66	68	1678
— — — —	111	145	1o4	65	67	36	17	17	562
—·—·—	88	165	16o	87	67	37	13	12	629

When comparing both figures, the most interesting difference seemingly lies in the fact that the "two-peak" form of the curve for chronological age nicely verifying the results of Pelz and Andrews tends to change when professional experience is considered. Here in academic natural science settings a peak after 15-20 years of steadily raising productivity is followed by a period of stagnation or very slow raising in the second part of a scientist's career. Scientists working in the technological sciences seemingly experience a decline of productivity towards the end of their career, with a very late peak after nearly 30 years of professional work in academic settings and an earlier one after nearly 25 years in industrial research laboratories. In the latter case, the curve is remarkably more flat than in academic settings, implying that age is playing less of a role for this kind of productivity in industry. Interesting to note, the late peaking of productivity with professional experience of technological scientists in academic settings is mirrored by an early peak when chronological age is considered, suggesting that perhaps professional career starts earlier in those fields.

Stagnation or decline after a certain period of raising 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 is pointing 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 % of time spent on research and a positive one with % of time spent on administration.[1)] However, upon closer examination

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[1)] The Pearson'r between age and years as head of the unit, % research and % administration are .47 (years as head), of the age curves for % 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. As an example, fig. 3 shows the decreasing involvement in research activities with age which hold in all three institutional settings studied in this paper.

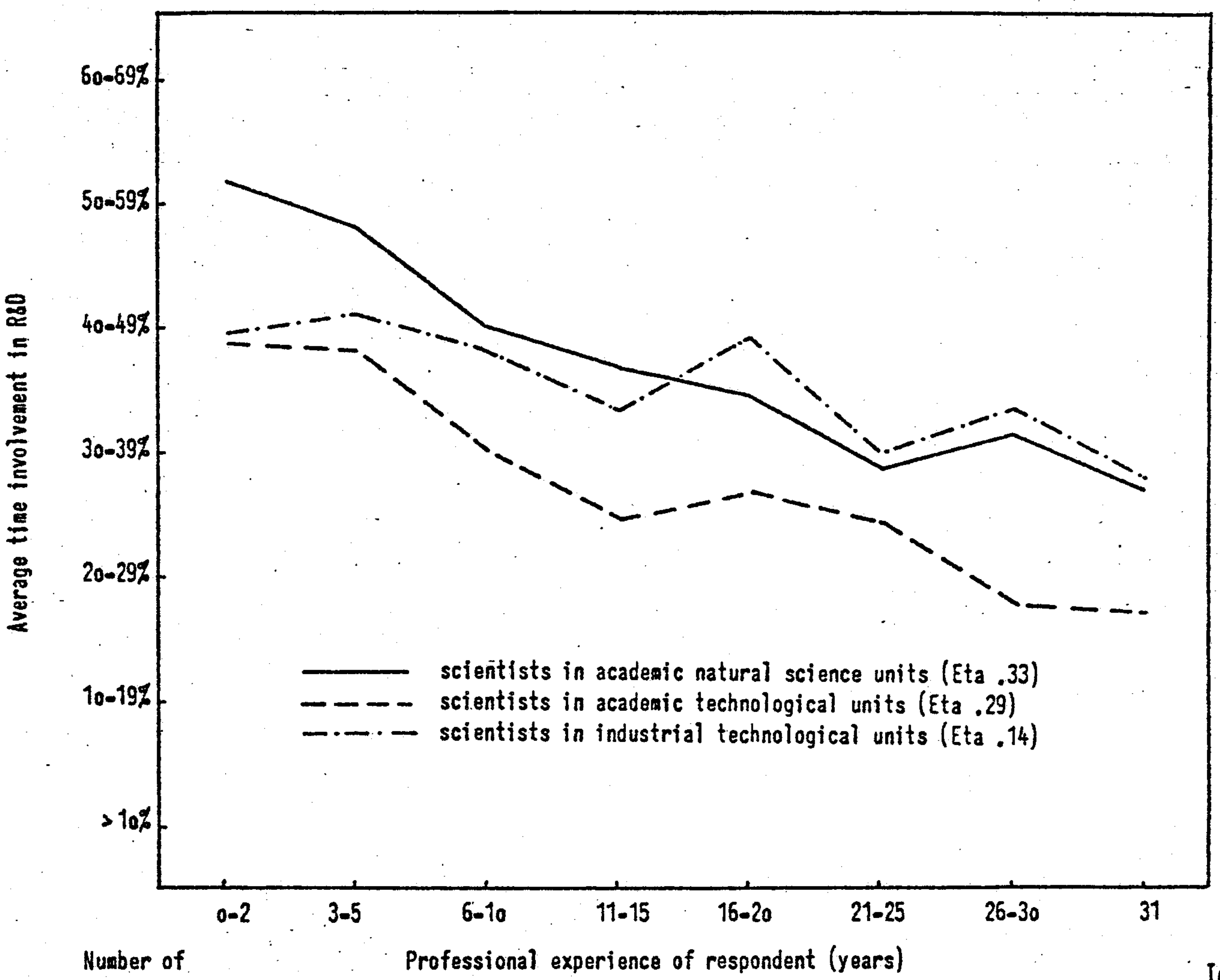
Phrased differently, the figures presented so far indicate that publication productivity is raising sharply (in academic settings) and moderately (in industrial settings) for about the first 20 years of a professional career inspite of the fact that non-research tasks are increasing steadily and time in research is decreasing continuously during all the same time. The most interesting question - somewhat ignored in the literature - seems to be now as to how we explain this more or less steady and continuous rise of productivity for such a long time period given the fact that

a) scientists are drawn off in work not directly productive of scientific output from the very beginning of their career; and

b) that it should take only a few years of professional work for a scientist to establish the scientific knowledge and technical competence necessary for scientific production.

-.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.

Figure 3: Mean percentage of time in research and professional experience for scientists in academic natural and technological science and for industrial units



Number of respondents	o-2	3-5	6-1o	11-15	16-2o	21-25	26-3o	31	Total
———	257	4o7	37o	2o2	155	128	65	69	1653
— — —	11o	139	1o4	65	67	36	17	17	555
—·—·	91	159	16o	85	69	38	13	12	627

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 a 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 done 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 was such a direct effect it should mean that increasing age stands for raising technical knowledge and competence which accounts for 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 scientific members 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 would go down and become insignificant whereas

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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.

in the case of scientific members (position not controlled for) it remained significant this should imply that position and not age accounts for productivity differences (compare table 1).

Table 1: Pearson'rs 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	.34xx	.43xx
technological scientists	.32xx	.44xx
Academic natural scientists (total)	.46xx	.51xx
Academic technol. scientists	.43xx	.50xx

