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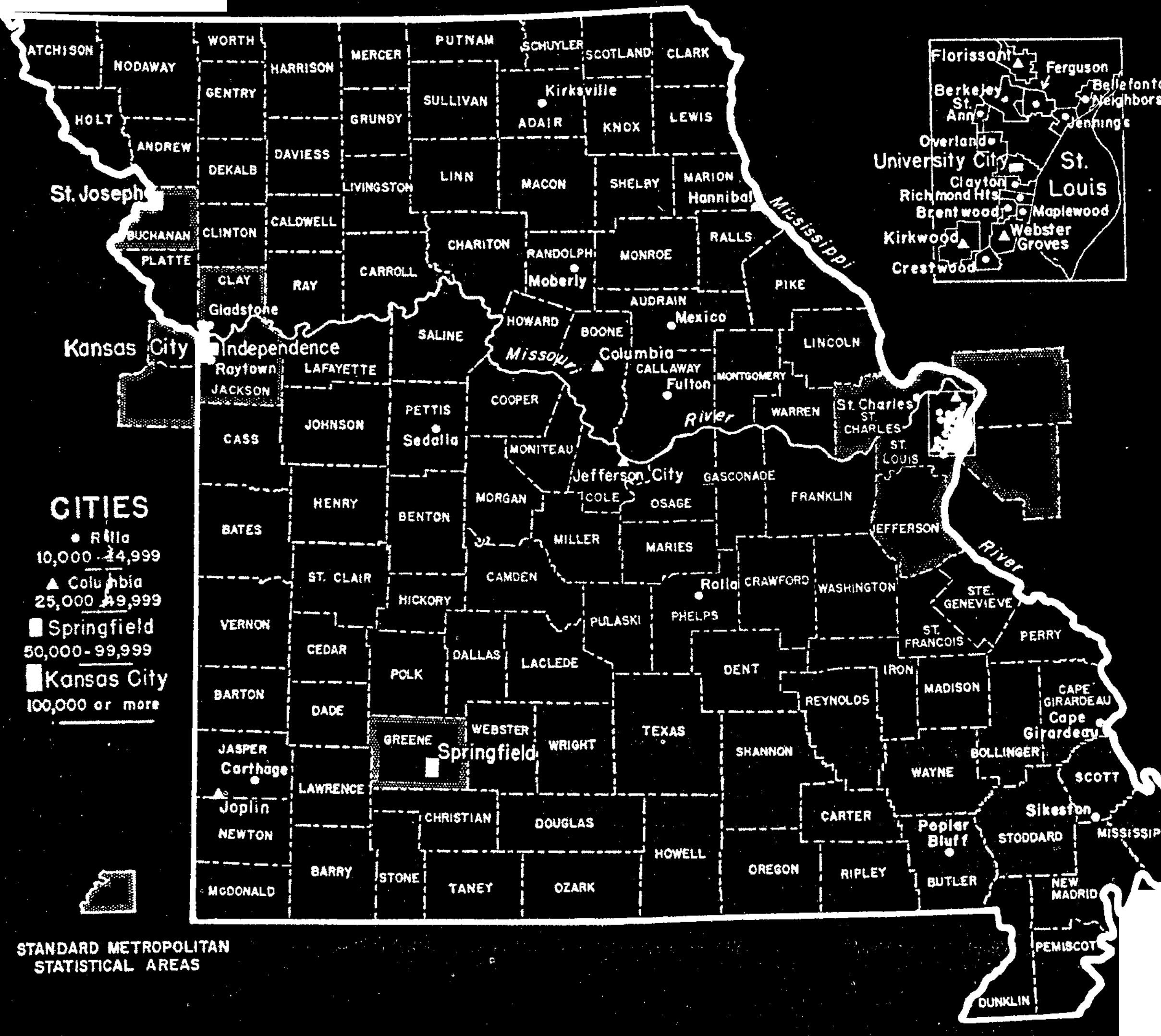
Research Center
School of Business
and Public Administration
University of Missouri

MISSOURI ECONOMY STUDY

SCIENTIFIC RESEARCH IN MISSOURI

Donald A. Murry

MISSOURI COUNTIES AND MAJOR CITIES



SCIENTIFIC RESEARCH IN MISSOURI

Donald A. Murry

Number 5
of a series of studies defining the problems
and prospects for Missouri's economy

RESEARCH CENTER
School of Business and Public Administration
University of Missouri
Columbia, Missouri

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STUDY ORGANIZATION

On September 21, 1961, representatives of 50 firms in Missouri met with staff members of the Research Center, faculty of the School of Business and Public Administration, faculty members of other divisions, and officials of the University to discuss the possibilities for undertaking a state-wide study of Missouri's economic development.

