DOCUMENT RESUME

ED 038 997 LI 001 924

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TITLE	Institutional Producers of Physics Research.
INSTITUTION	American Inst. of Physics, New York, N.Y. Information Div.
SPONS AGENCY	National Science Foundation, Washington, D.C.
REPORT NO	ID-69-3
PUB DATE	Oct 69
NOTE	28p.
EDRS PRICE	EDRS Price MF-$0.25 HC-$1.50
DESCRIPTORS	*Astronomy, *Geophysics, Information Systems, National Programs, *Physics, *Publications, *Research
IDENTIFIERS	AIP, *American Institute of Physics, National Information Systems

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ID 69-3
(October 1969)

INSTITUTIONAL PRODUCERS OF PHYSICS RESEARCH

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This program supported by the National Science Foundation under Grant No. NSF-GN 710

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ABSTRACT

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I. INTRODUCTION

As part of its program to design a national physics information system, the American Institute of Physics recently undertook a study of institutional producers of physics research. This study attempted to establish the primary characteristics, relative productivity and geographical distribution of institutions performing physics research in the United States today. Insofar as practitioners of physics research are believed to be potential users of a national physics information system, this study was also considered valuable from a market research point of view.

The number of papers published by a given organization was used as the measure of institutional productivity. If the number of papers originating from a given organization is proportional to the quantity of work performed there, this method is valid. Fisher[1/] and others have assumed that such a count is a reasonable measure of the quantity (not quality) and distribution of scientific activity. Our study, like Fisher's, was based upon this assumption.

Although no attempt was made to measure the quality or significance of the papers published, the journals selected for this study are of a high caliber and include a significant[2/] percentage of the papers published in the field of physics today.

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1. Fisher, J. C. "Basic Research in Industry", Science 15: 1653-37, June 19, 1959.

2. According to Keenan's and Brickwedde's study of the Journal Literature Covered by Physics Abstracts in 1965 (AIP ID 68-1), the sample journals represent 8989 abstracts or 28% of the 32,279 abstracts appearing in Physics Abstracts in 1965.

II. SCOPE OF THE STUDY

The source of the data used in this study was a printout from the Technical Information Project (TIP) at M.I.T. It consisted of the institutional affiliations of the authors of all papers published in nine journals during a six-month period in 1966/67.

TIP was designed and operated as a prototype communication system using the time-sharing computer at M.I.T. Access to the files is through terminals located on the M.I.T. campus and a few other locations; one of these terminals is located at the headquarters of the American Institute of Physics.

The TIP file contains a total of 38 physics journals. Fourteen of these are journals and translations published by the AIP; the remainder are important domestic and foreign physics journals. For the journals and volumes included, the TIP file contains complete bibliographic and citation information, i.e., the journal, volume and page numbers, year, authors and their affiliations, title, and the literature citations in condensed form as given in the article in question. Indexing information is not included. Searches can be made for any of the information in the file, either on single data elements or on combinations of the various types of information available.

This study was based on a search of the file by institutional affiliation. Separate searches were done for each journal, with the institutions arranged by geographical location. The amount of information contained in each entry varied, depending on how each author listed his employer in his publication.

Approximately 6900 papers were included in this sample, two-thirds of which represented work performed by organizations located in the United States and Puerto Rico, and one-third of which represented work performed by organizations located outside the United States and by international bodies, regardless of location.

Plans for this study included both the analysis of organizations on the departmental or divisional level and the classification of organizations by type, research interests, location, productivity, size and information system. Analysis on the departmental level and complete classification, however, were not found to be feasible because of limitations imposed by the data and the lack of readily available, comparable information on the organizations themselves.

In order to test the feasibility of organizational analysis on the departmental level, a subsample of 660 papers contributed by nine organizations of all types located in North America, the British Isles and Europe was drawn. Fifty-three percent of these papers provided no departmental information whatsoever; another nine percent presented hierarchical problems which required extensive outside verification. For these reasons, analysis of organizations on the departmental level was abandoned in favor of analysis on the institutional level exclusively.

Furthermore, since more hierarchical problems were presented by foreign organizations, this study was restricted to organizations located in the United States and Puerto Rico, thus reducing the size of the sample to 4648 papers.

Classification also posed problems. Analysis of research interests was made difficult because of the lack of departmental or divisional information (e.g., Department of Chemical Physics). And, the interests of these organizations as listed in sources such as Industrial Research Laboratories of the United States and Canada (1968) and The World of Learning (1968) were frequently too diversified for meaningful classification on either the institutional or departmental level. An alternate method, however, was devised and will be discussed in Section III. B. of this report.

Size, expressed in terms of personnel or budget, was elusive because of the lack of comparable information from outside sources such as Industrial Research Laboratories of the United States and Canada and Poor's Register of Directors and and Executives, United States and Canada. And, size would have to be defined differently for each type of organization, yielding incomparable results.

In order to obatin data on existing information systems used by these organizations, either a detailed questionnaire or interview schedule would have to be devised, and the findings analyzed. Neither time nor available staff permitted such an undertaking at this time.

For these reasons, the scope of the study was further restricted. Organizations were classified and analyzed only by type, location and productivity.