xxsignificance ≤ .001

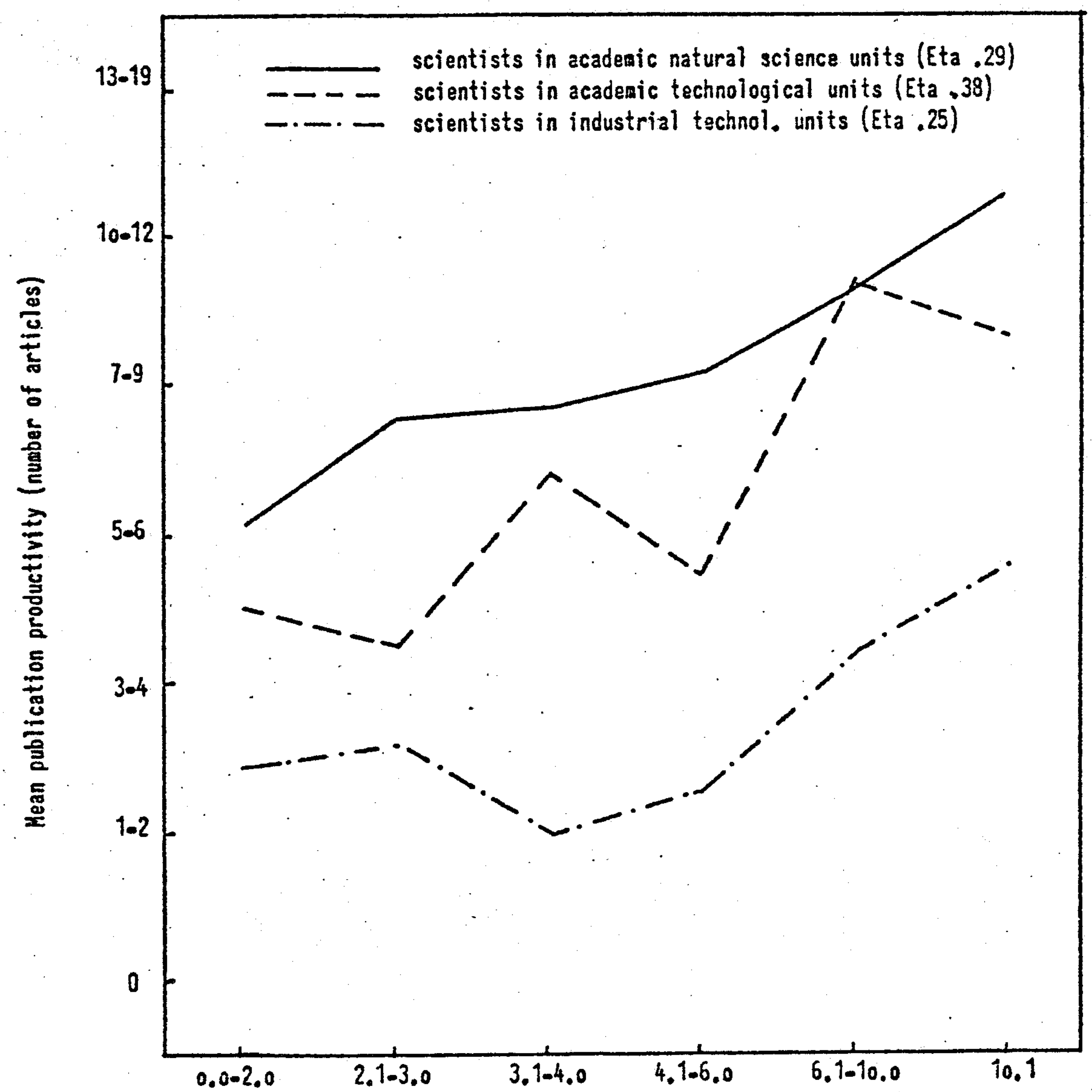
Another more indirect check of the theoretical priority attributed to position for which age stands as a proxy in the present analysis can be done by pointing to the following relationship: if position as opposed to age is to explain publication differentials, then there should be a positive relationship between a supervisory scientist's access to manpower resources 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 was age or professional experience and the presumed raise 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. Fig. 4 shows how publication productivity in this subgroup raises with the size of scientific manpower resources, fig. 5 documents the equivalent relationship for technical and service staff supervised.[1)]

As can be seen from figure 4, there is an almost linear increase of a supervisory scientist's publications (in natural sciences), a two-peaked increase (in technological sciences) with raising resources in highly qualified manpower, and a somewhat less pronounced relationship in industrial settings. Similarly, both fields and both kinds of institutions show a more or less continuous growth of productivity curves with increasing technical and service staff supervised by the scientist (fig. 5). Since availability of and access to (scientific and technical) manpower resources depends on the position a scientist holds in his laboratory we might conclude that the existence of the above significant positive relationship supports our general thesis.

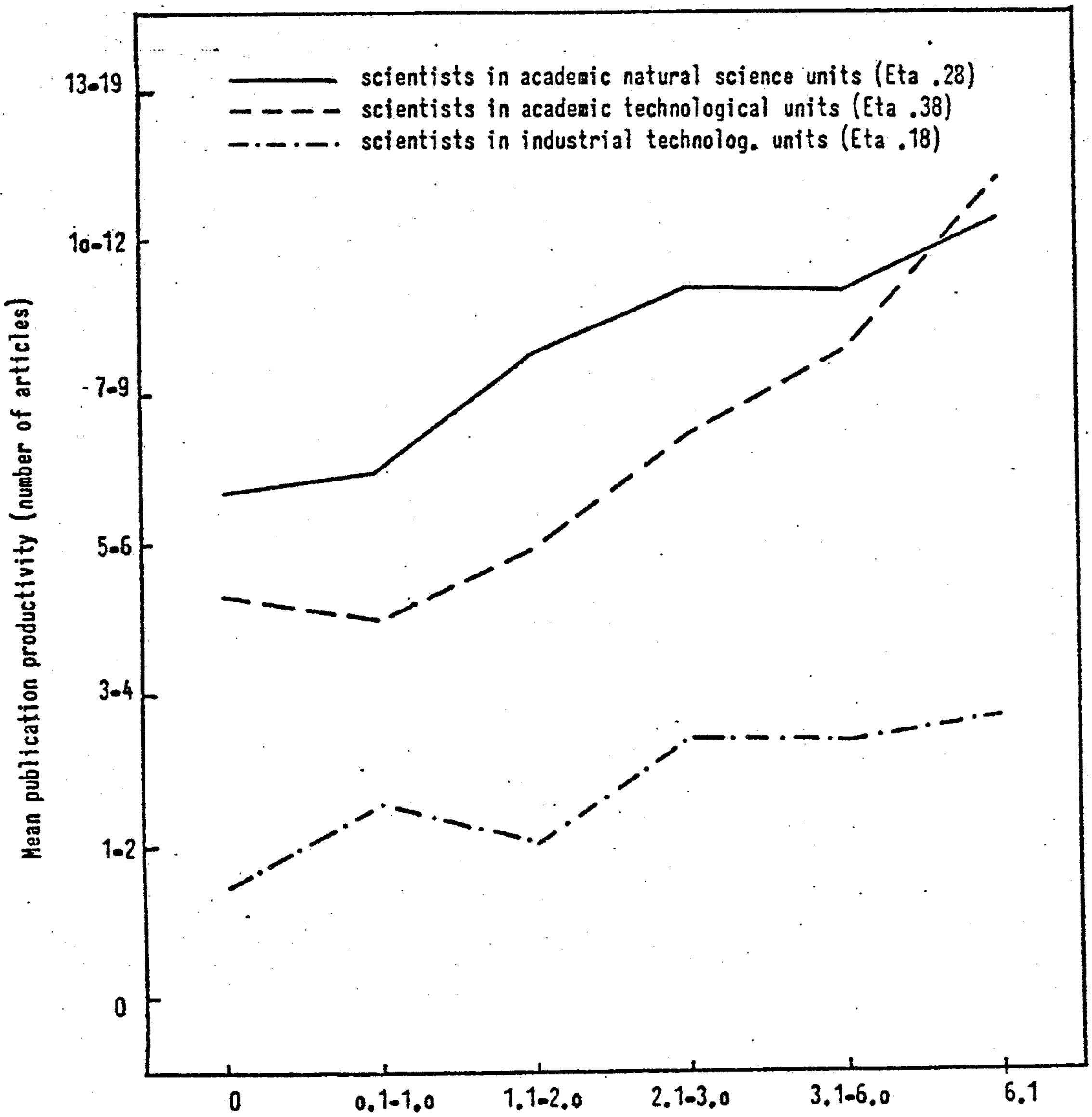
[1)] Manpower resources in both cases are measured in terms of the average number of man years of a) scientists and engineers (fig. 4), and b) technical and supportive staff (fig. 5) in the unit supervised by the scientist during the last three years.