As a result of the discussions a series of studies on particular aspects of Missouri's economic and governmental structure was organized. A cooperative method of financing was provided by an allotment of funds from the University and by grants from business firms interested in the overall development of the Missouri economy.

In May 1962 a meeting of officials of firms supporting the Missouri Economy Study and faculty researchers was held and studies were initiated in the following major areas:

Fiscal Structure
Government
Metropolitan Centers
Labor Force and Employment
Transportation
Research and Development
Income
Financial Markets
Manufacturing
Wholesaling and Retailing
Forestry
Recreation

Upon completion of the studies a summary of findings will be prepared. In addition it is anticipated that the Sponsors of the Missouri Economy Study will provide a document suggesting ways and means of improving the vitality and health of the economy of the state of Missouri.

SPONSORS OF THE MISSOURI ECONOMY STUDY

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FOREWORD

The national impact of research and development activities has become a matter of great concern to business and government leaders in the last few years. Regional and local impacts of a growing R&D industry have become of even greater concern to a wide-ranging list of observers.

This study is one of a very few that have attempted to specify the local consequences and prerequisites of research and development expansion.

From the standpoint of the local agencies whose function is the promotion of industrial expansion Mr. Murry makes the case that R&D type activities have a special appeal that rests on intangible as well as tangible qualities. The intangible appeal stems from the belief that:

1. The R&D industry is a "clean industry."
2. The R&D industry is a high prestige industry.

The tangible economic benefits that are believed to be associated with R&D activities are:

1. R&D efforts accelerate the growth of the locality (cluster effect).
2. R&D efforts ultimately result in the growth of manufacturing production.

Mr. Murry states that "despite their lack of publicity and appeal, the subsequent production contracts, although seemingly of less prestige, are likely to be the most important by-product of scientific research and development."

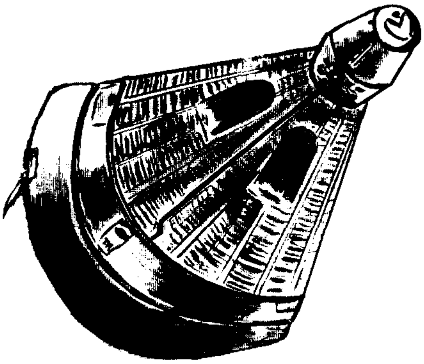
In chapters III and V, Mr. Murry has been able, by an imaginative series of steps, to document the expansion of the R&D industry in Missouri and to relate its growth to that in selected other states.

But, one may ask, what conclusions may be drawn from Mr. Murry's detailed study of R&D in Missouri? There are two major points covered by the author:

1. There appears to be little overall strength in research and development at this time in Missouri.
2. The role of catching up with others indicates that a considerable quantity of scientific resources, with some specific characteristics, must be made available.

These points have both been reduced in impact by actions taken during the 1963 session of the Missouri Legislature. Appropriations to undertake a space sciences research operation were passed and additional funds for scientific research were made available to existing agencies in the state. But, even so, a first-rate R&D industry depends upon the agglomeration of scientific talent, in the long run, and those of us who are here now must create the climate for accomplishing this difficult but challenging opportunity.

Robert W. Paterson
Director



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CHAPTER 1

A FRAMEWORK FOR THE STUDY OF MISSOURI'S SCIENTIFIC RESEARCH ACTIVITIES

The regional economic consequences of scientific research are not readily apparent because of the complexities of the activity. The study of scientific research in a particular region is very difficult because of sparse empirical evidence. Both of these problems greatly affect the procedure of this study of the role of scientific research in Missouri.

This chapter consists of four parts that together create the framework for this study of Missouri's scientific research projects, scientific research resources, and prospects of future scientific research.

I. DEFINITION OF TERMS USED THROUGHOUT THE STUDY

In order to establish continuity in the following analysis and the data employed, and because of the diverse connotations of terms related to research, the specific activities to be studied must be defined.