III. METHODOLOGY

A. General

Although, as indicated above, the original data sorting and listing was handled by computer, all further manipulations of the data were done manually. Terms such as "organization" were explicitly defined. Differences in the listings of an organization's name were resolved, and rules of entry formulated. Methods by which the papers would be counted and productivity analyzed were devised or selected, and implemented.

Several conventions were followed in counting and analyzing the number of papers published by the staff of given organizations:

1. Organizations were defined as geographical locations. Three geographically dispersed plants of Bell Laboratories were counted, therefore, as three organizations. Any organization at a given geographical location which was represented by more than one division or department was counted as one organization.

2. All work performed by a given organization was credited to that organization. In analyzing the data, however, funding was given some consideration; all work performed by a Federal Contract Research Center was credited to that Center, but was considered as part of the governmental sector for purposes of analysis. For example, Los Alamos Scientific Laboratory, a Federal Contract Research Center, although managed by the University of California, was included as part of the governmental sector because of its funding by the Atomic Energy Commission.

3. Each paper was considered to be a single unit. Joint authors were given equal fractional credit. In the final addition, however, only .5 was allowed; fractions were rounded to the closest number.

4. Incomplete printout entries which could not be attributed to known organizations were checked in appropriate reference tools. Those which could not be verified in this manner were then excluded from the sample. Eighteen entries with geographical locations in the United States fell int this last category.

Entries for the 4648 papers remaining in the sample, after the exclusions described above had been made, were then arranged by organization, geographical location and journal. In this way 382 organizations were identified. Each was then placed in one of the following major groupings:[3] industrial, governmental, educational or other non-profit organization. The following information was entered on a data collection form prepared for each organization: name of organization, complete address (including zip code), organizational type, productivity by journal and total productivity. The data thus summarized was subjected to statistical analysis. All organizations were ranked by productivity. The 382 organizations were then sorted by organizational type and ranked again. From these the productivity frequency distributions (cumulative numbers and percentages of papers, and numbers and percentages of institutions producing them) were determined.

B. Classification by Research Interests

As indicated previously, a method for determining organizational research interests was devised. It was assumed that subject headings employed in describing papers published in any given journal represent the research interests of organizations publishing in that journal. If the journals in which any given organization publishes and the subject headings assigned to papers in those journals are known, a profile of any given organization's subject interests can be obtained.

The subject headings assigned to journals in our sample, as well as the frequency with which each subject heading was used, are given in Keenan and Brickwedde's Journal Literature Covered by Physics Abstracts in 1965. A grid showing this data is provided in Table I.

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3. These groupings are similar to those used by Westbrook in "Identifying Significant Research", Science 132: 1229-34, October 1960.

Table 1.

Subject Headings Assigned to Journals in Sample

	J. Appl. Phys.	J. Chem. Phys.	J. Opt. Soc. Amer.	Nuclear Phys.	Nuovo Cimento	Phys. Rev.	Phys. Rev. Letters	Phys. of Fluids	Phys. Letters	Total	% Sample	% PA'65	Difference % Sample-% PA'65
Astrophys.			3		14	12	13		10	52	.576	3.99	- 3.414
Atom.& Mol. Phys.	82*	705*	40*	13	30	207*	85*	206*	95*	1463	16.2	11.95	+ 4.25
Biophys.	1				1					2	.022	.065	- .43
Chnge of State	5	33				5	6	3	1	53	.587	.76	+ .173
Elect. & Mag.	28	1			3			2		34	.376	1.61	- 1.234
Electromag.	17	2	1	1	8	8	1	26*	5	69	.765	1.70	- .935
E & M Waves & Osc.	47*	12	13		9	16	11	2	41	151	1.67	2.90	- 1.23
Fluids	13	212*	7		5	29	14	89*	19	388	4.30	4.82	- .052
General			2		2					4	.044	.424	+ .01
Geophys.	1		8		1	1	8	2	2	23	.254	5.45	- 5.20
Heat	2	3	4		2	25	24	9	6	75	.830	1.38	+ .55
Math. Phys.	6	40	1	14	66*	69	7	8	30	241	2.67	3.05	- .38
Nuc. Phys.	8		1	683*	353*	662*	268*		461*	2446	27.1	15.7	+11.43
Optics	12	1	187*		5	7	7		21	240	2.66	3.16	- .5
Phys. Chem.	8	183*			2			1	1	195	2.16	1.42	+ .74
Quantum The.		26		49*	335*	259*	126*		159*	954	10.6	4.80	+ 5.8
Solid State Physics	694*	435*	49*		30	762*	223*	1	404*	2598	28.8	34.6	- 5.8
Techn. Mat.	3									3	.033	.226	- .19
Vib., Waves, Acoust.	4	2			2		2	32*		42	.465	1.95	+ 1.48
X-Rays, Tubes & Techniques						3				3	.033	.165	- .1
TOTAL	931	1655	316	770	868	2065	795	381	1255	9036			

*Subject headings which describe 5% or more of the papers in each of the journals in the sample.

The number of subject headings used to describe each journal varied between five (Nuclear Physics) and seventeen (Il Nuovo Cimento). However, if only those subject headings that represent five percent or more of the abstracts in any given journal are considered, the range becomes two (Nuclear Physics) to four (Physical Review Letters, Physical Review, The Physics of Fluids, Physics Letters, and Journal of Chemical Physics). Eight of the 20 subject headings used by Physics Abstracts in 1965 are eliminated completely: astrophysics, biophysics, change of state, electricity and magnetism, general, geophysics, heat, and x-ray, tubes and techniques.