<u>Figure 4</u>: 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



Number of respondents	Man years of scientists and engineers						Total
——— (solid line)	59	67	68	98	95	57	444
— — — (dashed line)	24	23	35	3o	22	22	156
—·—·— (dash-dot line)	55	45	23	27	24	14	188

<u>Figure 5</u>: 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



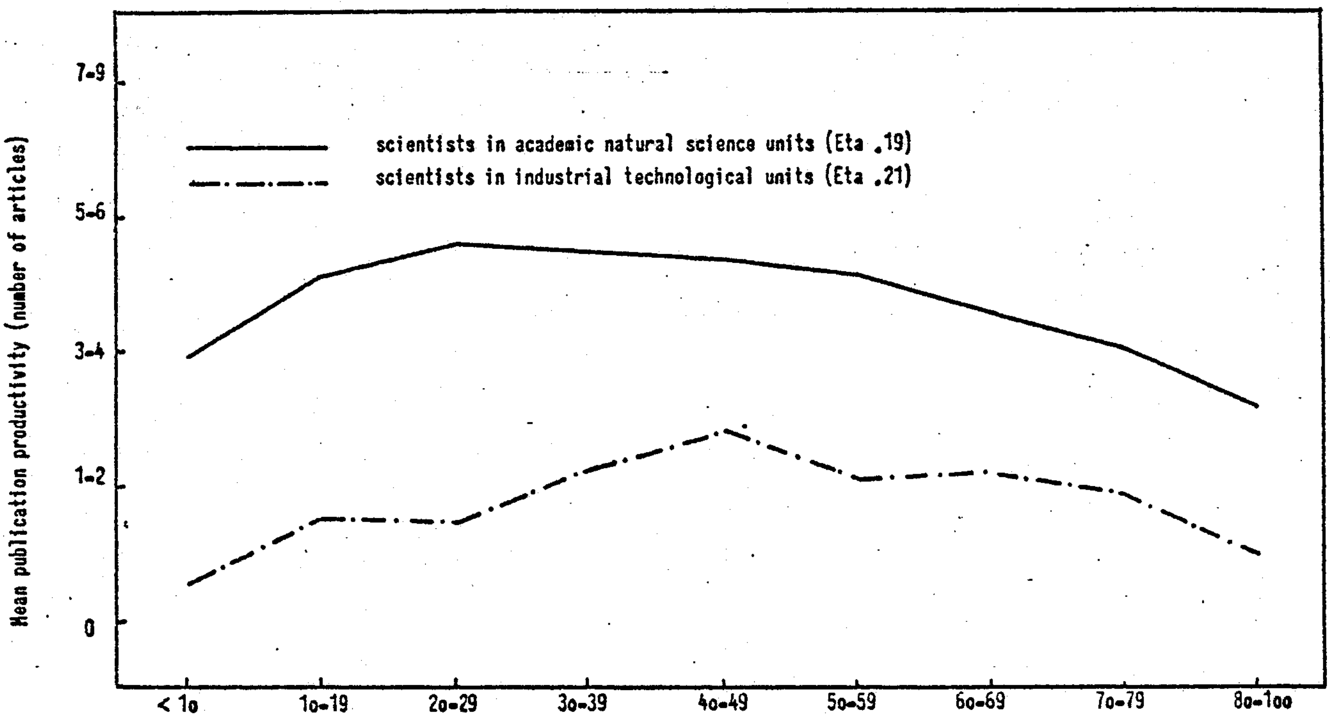
Number of respondents	Man years of technical and service staff						Total
———	92	1o3	73	57	9o	37	452
— — —	28	38	87	17	24	13	2o7
—·—·—	14	44	25	29	31	47	19o

Age, task structure and productivity

If age is acting as a proxy for position with a 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. We have already shown that the amount of time in research decreases with age from the very beginning of a career, whereas involvements in administrative tasks increase steadily. Since productivity at the same time raises continuously, we might suspect that scientists in general do not profit much in terms of their written productivity from sheer time spent in research. Since this seemed somewhat counterintuitive, productivity curves were plotted for different time involvements, controlling as usual for academic field and type of institution. Figure 6 shows the result for scientists in academic natural science settings and for industrial laboratories involved with technological research. In both cases, the shape of the curve is slightly curvilinear, replicating nicely some of the results in the literature (cf. Pelz and Andrews 1966): time involvements lower than 10% and around 80% or more do not contribute to achievements. In addition, there is a slight negative effect of more than 1/3 of time spent in research on productivity in academic settings and a peaking at a somewhat greater time involvement (between 40% and 50%) in industrial units.

In sum total, however, relationships do not look impressive, as indicated by Eta^2 coefficients of .04 in both cases. In order to more specifically address the question of supervisory task structure and its relation to productivity we controlled for a scientist's position in the unit, assuming that time spent on research might play a more pronounced role in the case of the researchers of the unit as compared to units heads (in academic settings often university professors).

<u>Figure 6</u>: Mean publication productivity for different time involvements in research with scientists in academic natural sciences and in industrial technological science units

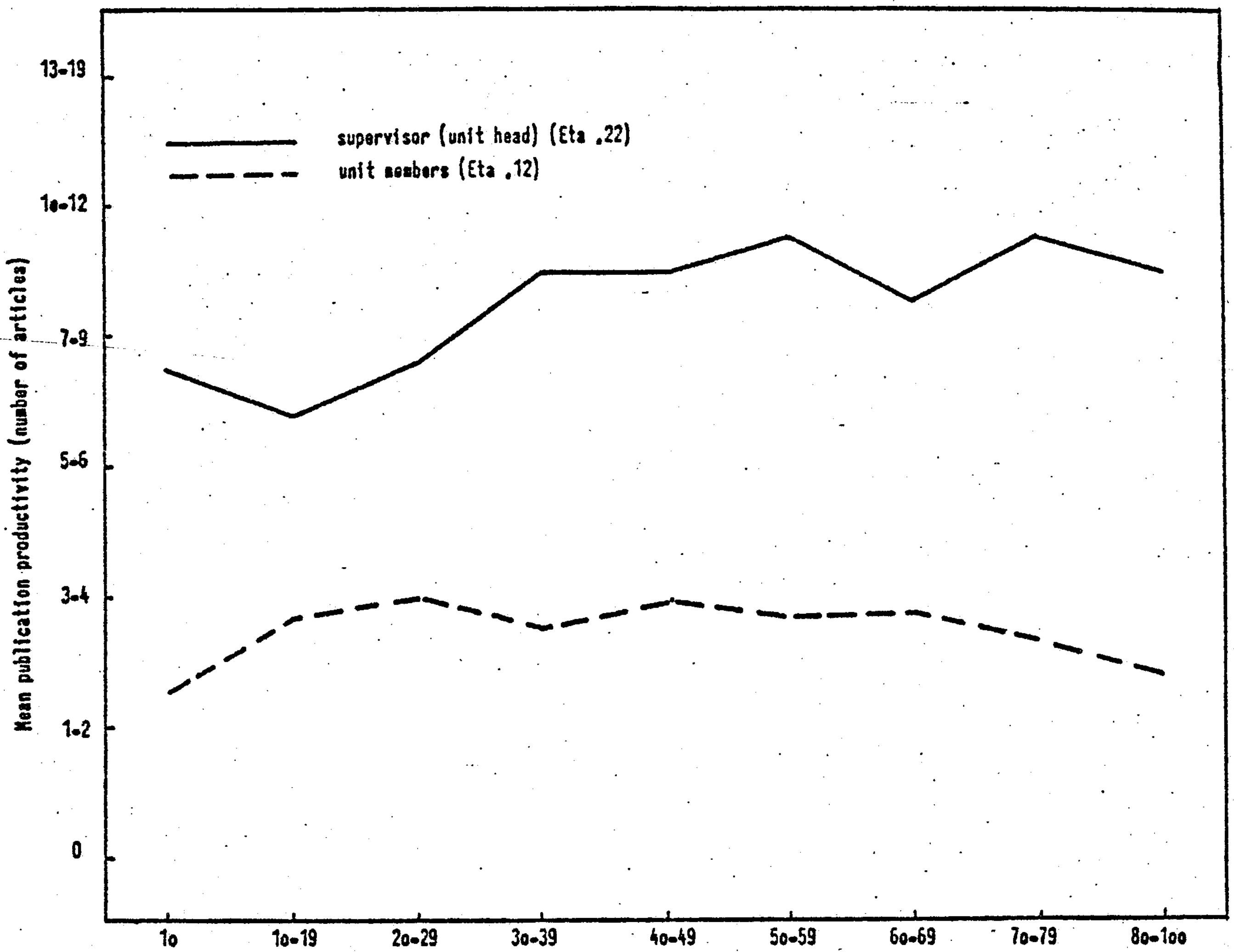


Number of respondents	% R & D inside unit									Total
———	8o	172	25o	23o	197	235	141	115	222	1642
—·—·—	62	75	1o5	71	65	65	48	5o	75	616

Fig. 7 shows the resulting productivity curves for both kinds of scientists in academic natural science units. Somewhat unexpectedly, relationships were particularly weak for researchers: except for the well known negative effect of extremely little or extremely much research, productivity seemed to be more or less independent of how much research a scientist was actually doing. If it pays for somebody to be more involved with research, then it is the supervisor in the highest position or head of unit who reaches a higher level of productivity by spending at least 30% of his time on research activities.