The National Science Foundation has standardized the definition of scientific terms used in their compilation of data concerning scientific research in the United States, and much of the data cited throughout this study are published by NSF. Therefore, using NSF definitions of some key terms that are used throughout this study is appropriate.

The term "research and development" according to the National Science Foundation connotes "basic and applied research in the sciences (including medicine) and in engineering, and design and development of prototypes and processes."[1] The NSF definition specifically excludes "quality control, routine product testing, market research, sales promotion, sales service, research in the social sciences or psychology or other nontechnological activities or technical services."[2] The term

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[1] National Science Foundation, Reviews of Data on Research & Development, No. 36, September 1962, p. 12

[2] Ibid.

"scientific research" is used in this study of Missouri interchangeably with research and development. The abbreviated R&D is used, also.

The component of research and development called "basic research" by the National Science Foundation is defined as "research which is directed toward increase of knowledge in science. It is research in which the primary aim of the investigator is a fuller knowledge of the subject under study, rather than a practical application thereof."[3]

The National Science Foundation's definition of basic research is predicated on the intent of the researcher. If he seeks new knowledge rather than a practical application of knowledge, the activity is termed basic research. The data-collection difficulties are obvious with such nebulous economic activity. However, a basic research category is required, and this definition seems to be appropriate.

From the above definition of basic research the definition of the component of R&D called "applied research" follows clearly. It is defined by NSF as research toward a practical application of knowledge.[4]

The component of research and development called "development" by the National Science Foundation means a "systematic use of knowledge directed toward the design and production of useful prototypes, materials, devices, systems, methods, or processes. It does _not_ include quality control or routine product testing."[5]

The definitions of scientific personnel used by the National Science Foundation can apply appropriately for this study, also. In cases where personnel data other than those published by NSF are used, the definitional distinctions will be made.

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[3] National Science Foundation, _Reviews of Data on Research & Development_, No. 35, August 1962, p. 6.

[4] _Ibid._, No. 33, April 1962, p. 8.

[5] _Ibid._, No. 23, October 1960, p. 4.

"Scientists and engineers" according to the National Science Foundation are "professional personnel in the fields of the natural and social sciences, psychology, and engineering. The natural sciences cover all life and physical science disciplines."[6]

"Professional personnel" according to NSF are persons who have received a bachelor's degree or higher and who are working at a professional level.[7]

II. THE PURPOSE OF THIS STUDY

The purpose for studying the role of research and development in Missouri is to ascertain the consequences of such activities in the state economy. The role of scientific research activities in regional economic growth has been discussed frequently, but despite this publicity the relationships between scientific research and the regional economy are not fully apparent. Therefore a brief yet detailed investigation of the consequences of research and development in a regional economy follows.

Scientific research can act as a stimulus to regional economic growth in two different ways which can be readily established. In the first case, regions that have developed mature, viable concentrations of research oriented activities, sponsored usually by federal research expenditures for such projects as defense, space, or health, may gain economic vitality from these research oriented activities. Secondly, research findings by definition mean new knowledge, and, if this knowledge enables the indigenous resources to be employed more productively, that too, is a stimulus to the regional economy. Therefore, in this study of regional economic consequences of local scientific research both facets are considered:

(1) the performance of research within the region

(2) the use of research findings by local industry in technological change.

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[6] National Science Foundation, Reviews of Data on Research & Development, No. 37, January 1963, p. 12.

[7] Ibid.

Regional Economic Consequences of Performance of Scientific Research

The traditional regional interest in acquiring research facilities has been caused primarily by the rapid growth and the preponderance of federal expenditures for scientific research and by the wide spread appeal that research related industries have developed.[8]

Of course, the initial effects from federal research expenditures in the local economy are no different from those of any government expenditure. They are typical of any federal program that expends funds with local organizations. There are, however, some characteristics of scientific research activities that appear to have a special attraction to regional interests.