If it is assumed that the editorial policies of these journals did not change between 1965 and 1967, these subjects may be used to describe the major research interests of any organization in the sample. The research interests of an organization publishing 23 papers in The Physical Review, eight papers in Physics Letters and one paper in The Journal of the Optical Society of America could thus be described by the following five subject headings: atomic and molecular, nuclear physics, optics, quantum theory and solid state physics. Since only one paper was published in The Journal of the Optical Society of America, optics was considered as a peripheral interest and removed from the profile. The validity of this method has not been determined as yet. It was applied to four industrial organizations. These results will be discussed in Section IV.B. of this report.

C. Limitations of Sample

As has previously been indicated, nine journals, published during a six-month period in 1966/67, formed the basis of the study. The journals and their basic characteristics are given in Table 2.

Table 2.

Characteristics of Journals in Sample

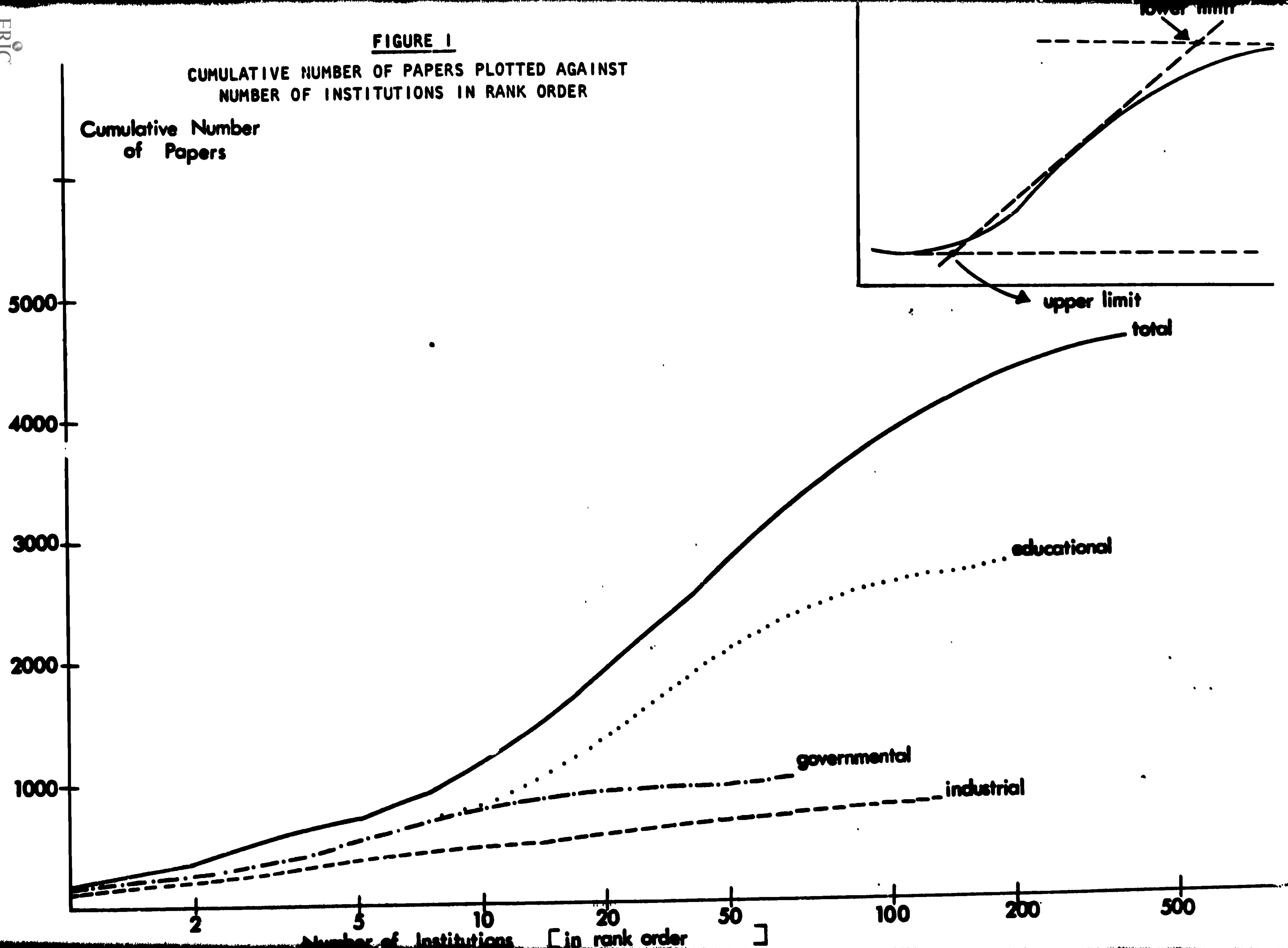
Journal	Volume/Year	Country of Publication	Publisher	Type of Publisher
J. Appl. Phys.	38/1967	USA	AIP	Non-Profit
J. Chem. Phys.	47/1967	USA	AIP	Non-Profit
J. Opt. Soc. Amer.	57/1967	USA	AIP (OSA)	Non-Profit
Nuclear Phys.	79-84/1966	Netherlands	North Holland	Commercial
Nuovo Cimento	44-46/1966	Italy	Soc. Italiana di Fisica	Non-Profit
Phys. Letters	22-23/1966	Netherlands	North Holland	Commercial
Phys. of Fluids	10/1967	USA	AIP	Non-Profit
Phys. Rev.	154-159/1966-67	USA	AIP (APS)	Non-Profit
Phys. Rev. Letters	18/1966	USA	APS	Non-Profit