If sheer time in research seemingly does not contribute significantly to the publication productivity of a scientist 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 (report and paper writing) clearly offers better opportunities for author- or coauthorship than devoting a large amount of time to actually do 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 should support our argument that it is the differential advantages associated with supervisory positions which account for much of the productivity differences in research organizations.

Figure 7: Mean publication productivity for different time involvements in research for unit heads and unit members in academic natural science settings



Number of respondents	% R & D inside unit									Total
——— (solid line)	22	82	113	86	56	59	25	11	13	467
– – – – (dashed line)	58	9o	137	144	141	176	116	1o4	2o9	1175

To check our argument the following 3 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 0% 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 as conceived of 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 were thought to mirror the position a scientist held in the unit in that the higher he moved in the hierarchy of the research laboratory the more he would be confronted with a variety of scientific and non-scientific functions in addition to

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1) The 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.

2) Indicators 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.

research, the more the nature of his involvement into research 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. As can be seen from table 2 representing correlation coefficients between the above dimensions of supervisory task structure and position (as approximated by "professional" age) or productivity respectively, the data substantiate these expectations.

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 position[1)] and that the manpower resources and task structure 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, 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. Jöreskog and van Thillo 1972, Jöreskog 1974).

[1)] More 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 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.

Table 2: Pearson'rs between various dimensions of the research task structure of a scientist, his publication productivity and his professional experience in academic settings

Dimensions of task structure	Academic natural scientists		Academic technological scientists	
	years of prof. experience	Publication productivity	years of prof. experience	Publication productivity
Diversity of functions	.34^{xx}	.28^{xx}	.32^{xx}	.24^{xx}
Degree of legislative involvement in research	.40^{xx}	.42^{xx}	.38^{xx}	.34^{xx}
Number of total projects involved in res.	.42^{xx}	.47^{xx}	.44^{xx}	.39^{xx}

^{xx} significance $\leq$ .001

Lisrel 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. In relation with this, 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 estimations 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[1)] 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[2)] variables indicate the amount of measurement error, those pointing to latent dimensions indicate disturbances or residuals.

As in previous analyses, we chose scientists in academic natural science and technological science units as well as scientists in industrial units as relevant subgroups for replicating the model. Results for academic natural sciences are shown in fig. 8, results for technological sciences in

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1) To ensure the identifiability of the model parameters representing symmetric linkages between the unobserved dimensions of functions and tasks performed by the scientist were constrained to be equal.

2) In case of only 1 observed indicator for a latent dimension (diversity of functions) the linkage between the two was fixed at 1.0 with a corresponding measurement error of 0.0. in the observed indicator.

industry are presented in fig. 9. 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 8 was .025, in figure 9 .024; highest discrepancies were -.134 and -.161 respectively.

What the model substantiates basically is that a scientist's age as a proxy for the degree to which he holds a supervisory position is related to his task structure in the research laboratory and this in turn is related to his or her publication productivity. Since the method allows for multiple indicators (as shown by rectangles in fig. 8 and 9) of one concept (as shown by circles), "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 (see p. 27). Positive relationships between these dimensions and the voluntary overtime a scientist devotes to his work or his attachement to the research unit can be shown[2)] but were left out of the model. While being output variables of the (professional) age and a scientist's position in the unit, they contribute practically nil to explaining publication productivity when other concepts are

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1) The highest residual in this case is -.191, the average residual .032, and the amount of variance explained is 81%.

2) Pearson'rs between the age of a scientist and his attachment to the unit are .36 for academic natural scientists and .24 for scientists in industry, to give an example.

Figure 8: Lisrel model of individual publication productivity as a social position effect for scientists in academic natural science units

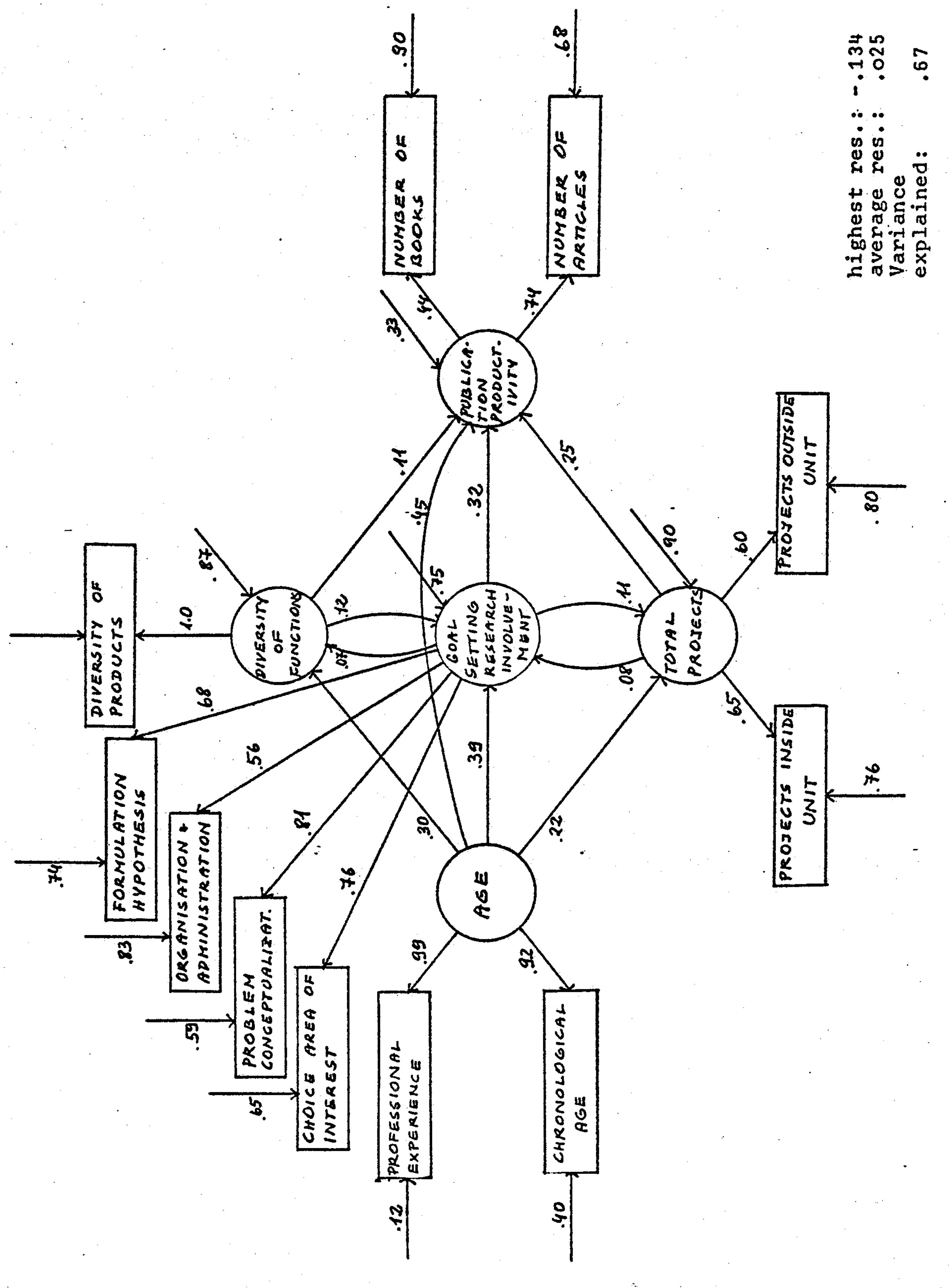
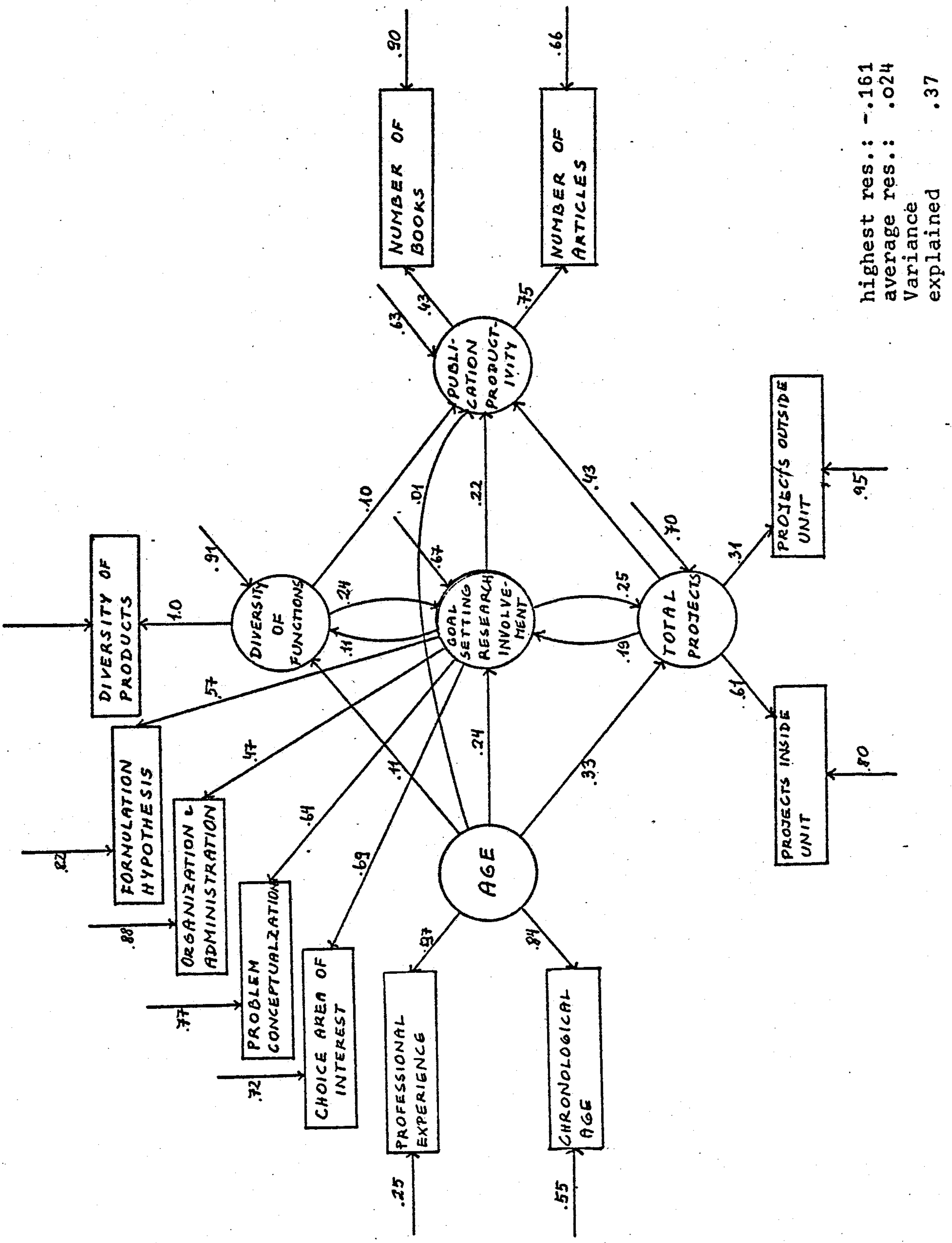