Two intangible qualities of science-based industry that apparently create special appeal in a region are identifiable. First, a research and development industry is a "clean industry." That is, research activities lack some of the liabilities commonly charged against traditional industrial production by the community. For example, scientific research seldom pollutes the proximate air or water. In most cases scientific activities are not noisy. The research laboratories often are housed in architecturally attractive buildings and are placed on landscaped grounds. Aside from creating high paying jobs for the local labor force, the outside personnel attracted by scientific research are typically well-educated and high salaried. A second intangible appeal of scientific research to the region seems to be associated with prestige. These prestigious elements of scientific research are difficult to isolate, but they do seem to exist. The esoterics of the burgeoning sciences, the national publicity surrounding the space effort, the engineer-gap and the missile-gap issues of recent years, and the general publicity surrounding the benefits afforded by the sciences have added to the apparent regional prestige of a scientific research industry. Despite the elusive nature of these qualities, the regional appeal which they have helped to generate is real enough.

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[8] The local effects from scientific research preformance may differ only slightly because of the sponsor. However, since two thirds of all research is federally sponsored and since attracting federal R&D is a stated goal of many regions, it will be emphasized.

In addition to such intangible qualities as aesthetic appeal and apparent prestige, federal research contracts offer tangible economic benefits to a region. These regional economic benefits go beyond the mere level of the federal R&D expenditure and the concomitant payments-effect.

One economic factor enhancing the appeal of research and development projects to a region rests on the proposition that the presence of scientific research attracts additional R&D to a region. If this proposition is true, a region can benefit, beyond the payments-effect to the research expenditure, by being a better contender for future federal scientific research contracts and by attracting industrial scientific research. Supporting this contention is at least one empirically obvious factor, the geographical clustering of scientific research resources.

Such a clustering of scientific resources is probably no historical accident but a rational spatial allocation. There is much evidence that economies of agglomeration are available to research projects located in these research clusters.

These economies of agglomeration can be associated with two economic characteristics resulting from indivisibilities[9] of many research and development projects:

(1) a requirement of bulky, indivisible inputs

(2) interaction among inputs in the cluster that generates technological external economies of scale.

A discussion of each of these characteristics is necessary to the understanding of regional R&D activity.

The first characteristic is a prevalence of bulky, indivisible inputs required for scientific research. Such indivisible inputs are, for example: high quality scientists, libraries, educational facilities, and testing devices such as computers, nuclear reactors, and cyclotrons. Even if individual R&D projects could not use these facilities to capacity, several projects in a cluster would be able to do so. Therefore, a geographical clustering of scientific research projects about these indivisible inputs may be a rational procedure. The cost of the required input is

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[9] _Cf_. Tjalling Koopmans and Martin Beckman, "Assignment Problems and the Location of Economic Activities," _Econometrica_, Vol. XXV, No. 1, January 1957, p. 53.

minimized to each project, and ceteris paribus, this clustering is the optimum spatial allocation of research resources. The economies of agglomeration are available to all R&D projects in the cluster that employ the indivisible input.

The second characteristic that leads to economics of agglomeration in interaction among scientific research inputs in a research cluster that generates technological external economies, i.e., the expansion of one research project induces an increase in productivity of scientific inputs employed in another research project within the cluster. Examples of such technological externalities that may occur in research clusters are evident.

The exchange of information among scientists and engineers employed in the research cluster increases their productivity as the clustering of projects, for some range of cluster sizes, facilitates communication. The expansion of an individual project produces new scientific knowledge, and its ready dissemination in the cluster increases the productivity of the scientific talent employed in other projects.

A stimulating environment may be created in the research cluster in which the scientific talent of all projects are more productive. The expansion of an individual project may improve the environment of the research cluster and the productivity of scientific talent employed in other projects.

A pool of scientific resources may be developed in a research cluster that reduces the uncertainty of an individual research project as to whether or not it can acquire additional resources. This uncertainty may be particularly important to federal R&D contractors. Federal R&D contractors often increase and decrease employment abruptly as they fulfill and initiate contracts. In a cluster of research projects, an expanding project can acquire resources released by a completed project and hence, growth of a cluster of research contractors would be more stable, with more gradual fluctuations, than the growth of a single research contractor. An individual contractor is more likely to acquire additional resources when he expands his R&D activity abruptly if he is situated in a research cluster.

Of course, interaction of research projects may generate external diseconomies as well as economies. However, the characteristics of R&D and the evidence of clustering suggest that net external economies prevail, at least for some range of R&D cluster sizes.

The nature of R&D performance strongly suggests that economies of agglomeration are available to firms in a research cluster. This provides a sound economic basis from which to assert that the presence of scientific research attracts additional scientific research to a region. Furthermore, the expansion of R&D in the cluster improves further the productivity of resources within the cluster. These conclusions are, of course, conditional on the presumption that the cluster of scientific resources is sufficiently large and sufficiently composed to be viable.