Although these publications represent 28% of the field of physics, as defined by Keenan and Brickwedde in their study of the coverage of Physics Abstracts in 1965, they are not representative of the field as a whole. They are primarily American, 67% of the total, as opposed to the 18.8% American representation in PA'65. 77.7% of the publishers in the sample are non-profit societies, to be contrasted with 30.3% in Keenan and Brickwedde's universe. The six months sampling in time is inadequate also because it excludes any possibility for recurrence of events and thus formation of and solidification of discernible patterns.

As shown in Table I certain subject areas are significantly over-represented in the sample. These are: atomic and molecular physics, nuclear physics, and quantum theory. They constitute 53.9% of the sample as opposed to 32.45% in PA'65. Inter-disciplonary areas, such as astro and geophysics are under-represented as is solid

FIGURE I

CUMULATIVE NUMBER OF PAPERS PLOTTED AGAINST NUMBER OF INSTITUTIONS IN RANK ORDER



state physics. The above figures imply that the sample is biased toward fundamental as opposed to applied research.

IV ANALYSIS

Figure 1 displays the productivity of all organizations as a cumulative distribution curve. As illustrated, three straight lines were drawn through groups of points until, by eye, the distribution curve and the straight line differed significantly. The intersections of these straight lines isolated three distinct groups of producers as having high, medium and low levels of productivity.

When ranked by total productivity, it was found that of the 382 organizations, 10, or fewer than 3%, had published an average of 116 papers per institution. The high producers published almost 25% of the total number of papers. Eighty-seven organizations, constituting the medium producer class, published an average of 31 papers per institution, accounting for almost 60% of the total number of papers. The 285 low producers, on the average, published fewer than 3 papers per institution. These data are summarized in Table 3.

Table 3.

Total Sample
High, Medium and Low Producers

Level	No. of Orgs.	% of Orgs.	No. of Papers	% of Papers	Avg. Prod.
High	10	2.63	1160.5	24.97	116.05
Medium	87	22.89	2679	57.65	30.79
Low	285	74.48	807.5	17.38	2.83

Table 4 lists the 10 organizations, or high producers, that published 82 or more papers in the sample. The information given for each includes name and address, classification by type, productivity figure, cumulative number of papers, cumulative percentage of papers, and cumulative percentage of institutions.

Table 4.

Total Sample
High Producers

Name & Address	Type	Prod.	Cum. Papers	Cum. % of Papers	Cum. % of Inst.
1. U.S. ATOMIC ENERGY COMMISSION Argonne National Lab. Argonne, Ill.	Governmental	192	192	4.13	.26
2. BELL TELEPHONE LAB. Murray Hill, N.J.	Industrial	179	371	7.98	.53
3. MASSACHUSETTS INSTITUTE OF TECHNOLOGY Cambridge, Mass.	Educational	157	528	11.36	.79
4. U.S. ATOMIC ENERGY COMMISSION Brookhaven National Lab. Upton, N.Y.	Governmental	106	634	13.64	1.05
5. STANFORD UNIVERSITY Stanford, California	Educational	101	735	15.82	1.32
6. CORNELL UNIVERSITY Ithaca, N.Y.	Educational	97	832	17.90	1.58
7. U.S. NATIONAL BUREAU OF STANDARDS Washington, D.C.	Governmental	82.5	914.5	19.68	1.84
8. CALIFORNIA UNIVERSITY Berkeley, California	Educational	82	996.5	21.44	2.11
9. HARVARD UNIVERSITY Cambridge, Mass.	Educational	82	1078.5	23.21	2.37
10. U.S. ATOMIC ENERGY COMMISSION Lawrence Radiation Lab. Berkeley, Calif.	Governmental	82	1160.5	24.97	2.63

When the organizations were grouped by organizational types, and ranked accordingly, it was found that governmental and educational organizations were the most productive groups. Governmental organizations produced, on the average, 17 papers per organization, while educational organizations produced 15. The equivalent figures for the industrial and other groupings were approximately 6 and 5 respectively. The numbers and percentages of organizations and papers, by organizational types, are given in Table 5.

Table 5.

Organizational Productivity by Type

Org. Type	No. of Orgs.	% of Orgs.	No. of Papers	% of Papers	Avg. Prod.
Educational	180	47	2761	60	15.34
Industrial	133	35	835	18	6.28
Governmental	59	15	1004	21	17.02
Other	10	3	48	1	4.80

A. Educational Institutions

As indicated in Table 5, 180 (47%) of the institutions were educational, contributing 2761 (60%) of the papers. Their productivity is displayed as a cumulative distribution curve on Figure 1. Again, three distinct groups of producers can be identified as having high, medium, and low levels of productivity. These levels are shown along with the cumulative percentage of institutions publishing the cumulative percentage of papers and the average number of papers per institution in Table 6.