Figure 9: Lisrel model of individual publication productivity as a social position effect for scientists in industrial technological science units



controlled for. When screening the data with a view to detecting potential other organizational effects upon individual publication productivity, no further variables imposed themselves as being significantly related to individual scientists' output in academic settings. It is important to note that the five-variable pattern of relationship which identifies supervisory position as the major explanatory concept accounting for intraorganizational productivity differences seemingly dominates over all other relationships between organizational variables and publication productivity which might be hypothesized.[1)]

Control for a scientist's position

As can be seen from an inspection of the models presented so far there remains a relatively high direct effect of age and professional experience on publication productivity in academic settings.[2)] We have already shown that the relationship between age/experience and productivity tends to disappear when a scientist's supervisory position is

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1) The 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 would expect from the Lisrel results (see Waller 1976).

2) This is indicated by a parameter of .45 in the Lisrel model of academic natural scientists (see fig. 8) and by a parameter of .36 for academic technological scientists (model not included). It is worthwhile noting that this direct effect disappears in industrial settings and hence the linkage has been eliminated in the final model (see fig. 9 and fig. 12).

controlled for (see page 18). In order to check the validity of our previous argument in the case of 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 unit members separately. In accordance with what we have said so far the model would be expected to replicate nicely for unit members (since this subgroup includes various kinds of supervisory position below unit heads), but should, being a social position model, change significantly when unit heads are looked at exclusively. Figures 10 and 11 substantiate these expectations: In the case of scientific members (fig. 10) of a unit the model maintains its significance, with only slight changes in the parameters linking concepts, and an explained variance in productivity of 65% (as compared to an original 67%). In the case of unit heads (fig. 11) the model was replicated including the variable quantity of manpower resources at the heads' disposal (and not measured for unit members). The latter variable yields the highest path coefficient in the resulting model, followed by the variable "number of projects" the supervisor is involved in and suggesting that once a supervisory position is attained <u>manpower resources</u> and <u>project tasks</u> account for most of the variance in <u>further</u> 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.

<u>Figure 10</u>: Lisrel model of individual publication productivity as a social position effect for academic natural sciences (excluding unit heads)