For these reasons, the regional benefits of federal research contracts may differ from regional benefits occurring from some other more traditional government projects or contracts. Because scientific research provides a conducive environment for additional federal research contracts and private industrial research, an entirely new science-based industry conceivably could become viable in the region. This facet of federal research contracting has obvious regional appeal.

A second economic factor enhancing the attractiveness of federal research contracts to a region is the relationship of development to production. The preponderance of federal R&D expenditures is spent for development. These federal expenditures for development, if the projects are successful, eventually will culminate in the building of a product. For example, R&D on a new aircraft, missile, or electronic device will lead hopefully to production. Presumably a federal agency contracting for the R&D will eventually want delivery of the production item. At that time, one should not be surprised if the company that performed the R&D also possesses an advantage in producing the item for delivery to the federal agency. That company employs the personnel who designed the product, built the prototype, and are familiar with its idiosyncracies.

This production phase is of added importance to the regional economy. In the production state different resources are required from those that were required by research and development. People with production skills must be employed, and the number of people required with these skills may far exceed the number required for research. Thus, the economic impact upon local resources of the production of the item may surpass by far the economic impact inherent in the R&D activity.

This research-production nexus is particularly evident in military contracting, and the simultaneous performance of research and production of military hardware suggests another important characteristic. Scientific research and production seem to complement one another. For example, original research provides the know-how for production, and the knowledge gained in production engineering improves further the R&D potential. Also, research seeking improvements to the first model leads to significantly different findings, and to the production of subsequent models. This regenerative facet of federal research contracting has obvious regional appeal.

These economic factors appear to be reasonable justification for the traditional regional interest in local R&D expansion. Federal research contracts do seem to provide an environment which attracts additional scientific research and production contracts of items developed with R&D contracts. Evidently, such has been the case in the federal R&D contracting in recent years. These characteristics make federal research contracts attractive to the regional economy--beyond the value of the dollar expenditure and the aesthetics of science, and they explain the regional interest in R&D. Federal R&D expenditures have the potential of viability that many types of federal projects do not have. Curiously, despite their lesser publicity, the subsequent production contracts, which are seemingly of less prestige, are likely to be the most important by-product of scientific research and development.

Regional Economic Consequences of Technological Change in Regional Industry

Scientific research findings, whether the research was undertaken in the region or not, clearly affects the regional community when employed by local industry as new technology.[10] These consequences of technological change in

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[10] There have been attempts at isolating technological change in the U.S. economy. For example, Robert Solow, "Technical Change and the Aggregate Production Function," Review of Economics and Statistics, August 1957, attributed only 13 per cent of the per capita growth of net national product 1900-50 to capital accumulation. Cf. Moses Abramovitz, "Resource and Output Trends in the United States Since 1870," American Economic Review, May 1956.

regional industry are considered in the following discussion.

Technological change can take three forms which, because the immediate impact upon the economy differs, will be identified. First, new technology may affect directly the complex of products and services available to consumers. Technology may improve the quality of existing products being supplied presently, or it may offer an entirely new product with experiences or satisfaction not previously available to society. Secondly, new technology may alter the method of production of the present complex of products. That is to say, new technology may provide a new production technique that enables the substitution of a relatively less expensive input for a previously employed input without altering the intrinsic utility of the product. Thirdly, a new technique of production may alter the technical coefficient of production, i.e., decrease the number of inputs required to produce a given number of outputs. The motivation for an industrial organization to employ the first type of technological change is market advantage; the motivation of the latter two types of technological change is cost reduction.

Naturally, the vitality afforded an industry by technological change or by an "innovation," a major technological change, may be considerable.[11] An innovative new product or service ultimately may establish an entirely new industry. Such stimulus to economic activity is obviously important in our current economy. For example:

> ...the constant flow of new chemical products has produced an industry which, over the postwar period to date, has grown at the rate three fourths again as fast as the economy as a whole, one which employs more than twice as many people today as it did in 1935.... Whole industries have been based on chemical discoveries and it is certain that chemistry has been a dynamic force in the expansion of the economy.[12]

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[11] Although innovation in the Schumpeterian sense is a spectacular element of economic dynamics, most technological change comes about more gradually. Cf., S. Colum Gilfillan, The Sociology of Invention (Chicago, Follet Publishing Company: 1935).