Table 6.

Educational Organizations
High, Medium and Low Producers

Level	No. of Orgs.	Cum. % of Institutions	Cum. % of Papers	Avg. Prod.
High	10	5.56	32.33	89.25
Medium	49	32.78	85.26	29.83
Low	121	100.00	100.00	3.36

In order to gain further understanding of the educational sector, two additional facets were introduced in the classification: type of educational institution (i.e., private or public) and highest physics degree offered by an institution. It was found that public educational establishments published 12.4 papers per institution, while private institutions published 19.4 papers per institution. Thus private institutions appear to be 56% more productive on the whole than their public counterparts.

When this further breakdown was applied to the three productivity levels of the educational sector, the following additional information was gained:

High Producers: 10

3 public or 30% contributed 25% of the papers.

7 private or 70% contributed 75% of the papers.

Medium Producers: 49

27 public or 55% contributed 54% of the papers.

22 Private or 45% contributed 46% of the papers.

Low Producers: 121

73 public or 60% contributed 62% of the papers.

48 private or 40% contributed 38% of the papers.

It is interesting to note that while in the high producer category private institutions contributed a slightly disproportionate number of papers, there does not appear to be any significant disparity in the other two classes.

Table 7 lists the 10 high educational producers that published 69 or more papers in the sample. The information given for each includes name and address, highest physics degree offered, classification by type, productivity figure, cumulative number of papers, and cumulative percentage of institutions.

Table 7.

Educational Institutions
High Producers

Name & Address	Highest Physics Degree Offered	Type	Prod.	Cum. Papers	Cum. % of Papers	Cum. % of Institutions
1. MASSACHUSETTS INST. OF TECHNOLOGY Cambridge, Mass.	* * *	Private	157	157	5.68	.55
2. STANFORD UNIV. Stanford, Calif,	* * *	Private	101	258	9.34	1.11
3. CORNELL UNIV. Ithaca, New York	* * *	Private	97	355	12.85	1.66
4. HARVARD UNIV. Cambridge, Mass.	* * *	Private	82	437	15.82	2.22
5. CALIFORNIA UNIV. Berkeley, Calif.	* * *	Public	82	519	18.79	2.77
6. PRINCETON UNIV. Princeton, N.J.	* * *	Private	80.5	599.5	21.71	3.33
7. CHICAGO UNIV. Chicago, Ill.	* * *	Private	79	678.5	24.57	3.88
8. PENNSYLVANIA UNIV. Philadelphia, Penn.	* * *	Private	75	753.5	27.29	4.44
9. ILLINOIS UNIV. Urbana, Ill.	* * *	Public	70	823.5	29.82	5.0
10. CALIFORNIA UNIV. Los Angeles, Calif.	* * *	Public	69	892.5	32.32	5.55

***=Doctorate

In order to determine the extent to which educational institutions offered doctoral degrees in physics, the American Institute of Physics' Directory of Physics and Astronomy Faculties 1967-1968, United States, Canada, Mexico was consulted. It was found that while all high and medium producers offer doctorates in physics, this is not true for the lowest producer group. It is interesting to note that in the low producer class while 79% of the public institutions and 52% of the private institutions offer doctorates in physics, public institutions are only marginally more productive than their private counterpart. Table 8 illustrates this latter point.

Table 8.

Low Producers
Highest Physics Degree Offered

Type	Doctoral	Masters	Baccalaureate	Other	Unknown
Public	58	9	3	3	
Private	25	10	11		2

B. Governmental Agencies

Fifty-nine agencies of nine governmental institutions contributed 1004 of the 4648 papers. One institution, the Atomic Energy Commission was responsible for 70% of the papers published by the governmental sector. Four institutions were responsible for 99% of the papers. These are the Atomic Energy Commission, the Department of Defense, the National Bureau of Standards, and the National Aeronautics and Space Administration. The Department of Commerce, the Department of Health, Education and Welfare, the Department of the Interior and Smithsonian Institution contributed the remaining 1%.

When productivity was analyzed on the agency level, it was found that five agencies, or 8.62%, were high producers. They published 80.5 or more papers per institution, accounting for 54% of the papers published by the governmental sector. The medium producers consisted of nine agencies, or 15.52%, which had published fifteen or more papers per institution, accounting for 86% of the papers contributed by this group. Table 9 shows the three levels of productivity, along with the cumulative percentages of papers and institutions and the average number of papers per agency. Table 10 lists, in rank order, the fourteen most productive agencies.

Table 9.

Governmental Agencies
High, Medium and Low Producers

Level	No. of Orgs.	Cum. % of Institutions	Cum. % of Papers	Avg. Prod.
High	5	8.62	54.11	108.60
Medium	9	24.14	85.60	35.11
Low	45	100.00	100.00	3.22

Table 10.