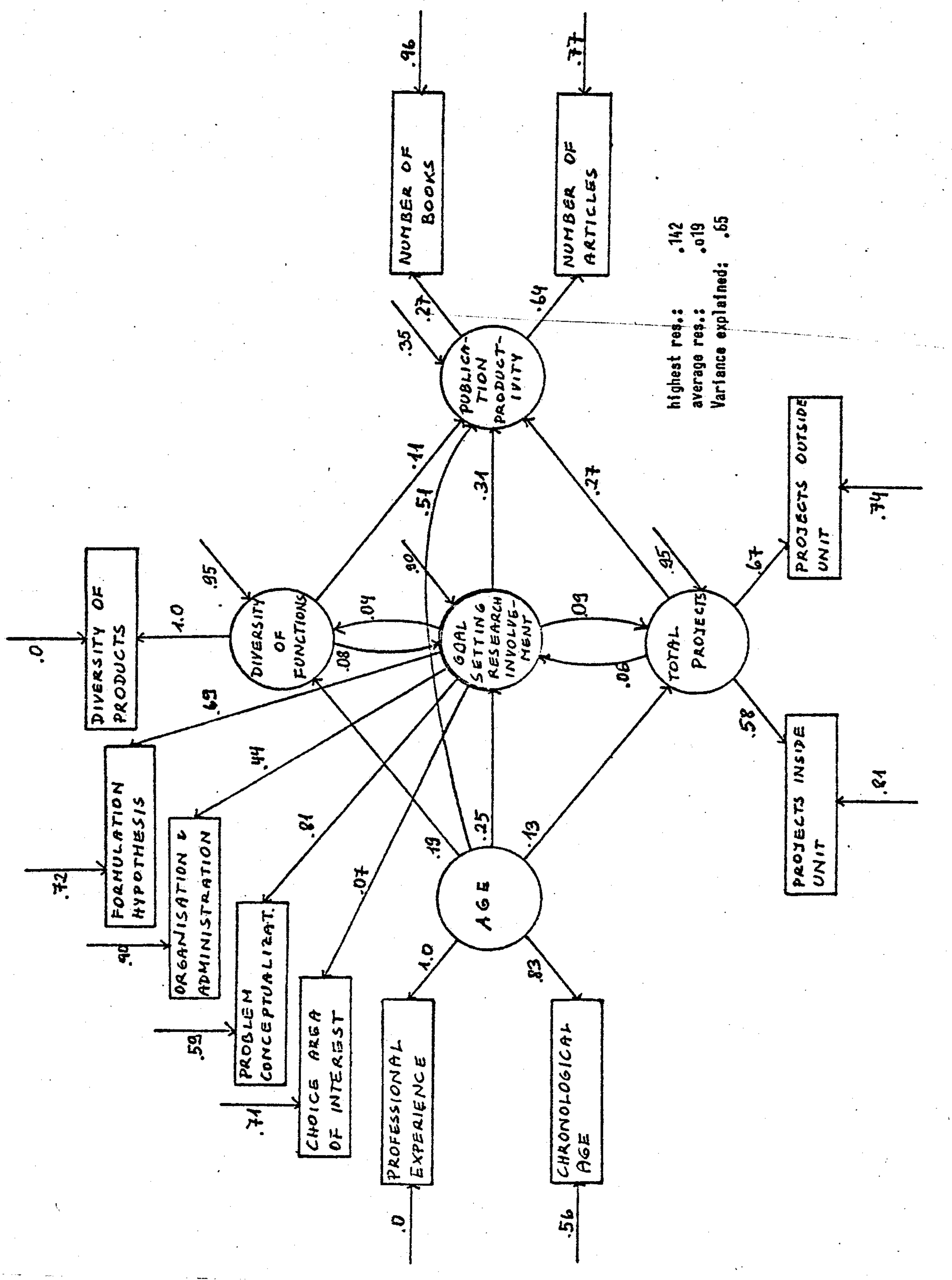
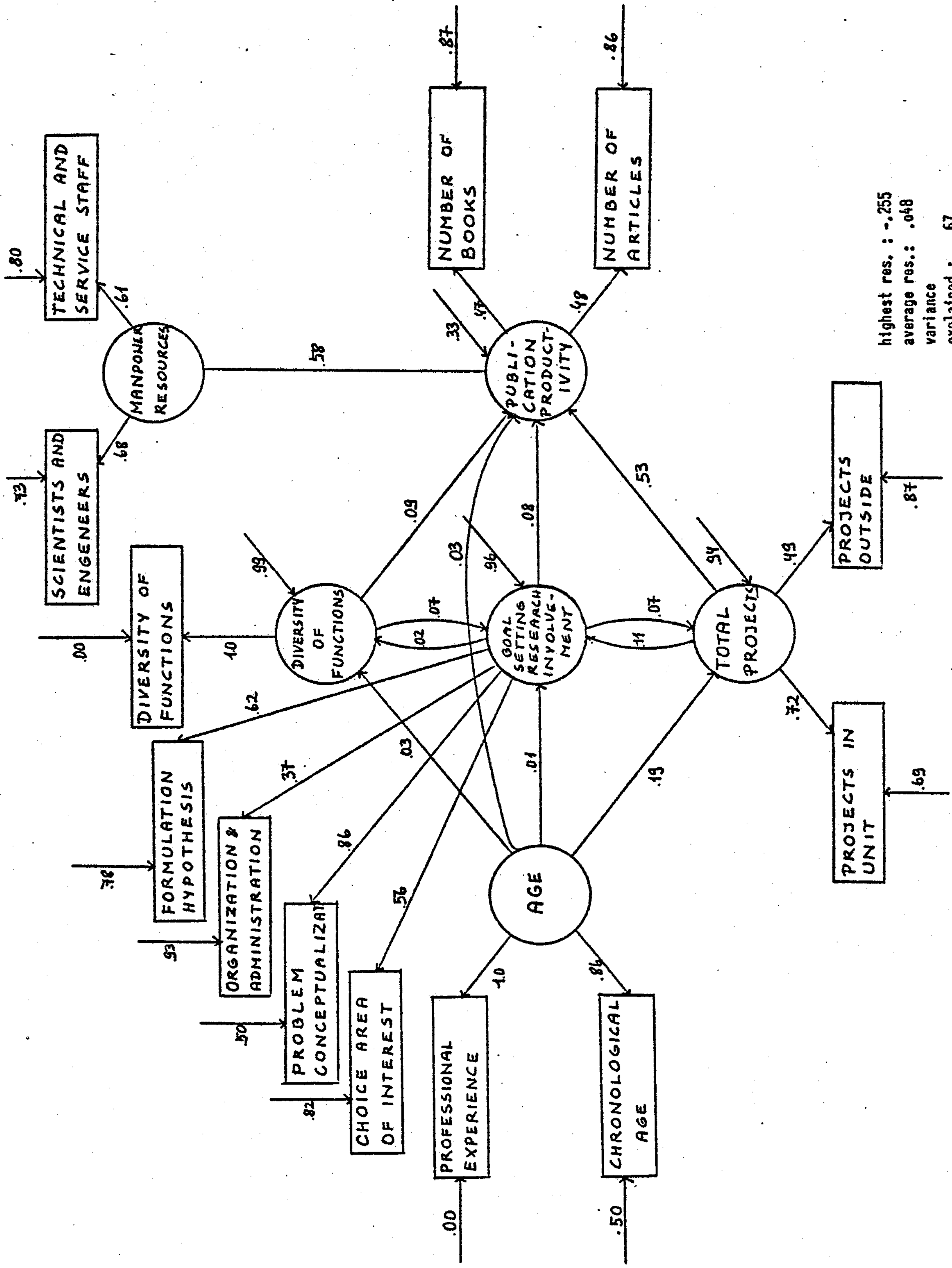


Figure 11: Lisrel model of individual publication productivity for supervisory scientists (unit heads) in academic natural science settings



Technological scientists in industrial research units

From an inspection to fig. 8 and 9 it can be seen that both models in general show good fit as indicated by highest and average residuals, yet the amount of variance explained in individual productivity varies greatly between both types of institutions involved: there is a decrease of 30% between the variance explained with the model for scientists in academic natural science settings (67%) and for scientists in industrial firms (37%).[1)]

The lower amount of variance explained by the social position model of publication productivity in industrial research suggests that there might be some other factors specific to this setting which should be taken into account. Fig. 12 presents a model which includes two principal other sources of explanation, one referring to what influences - and to which degree - the choice of the research theme of an industrial laboratory, the other referring to the degree of external communication[2)] the unit maintains.

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1) Parameter estimates for both models differ most markedly as far as the importance of the total number of projects is concerned - which seems more pronounced in the technological sciences than in the natural sciences - and in relation to the direct linkage between age and publication productivity which practically disappears in industrial research units.

2) Two indicators have been chosen as measures of unit - external scientific communication: the number of visiting scientists from the country who had visited the unit during the past year and the number of publications of the unit sent to other individuals or organizations in the field. Several other indicators could also be used here; e.g. the number of scientists from abroad or the number of publications received by the unit (cf. Knorr et al. 1976). It must be noted, however, that the number of publications sent to other groups might be a result rather than an origin of publication productivity; the same holds - to a less obvious degree - for all indicators of external contacts. This points to the hypothetical character of the causal links specified, which should be kept in mind when interpreting the models.

The first source subdivides into 2 different factors relevant for enhancing productivity through making an impact on the research topic: not surprising, it is the degree to which scientific significance is taken into account when the research tasks of a laboratory are being determined which influences - directly and indirectly through promoting the external scientific communication of the unit - the probability of an individual researcher publishing his or her results. Second, it is the degree to which science policy making bodies determine the choice of research tasks (as in socialized industry) which is also related positively to publication activities. Whereas the first factor seemingly points to an industrial research unit's orientation towards basic research which is linked to external communication and to more emphasis on publications, the second factor could imply a certain policy of legitimizing public (government) money spent on research by pressure towards publishing all the results obtained.