[12] Ralph E. Burgess, "Impact of Research and Development and its Impact in the Chemical Industry," Proceedings of a Conference of Research and Development and its Impact on the Economy, National Science Foundation, 1958, p. 59.

The role of product innovation in the current economy can be emphasized further by a list of products which has been compiled by Leonard Silk according to growth rate.[13] This list includes:

- products with growth rates of 40 per cent per year--or more

  transistors, titanium sponge, power steering, power brakes, antibiotics, television sets, polyethelene, styrene plastics and resins, vitamins, helicopters (nonmilitary), synthetic rubber, butadiene, synthetic detergents;

- products with growth rates of 30 to 40 per cent per year

  television broadcasting stations, ton miles of air flown, synthetic fibers (except rayon), electric dryers, automatic coffee makers, argon, room air conditioners, tape recorders, pentaerythritol;

- products with growth rates of 20 to 30 per cent per year

  tractors, polyvinyl resins, passenger miles of air flown, pickup hay balers, electric blankets, helium, rayon and nylon cord, DDT, synthetic ammonium sulphate.

Obviously, technological change is a dynamic facet of economic growth. However, this study is focused primarily on the impact of technological change within a region industry upon the regional community. For this reason, despite the obvious dynamism of technology in the aggregate economy, a slightly different view of technological change is required for relating it to the regional economy.

To begin, one should observe that a region is merely a segment, divided spatially, of society as a whole. Then, to some extent, the analysis of regional economic consequences of technology turns on the consequences of technological change to society as a whole. This can be seen best in the following example.

For the sake of analysis, the society can be expressed as a community with perfectly competitive factor and labor markets all of which are at equilibrium. The region to be considered is an abritary spatial subdivision of this community. The first problem to be discussed is one which explores the consequences of technological change in the entire community.

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[13] Leonard S. Silk, The Research Revolution (New York: McGraw-Hill Book Company, Inc., 1960), pp. 56-57.

Since the three types of technological change, stated broadly, can be viewed as a new method of achieving economic goals, persons who are motivated to incorporate these new techniques obtain net benefits. However, the other sections of the economy must be considered as well. A reallocation of resources necessarily occurs with each of the three types of technological change. This reallocation of resources leads to important and inescapable observations of technological change.

Although social benefits are forthcoming to one sector of the community from technological change, social costs are certain to be incurred in some other sector of the community. Therefore, despite the obvious significance of technological change in a dynamic economy, unless strong assumptions are introduced about the economic community, one cannot conclude unambiguously that each change of technology provides net benefits to society as a whole. Although technological change undoubtedly is, in the main, beneficial to society, each change of technology does not necessarily provide net benefits to society. Considering the obvious significance of technological change and its prevalent benefits in our society today, this conclusion is significant.

This condition provides some basis for analysis of the region. Since a region is only an arbitrary segment of the whole community studied, the above observations serve it also. Social costs may occur within the region. One cannot make an unambiguous statement that technological change will provide net regional benefits. Although a technological change that incurs social costs only (without the region) can be envisioned, thus enabling such a statement, an allocation of resources based on such a narrow definition of optimality (even for the region) does not seem warranted. Technological change in a regional industry may provide strong impetus to the local economy, but the concomitant reallocation of resources precludes making an unambiguous statement that each technological change will provide net benefits to the community as a whole.

III. THE DETERMINANTS OF REGIONAL R&D GROWTH

The economies of agglomeration that were observed above provide a strong economic basis for discussing general locational determinants of R&D which heretofore have been unavailable. This comes about in the following manner. In general, the transfer costs of R&D outputs and inputs are negligible. This induces uncertain locational determinants; a sort of fluidity exists in scientific research location. However, the economies of agglomeration encourage a clustering of research resources, because of prevalent indivisible inputs and technological external economies. In the absence of significant transfer costs, if the cost of a given scientific research project is to be minimized, the present location of scientific research and the present location of required indivisible inputs become criteria for locating the project.

Because economies of agglomeration in R&D performance provide relevant criteria for the optimum allocation of research resources, they also offer significant criteria to the regional economy which is attempting to use R&D as a vehicle of economic growth. These criteria can be derived from the economic properties of the inputs that lead to economies of agglomeration.