Government Agencies
High and Medium Producers

Name & Address	Prod.	Cum. Papers	Cum. % of Papers	Cum. % of Inst.
1. U.S. ATOMIC ENERGY COMMISSION Argonne National Lab. Argonne, Ill.	192	192	19.12	1.69
2. U.S. ATOMIC ENERGY COMMISSION Brookhaven National Lab. Upton, N.Y.	106	298	29.68	3.39
3. U.S. NATIONAL BUREAU OF STANDARDS Washington, D.C.	82.5	380.5	37.90	5.08
4. U.S. ATOMIC ENERGY COMMISSION Lawrence Rajiation Lab. Berkeley, Calif.	82	462.5	46.07	6.78

Table 10. (cont.)

	Name & Address	Prod.	Cum. Papers	Cum. % of Papers	Cum. % of Inst.
5.	U.S. ATOMIC ENERGY COMMISSION Oak Ridge National Lab. Oak Ridge, Tenn.	80.5	543	54.08	8.47
6.	U.S. ATOMIC ENERGY COMMISSION Los Alamos Scientific Lab. Las Vegas, Nev.	73	616	61.35	10.17
7.	U.S. ATOMIC ENERGY COMMISSION Lawrence Radiation Lab. Livermore, Calif.	56.5	672.5	66.98	11.86
8.	U.S. ATOMIC ENERGY COMMISSION Stanford Linear Accelerator Stanford, Calif.	50	722.5	71.96	13.56
9.	U.S. DEPARTMENT OF DEFENSE AIR FORCE Lincoln Lab. Lexington/Cambridge, Mass.	32.5	755	75.20	15.25
10.	U.S. DEPARTMENT OF DEFENSE NAVY Naval Research Lab. Washington, D.C.	25	780	77.69	16.95
11.	U.S. ATOMIC ENERGY COMMISSION Sandia Lab. Albuquerque, N.M.	24	804	80.08	18.64
12.	U.S. DEPARTMENT OF DEFENSE AIR FORCE Aerospace Research Lab. Wright-Patterson AFB Dayton, Ohio	21	825	82.17	20.34
13.	U.S. DEPARTMENT OF DEFENSE NAVY Naval Ordnance Lab. Silver Spring, Md.	19	844	84.06	22.03
14.	U.S. ATOMIC ENERGY COMMISSION National Reactor Testing Station Idaho Falls, Idaho	15	859	85.56	23.73

Federal Contract Research Centers, although managed by educational, industrial and other organizations, were included in the governmental grouping because of their funding by the federal government. A list of these centers was obtained from Federal Funds for Research, Development, and Other Scientific Activities, 1966, 1967 and 1968. Twenty-one of the 45 centers published papers which appeared in the sample. Two additional organizations funded exclusively by the federal government were placed in this grouping for purposes of analysis, bringing the number of agencies managed by outside groups to 24. The number and percentage of the 59 agencies and their productivity and percentage of productivity, by management grouping, are given in Table 11. Those managed by educational organizations are by far the most productive.

Table 11.

Governmental Agencies
by Type of Management

Management	No. of Agencies	% of Agencies	Prod.	% of Prod.	Avg. Prod.
Educational	14	24	618.5	61	44.17
Industrial	9	15	142	14	15.77
Other	1	2	5.5	1	5.5
Governmental	35	59	238	24	6.8

C. Other Non-Profit Organizations

Ten, or .03% of the institutions were classified as other non-profit organizations. Their productivity ranged from 12 to one, with an average productivity of 4.8 per institution. Only one of these organizations was in the medium producer class of the total sample. The remaining nine ranked as low producers.

Seven of these 10 organizations were described in sources such as the Foundation Directory(1968) as research organizations, two as research and educational organizations, and one as a cancer research and treatment organization.

D. Industrial Laboratories

One hundred and thirty-three laboratories of 101 parent companies contributed 835 papers. This is equivalent to 35% of the total organizations, publishing 18% of the total number of papers. The average productivity per laboratory was 6.3 papers.

Twelve of the parent companies were represented by more than one laboratory. The number of laboratories involved ranged from two to seven. These 12 parent companies and the forty-four laboratories thereof published 505, or 60%, of the 835 papers contributed by the industrial sector. The 44 laboratories published an average of 11.47 papers per laboratory. This is to be contrasted with the remaining 89 single laboratory companies. They produced 330 papers and thus had an average productivity of only 3.71 papers per laboratory.

As shown in Figure 1, the industrial sector's productivity is represented by a line with a smooth continuing transition from the lowest to the highest producer; no clear point of inflection is exhibited. Nevertheless, the three categories of high, medium and low producers were retained by selecting dividing points arbitrarily. This, of course, was done to parallel the treatment of the other groups. Table 12 shows these levels along with the cumulative percentages of institutions and papers, and the average number of papers per laboratory.

Table 12.

Industrial Organizations
High, Medium and Low Producers

Level	No, of Orgs.	Cum. % of Institutions	Cum. % of Papers	Avg. Prod.
High	3	2.27	33.45	93
Medium	17	15.15	68.88	17.38
Low	113	100.00	100.00	2.3

As has been previously been shown, the sample was apparently biased toward fundamental research under-representing applied and developmental areas. Accordingly, our findin gs that governmental and educational institutions, primary producers of fundamental work, were more productive than their industrial counterparts, appears to be justified. In view of the under-representation of industrially oriented research, there is no point in identifying industrial producers by name.