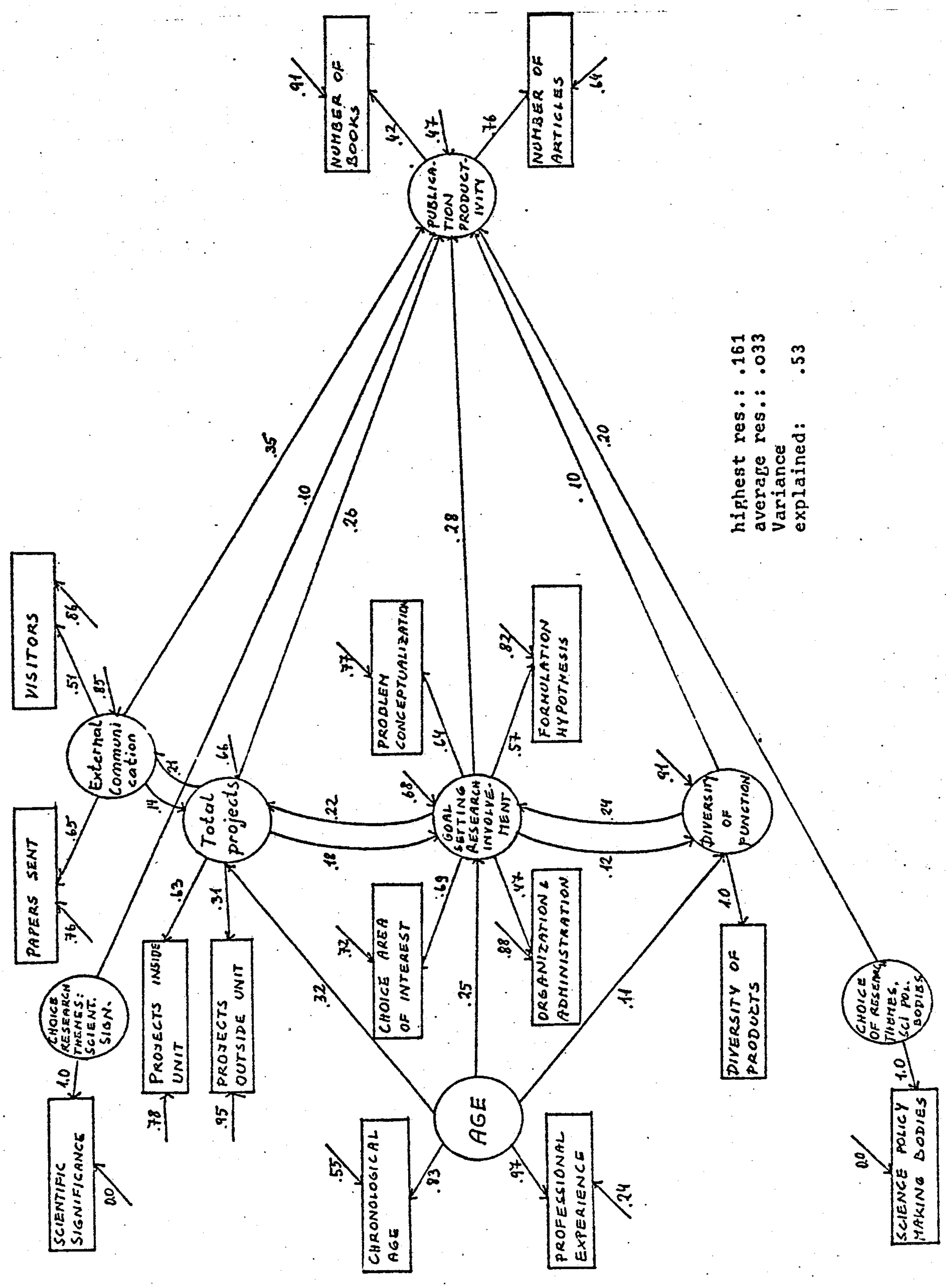
Both factors are identical in that they refer to characteristics of the organizational context in which a scientist is working. It is plausible to assume that this context plays much more of a key role in industry by enhancing or restricting publication productivity since

a) scientists in industry are generally operating under more organizational constraints than in academic settings; and

b) publications are not a typical form of industrial research output and hence will florish only under special conditions largely determined by the organization.

Reproduction of observed correlations by parameters produced by the Lisrel program was good again: the average discrepancy between observed and fitted covariances is .033, the highest discrepancy is -.161. The model now accounts for somewhat more than half of the variance in individual publication productivity in setting (53%), with about 15% of gain by adding organizational context variables to individual position effects.

Figure 12: Lisrel model of individual publication productivity including choice of research themes for technological scientists in industry



Group productivity and its correlates

Having outlined the position of a scientist and the manpower resources and supervisory task structure associated with it as the major explanatory concept in accounting for intra-organizational productivity differences of scientists, we were interested in exploring whether group publication productivity can essentially be explained by individual members' productivity or whether the analysis would have to incorporate additional concepts. Group publication productivity can be introduced here as a measure of the quantity of papers (and eventually books) published in scientific journals by the members of a research unit during the last 3 years in connection with the work of the unit. Group productivity defined this way is not identical with the sum of publications reported by group members during that period, nor with mean productivity as defined by the sum divided by the number of persons in the group. The quantity of group publications differs from the sum of individual members' publications

a) in that the effect of multi-authorship has been eliminated[1)], and b) in that the aggregate character of the concept assures that individual productivity differentials are wiped out in the group measure. Seen this way, group quantity of publications should be a more valid indicator of the overall contribution to science than individual publication productivities (since it is the number of actual products counted), and furthermore, group productivity scores might allow for a better exploration of context (organizational) effects than individual productivity differentials (and their possibly more personality linked origins).

[1)] With group publications it is the number of papers counted and not the number of authors as would be the case if publications reported by group members were added together.

Before attempting to account for group productivity let us show how productivity scores of supervisory scientists (unit heads) and scientific members of the unit relate to group productivity. Since many of the results in the literature refer to departmental prestige in relation to quantitative productivity, table 3 includes a measure of the recognition[1] received by the research unit in order to check for its association with quantitative output.

In accordance with the analysis presented so far there is a dominant relationship of supervisory productivity to group productivity as exemplified in table 3 by the fact that on the average supervisory productivity accounts for 3-5 times as much of the variance in group productivity than does the output of the research members of a group in academic settings. In industrial settings this ratio is somewhat lower, but there are still pronounced effects of the supervisor especially as far as articles abroad and books are concerned. The same holds for departmental prestige as measured by the recognition the unit receives by the scientific community: here too the correlations are higher for supervisory scientists than for scientific members of the unit.

[1] Recognition has been measured by aggregating responses of unit members as to the degree to which the unit has a high international reputation and the degree to which publications of the unit are in high demand and often cited in the literature. The index was built by taking the means of the scores of unit members.

Table 3: Pearson'rs between publication productivity scores of individual scientists of a unit and group productivity scores of the unit for different measures of productivity

Publication productivity of:	Group productivity measure							
	articles publ. in country		articles publ. abroad		articles and books		recognition of unit	
	r	r^2	r	r^2	r	r^2	r	r^2
Academic natural scientists:								
unit heads	.39	.15	.48	.23	.62	.38	.44	.19
unit members	.26	.07	.19	.04	.29	.08	.26	.07
Academic-technological scientists:								
unit heads	.61	.40	.43	.18	.68	.46	.39	.15
unit members	.39	.15	.18	.03	.34	.12	.19	.03
Industrial technological scientists:								
unit heads	.60	.36	.36	.13	.68	.46	.44	.19
unit members	.50	.25	.23	.05	.38	.14	.32	.10

The existence and size of the above correlations already suggest that individual publication productivity accounts for a substantial amount of variance (varying according to individual position) in group productivity. When attempting to explore different organizational characteristics by means of Multiple Classification Analysis[1] with a view to further explaining group productivity, we found that the following 3 variables - in addition to individual productivity - seemingly influence the published output of a group: most pronounced the size of the research units as measured by the average number of manyears of scientists and engineers working in the group during the last three years; the age of the unit as measured by the number of years the unit has existed formally under its present name and goal structure; and the scientific exchange maintained by the unit through sending and receiving their publications to other groups or individual scientists working in the field. Table 4 lists the Beta-[2] and Eta ^{2}-parameters (correlation ratios indicating the proportion of the total sum of squares explainable by the predictor) as well as Multiple Correlation coefficients for this set of predictors for academic groups in natural and technological sciences and for industrial groups in technological sciences.[3]

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1) Multiple Classification Analysis is a multivariate technique for examining the raw, adjusted and multiple effects of several predictor variables on a dependent variable based on an additive model. As against traditional regression analysis the technique can handle predictors with no better than nominal measurement and nonlinear interrelationships, but cannot handle (directly) interaction effects (see Andrews et al. 1975).

2) Analogous to standardized regression coefficients; see Andrews et al. 1975: 47 ff. for a full discussion.

3) Dealing with conceptual questions on the group level, the present and following analysis refers to the "research unit" as the unit of analysis to which the variables size, age and scientific exchange pertain; group members' publication productivity is calculated as the average individual member's productivity in the unit, scores of the unit heads' publication productivity were kept separately and attributed to the respective units.