The type of indivisible inputs which are prevalent in scientific research suggests that a research cluster will become viable only after sizeable capital investment is made in these inputs in the region. In addition, a research cluster becomes cost competitive with established, viable clusters only after there has been a considerable accumulation of additional resources, such as scientific talent. Although the fluidity of much scientific research underscores the possibility, a region must attract or acquire a large quantity of research resources before a viable, cost competitive R&D industry can be established.

The likelihood that external economies are available among research projects in a research cluster provides an additional basis for studying R&D expansion in a regional economy. Net external economies mean that an individual R&D project will not expand to its optimum size from the standpoint of the cluster as a whole. If the expansion of one R&D project makes technological external economies available to other R&D projects in the cluster, the marginal costs to the expanding research project are greater than its marginal social costs. Of course, the existence of external economics implies that a tax-subsidy arrangement could achieve socially optimal project expansion.

Without some such compensation this phenomenon impedes the expansion of individual R&D projects already located in the cluster, and thereby, it impedes the expansion of the entire cluster. Although agglomeration economies obtainable in a research cluster may provide a cost inducement for R&D projects to locate in the cluster, new R&D projects are attracted most strongly by the least cost R&D clusters. From the characteristics of the inputs these are probably the large, established clusters. In this way, the tendency of technological external economies to impede the expansion of individual projects already located in the R&D cluster impedes the small R&D clusters which are trying to expand to a point where they are cost competitive. That is to say, it impedes those trying to "catch-up."

These general characteristics of research and development performance emphasize that unless the R&D projects are already forthcoming the regional attraction of these projects will be difficult indeed. New R&D projects will locate in the least cost R&D clusters. The attainment of a cost competitive, viable scientific research cluster requires a heavy concentration of scientific research capital and talent.

IV. THE METHOD OF THIS STUDY

This study employs the existing data relevant to R&D in a manner that circumvents some of the inherent difficulties of studying an area of regional economic activity with so little empirical information.

The data pertaining to scientific research in Missouri are examined and compared with data from five selected states in order to point out the similarities and differences in the characteristics of scientific research sectors of various sizes. This comparison is developed in a context of the stipulated effects of regional scientific research, of the determinants of regional R&D growth, and of the national growth of scientific research.

CHAPTER II

RECENT EXPANSION OF RESEARCH AND DEVELOPMENT ACTIVITY IN THE U.S.

The most important facet of research and development activity in the United States, as far as a regional study is concerned, is its growth in recent years. This growth is quite evident from a comparison of the findings of the first National Science Foundation survey in 1953-54 with the findings of the most recent in 1961-62.