In an attempt, however, to characterize industrial laboratories, methods of identifying their research interests were sought. Sources such as Industrial Research Laboratories of the United States and Canada, as mentioned earlier, were consulted for specific information regarding research interests of individual laboratories. Research interests as represented in this work, however, were too diversified for our purposes. An effort was made to convert these interests into a standardized vocabulary as provided by the Standard Industrial Classification. This was fruitless because the Standard Industrial Classification is basically product oriented rather than research and development oriented.

In Section III.B. of this report, mention was made of an alternate method for determining the research interests of given organizations. This method was applied to four of the parent companies in the industrial grouping. The results are shown in Table 13.

Table 13.

Journal Subject Headings
Applied to Four Multi-Laboratory Parent Companies

Journals and Subject Headings	% of Papers per Journal by Company			
	A	B	C	D
Journal of Applied Physics				
Atomic and Molecular Physics Electromagnetic Waves and Oscillations Solid State Physics	32.4	38.7	32.3	32.6

Table 13. (cont.)

Journals and Subject Headings	% of Papers per Journal by Company			
	A	B	C	D
Journal of Chemical Physics				
Atomic and Molecular Physics	9.34		12.4	9.6
Fluids	9.6	5.6		
Physical Chemistry				
Solid State Physics				
Journal of the Optical Society of America				
Atomic and Molecular Physics	3.5	--	--	13.4
Optics				
Solid State Physics				
Nuclear Physics				
Nuclear Physics	.5	2.9	--	--
Quantum Theory				
Ill Nuovo Cimento				
Mathematical Physics	--	--	--	--
Nuclear Physics				
Quantum Theory				
Physical Review				
Atomic and Molecular Physics	19.6			
Nuclear Physics	--	17.6	28.5	15.4
Quantum Theory				
Solid State Physics				
Physical Review Letters				
Atomic and Molecular Physics				
Nuclear Physics	13.6	8.6	8.9	1.9
Quantum Theory				
Solid State Physics				
Physics of Fluids				
Atomic and Molecular Physics	.5	--	--	5.6
Electromagnetism				
Fluids				
Vibrations, Waves, Acoustics				
Physics Letters				
Atomic and Molecular Physics	21	--	17.9	21.1
Nuclear Physics		26.2		
Quantum Theory				
Solid State Physics				

From a table such as this, a profile of a company's research interests can be derived. Company A, for example, published papers in journals whose major subject interests were in the following areas:

atomic and molecular physics
solid state physics
nuclear physics
quantum theory
physical chemistry
fluids
optics
electromagnetic waves and oscillations
electromagnetism
vibrations, waves and acoustics

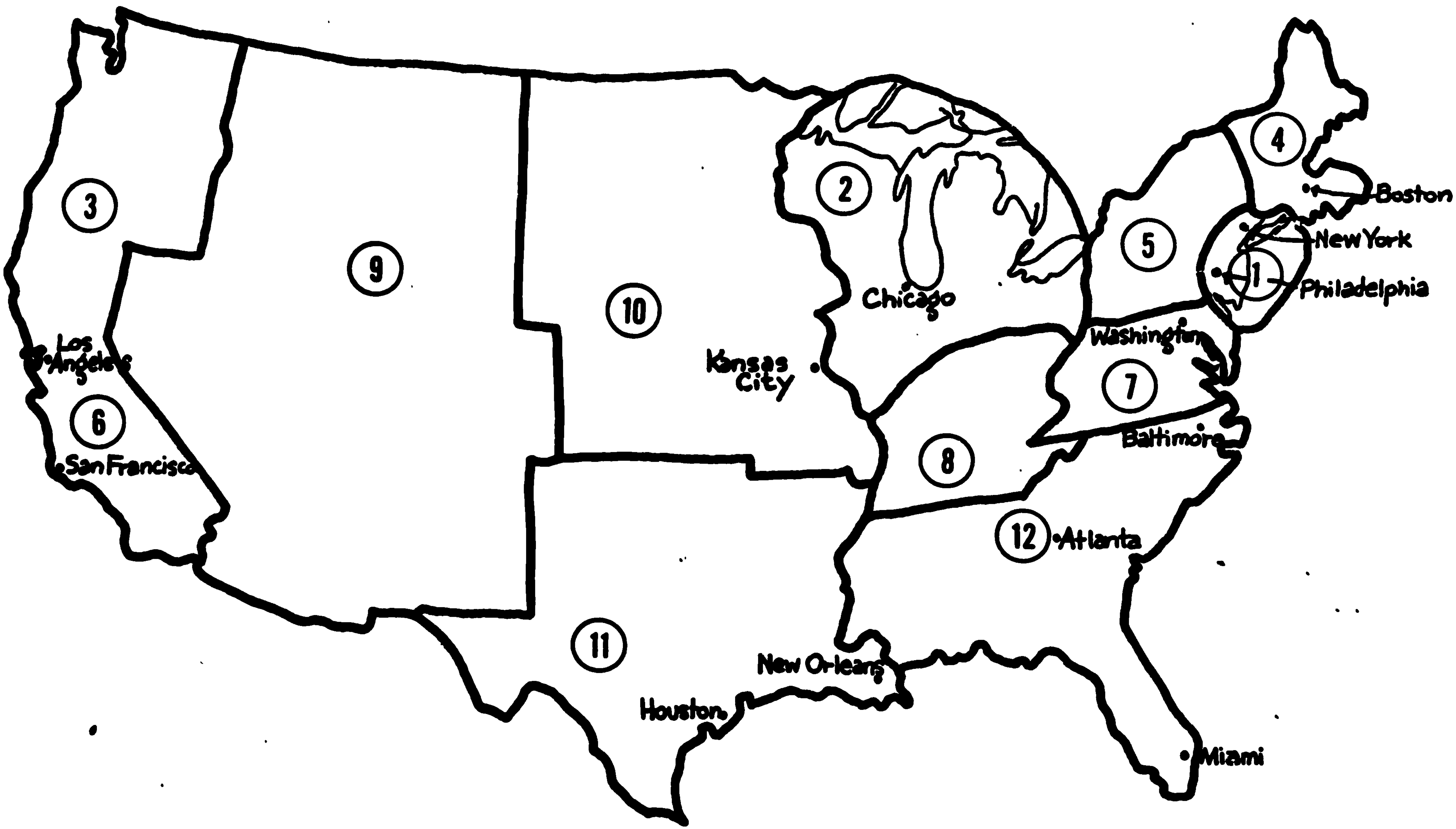
Since the subject heading vibrations, waves and acoustics pertain to only one journal in this sample, and since only .5% of Company A's papers appeared in this journal, this subject heading, and others in the same category, might be eliminated from the Company's profile. While this method seems crude for establishing a company's research interests, it is based upon quantifiable data. Thus the authors believe that it has validity.