<u>Table 4:</u> Predictive power of several predictor variables in explaining group publication productivity as resulting from multiple classification analysis

Predictor variable	Academic natural science groups (N = 450)		Academic technolog. science groups (N = 154)		Industrial techn. science groups (N = 180)	
	Beta	Eta^2	Beta	Eta^2	Beta	Eta^2
Group head's publication productivity	.47	.38	.49	.46	.52	.40
Group members' publication productivity	.23	.19	.24	.23	.17	.16
Size of research unit	.22	.17	.29	.26	.31	.15
Scientific exchange of group	.14	.15	.24	.22	.15	.13
Age of research unit	.12	.08	.14	.11	.16	.03
Multiple R^2 unadjusted:	.54		.64		.54	
Multiple R^2 adjusted:	.50		.59		.44	

Tab. 4 confirms that the supervisor's productivity accounts for most of the variance in group productivity in all subgroups, followed by either group members' productivity or unit size. Scientific exchange and especially age contribute less to overall explanatory power. Relationships of head's and members' productivity, of size and scientific exchange to group productivity are all positive and tend to be monotonous, with most pronounced curvilinearities coming up in the case of unit size.[1)]

Generally, one could say that while the variable set as listed above accounts for a reasonable amount of variance in the dependent measure, it does not contribute significantly to our understanding of mechanisms associated with group productivity: That size of a research team should be related to the number of articles it produces comes as no surprize, and it would have been a serious blow to our confidence in the results if individual productivity had not come up as a major contribution to group productivity. The same holds true for scientific exchange of a group: high publication productivity in most cases will be associated with more activities in sending out and receiving papers, and this may be a resulting much more than a causal prior effect of the quantity of output of a group. The least clearcut and least easily predicted relationship is that with unit age; however, unit age seemingly contributes only marginally to explaining group productivity.

In order to check the above results and to improve our understanding it seemed essential to adjust raw scores of number of group publications for the average size of the

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1) To give an example, youngest and oldest units are most productive in academic natural science settings, while the same holds for groups of medium age in industrial settings when other variables are controlled for.

group during the last three years[1] and to consequently try and predict the resulting per capita publication productivity of the group by the same and other variables. While relationships between per capita productivity and the variables above did change in size and forms of the curves, it is interesting to note that no other variables imposed themselves as substantially contributing to explaining group productivity when looking at bivariate relationships in the data set.

Table 5 presents the results of the Multiple Classification Analysis on the above input variables when adjusted productivity measures have been used.

From comparison of Beta- and Eta^2-coefficients between table 4 and table 5 it can be seen that the contributions of the head's and member's productivity to group productivity remain about the same in academic units and tend to be somewhat higher in industrial settings[2]; similarly, the relationship between scientific exchange and group productivity remains positive and is sometimes more pronounced than with unadjusted productivity scores. Additionally, the effect of unit age again contributes only marginally to the overall

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[1] This was done by simply dividing the raw score of number of articles in the unit during the last three years by the average number of manyears of scientists and engineers in the same period.

[2] The result that the Multiple Classification Analysis explains only about half of the variance of per capita group publication productivity in spite of the inclusion of individual group members' publication productivity among the predictor variables must be related to the fact that the group measure refers to the number of products in the group while the measure of individual publication productivity refers to authorship.

Table 5: Predictive power of several predictor variables in explaining per capita group publication productivity as resulting from Multiple Classification Analysis

Predictor variable	Academic natural science groups (N = 456)		Academic technol. science groups (N = 157)		Industrial techn. science groups (N = 175)	
	Beta	Eta^2	Beta	Eta^2	Beta	Eta^2
Group heads' publication productivity	.45	.23	.46	.33	.59	.49
Group members' publication productivity	.27	.16	.26	.16	.28	.24
Size of research unit	.46	.16	.36	.14	.15	.09
Scientific exchange of group	.17	.10	.22	.14	.22	.18
Age of research unit	.11	.02	.16	.09	.19	.05
Multiple R^2 unadjusted:	.55		.54		.65	
Multiple R^2 adjusted:	.51		.42		.57	

variance explained[1]. The most interesting result clearly pertains to the relationship between group size and adjusted productivity scores. Table 6 presents the raw means and means adjusted[2] for all the other predictor variables in academic and industrial settings; it shows that size is negatively related to per capita productivity in natural science groups, and that raw relationships which still tend to be positive in technological sciences become negative when the effect of other variables is controlled for and adjusted means are looked at.

A number of studies have appeared on the effect of organizational size with inconsistent findings. Whereas Meltzer and Salter (1962) for instance report that size remained totally unsignificant to explaining the productivity of physiologists, Wallmark et al. (1966, 1973) claim that the efficiency of research teams increases exponentially with the size of the team. However, both authors use definitions of the "team" or "unit" which are not comparable to our case.[3] Hagstrom (1971) presents an argument in favor of a positive effect of size by saying that size permits breath to be combined with that specialization which is necessary for rapidly developing research fronts. Furthermore, one could argue that if innovations occur randomly in a specialty field, then the likelihood of this phenomenon

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[1] It should be noted, however, that the form of the relationship in industrial settings changes from a negative one to a curvilinear relationship.

[2] With adjusted means the effects of individual publication productivity (heads' and members' productivity), unit age and scientific exchange are controlled for.

[3] Additionally, Wallmark et al.'s definition of team size as the number of authors from a given organization in a number of journals seems to be correlated with his productivity measure.

Table 6: Raw and adjusted means of per capita group productivity for group size categories in natural and technological sciences as turned out by Multiple Classification Analysis

Group size (average scientific manyears)	Per capita group productivity (number of articles): Academic natural science groups (N = 456)		Academic technological science groups (N = 157)		Technological science groups in industry (N = 175)	
	raw mean	adj. mean	raw mean	adj. mean	raw mean	adj. mean
0 - 2.0	3.8	4.3	2.6	3.3	1.6	1.8
2.1 - 3.0	3.9	4.3	3.0	3.7	1.7	1.7
3.1 - 4.0	4.0	4.2	3.4	3.3	1.3	1.4
4.1 - 6.0	3.5	3.5	2.6	2.7	1.8	1.7
6.1 - 10.0	3.8	3.4	3.8	2.9	1.7	1.2
> 10.0	3.2	2.7	3.0	2.5	2.3	1.5
Eta	.40		.37		.29	
Eta^2	.16		.14		.09	

would be greater in larger units. Similarly, if productivity depends on the availability of substantial resources and is linked to high status scientists (cf. Mullins 1975) then again larger groups should provide more chances of fulfilling this requirement. On the other hand according to Worthy's (1950) well known theory larger size is accompanied by a proliferation of hierarchical levels and institutionalized relationships which prevent the exploration of an individual's full capability and lead to low morale and output. We might add that scientific field and the associated technology requirements could play a key role in determining optimal group size as suggested by the far less pronounced negative effect of size in technological science research units and especially in industry in our data. Blume and Sinclair (1973) for instance found that the relationship between size and productivity varies considerably between areas of a single discipline (chemistry). They speculate on the multiplicity of skills required for some types of research and on the degree of "mechanization" and typification of the research procedure as influencing this relationship. Whereas considerations such as these might be relevant for explaining the differential importance of size in natural and technological science disciplines, the results are not directly applicable to the present analysis since measures of individual publication productivity are looked at. Finally we should point to results by Stankiewicz (1976) on the present data set which show that the relationship between group size and productivity varies in different countries in academic settings, suggesting that differing organizational structures of the university system (is size associated with a flat type of structure or highly correlated with the number of levels in the organization?) will have to be taken into account when analyzing the problem.

Summarizing our results on group productivity we might say that there are two major results worth while noting

a) that individual publication productivity is reinforced as the major explanatory variable of group per capita output (which means that we are referred back to our individual publication models); and
b) that size of the groups tend to relate negatively to per capita productivity (varying in degree according to field and institution) in the six-country data set.

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 author- 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 orientation[1] 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 of 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 publications in the Lisrel model.

The present data do not allow for a check of original productivity capacities. They do, however, allow to call in question the argument that a scientist's productivity suffers as he takes on supervisory duties which involve higher percentages of nonresearch tasks and hence keep him from persueing research work. Except for the more rare case where a scientist leaves the scientific hierarchy he seems to be not drawn off, but rather drawn <u>into</u> publication productiveness by advancement in the hierarchy whatever his original production capacities may have been. In connection with this the results obtained 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.[2] If what is measured is authorship rather than talent for creating research results and if - as pointed out by

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[1] Meltzer 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.

[2] The 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

Crane[1] - in some fields norms allow supervisors to claim authorship for the students' or staff scientists' 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.

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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.

[1] Comment on this paper.

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