E. Geographical Distribution

Although the geographical location of each institution was included as an organizational characteristic, geographical information is only interesting in a larger context. Therefore, the analyses were confined to a comparison of state and regional productivity. States were ranked by total productivity. The number of organizations per state was also determined. Zip codes were used to obtain information on regional productivity. In order to establish large productivity areas, only the first digit of the zip code was considered. Areas of high concentration were divided. For example, Los Angeles and the rest of Southern California was separated from Northern California, Oregon and Washington. Thus, twelve regions were isolated and productivity determined. See Figure 2. for a presentation of this

FIGURE 11

REGIONAL PRODUCTIVITY



data. The three most productive regions, in rank order, are the New York Metropolitan Area, the Midwest, and the Pacific Northwest including Northern California.

State productivity ranged from 847.5 to zero. Alaska, Montana, and North Dakota were not represented. The five most productive states are as follows:

Table 14.

Most Productive States in Rank Order

State	Number of Institutions	Productivity
California	61	847.5
New York	45	613
New Jersey	16	439
Massachusetts	44	436.5
Illinois	11	418.5

Whereas the total number of organizations and the educational segment were dispersed throughout 47 and 46 states, respectively, industrial and governmental organizations were found in only 25 and 22 states, respectively. No industrial organizations were found in the District of Columbia. This pattern is not surprising, since educational institutions far outnumbered industrial and governmental establishments in the sample. Also, educational institutions are more evenly distributed throughout the country than the other two sectors.

V. CONCLUSIONS

1. Institutions in the sample differed in their rates of publication. Three levels of productivity were found: high, medium and low. This difference can be expressed in terms of ranges of productivity. High producers published from 82-192 papers per institution; productivity of low producers extended from .5-10.

2. Four major categories of producers were identified; educational, industrial, governmental and other. A difference in publication activity could be discerned. Expressed in terms of average productivity, the difference is as follows: governmental, 17; educational, 15.3; other, 4.8; and industrial, 6.3. Thus governmental, on the whole, seems to be the most productive segment.

3. Differing levels of productivity were isolated for three of the four groups. The average productivity and the ranges are shown in Table 15.

Table 15.

Average Productivity and Productivity Ranges by Type

Type	Avg. Prod. HIGH	Avg. Prod. MEDIUM	Avg. Prod. LOW
Total Sample	116 (82-192)	31 (10.5-80.5)	3 (.5-10)
Governmental	109 (80.5-192)	35 (15-73)	3 (.5-11.5)
Educational	89 (17.5-179)	30 (5-17)	3 (.5-4.5)
Industrial	93 (48-179)	17 (8-39.5)	2 (.5-7)

4. Educational organizations constituted the largest producer group. They accounted for 47% of the organizations and published 60% of the papers.

5. Private educational institutions were found to be more productive than public ones. Private institutions published an average of 19.4 papers per institution, while public institutions averaged 12.4 papers.

6. Governmental agencies managed by educational institutions were more productive than those managed by industrial, other or governmental organizations. 24% of the agencies were managed by educational organizations and produced 61% of the governmental papers.

7. Industrial organizations which were represented in the sample by more than one laboratory were more productive than those which were represented by a single laboratory. Multi-laboratory organizations published an average of 11.47 papers per laboratory, while single laboratory organizations published an average of 3.71 papers per laboratory.

8. The three most productive geographic regions were the New York Metropolitan Area, the Midwest and the Pacific Northwest which included Northern California. California, New York, New Jersey, Massachusetts and Illinois were the most productive states.

9. Since producers of physics are believed to be potential users of a national physics information system the identification of different categories of producers, their differing levels of productivity, and their geographical situation, is an important step in surveying the potential need for such services. It is anticipated that future case studies of high producers of all types will make determining relationships between size, productivity, and internal information systems possible.