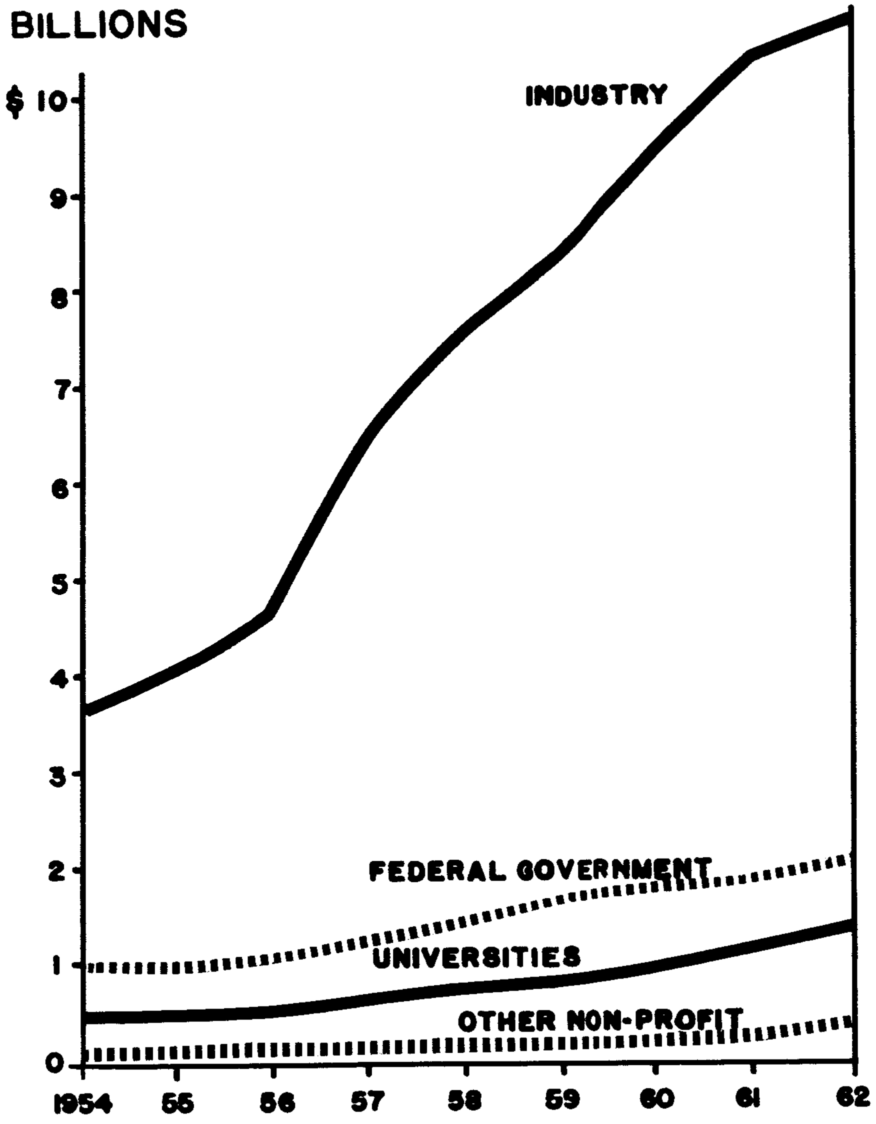
This growth has been widely publicized, and it frequently is alluded to by persons advocating scientific research as a stimulus to a regional economy. Receiving equal publicity has been the principle sponsor of the R&D growth, the federal government. Thus, the data published by the NSF have received considerable attention and are quite familiar already to persons interested in the expansion of R&D. Nevertheless, since scientific research in Missouri is tied closely to the national expansion of R&D and the significant national developments are inseparably important to Missouri, this chapter will sketch briefly the data published by NSF that are the most relevant to this Missouri study.

These data identify the various sources of R&D funds and the various performers of R&D, and in their presentation the significance of each is highlighted. Relevant trends in the development are noted for a subsequent comparison to Missouri data.

I. INTERSECTOR FLOW OF FUNDS FOR RESEARCH AND DEVELOPMENT

The four categories used by the NSF to identify sources and recipients of funds for research and development are the federal government, industry, colleges and universities, and other nonprofit organizations. Tables I and II illustrate the flow of R&D funds among sectors. The federal government stands out, by far surpassing the other three sectors in sponsoring research and development projects. The role of each of these sectors will be discussed in turn.

FIGURE I
PERFORMANCE OF RESEARCH AND DEVELOPMENT
BY SECTOR



Federal Government

The federal government obviously has provided the necessary funds that enabled the rapid growth in scientific research during the period. In 1953-54, of the $5,150 million spent for research and development, the federal government sponsored $2,740 million (Table I) or 53 per cent of the total. However, by 1961-62, where the total R&D expenditure had grown to $14,740 million, the federal government sponsored $9,650 million, 66 per cent of the total research and development. The total expenditures by the federal government for research and development had grown by 252 per cent over this 9 year period.

Although the federal government has provided the funds that enabled the rapid growth of research and development, clearly the other three sectors have been relied upon to perform the research and development projects. The 1953-54 NSF survey found that the federal government itself performed $970 million (19 per cent) of the total research and development undertaken and the 1961-62 survey showed that the federal government performed $2,090 million (14 per cent). This growth (115 per cent) in the performance of research and development by the federal government is less than the growth of the other three sectors.

Private Industry.

Private industry, the major performer of R&D, undertook $10,870 million (74 per cent) of the estimated total value of research and development in 1961-62. This was an increase from the $3,630 million (71 per cent) of research and development performed in 1953-54. Private industry's share was even larger during the post-sputnik periods of 1956-57 and 1957-58.

Private industry in searching for new products and production processes was the second largest sponsor of R&D. Industry increased expenditures on research and development from $2,240 million in 1953-54 to $4,705 million in 1961-62, a growth of 110 per cent. However, at the same time the federal government R&D contracts to private industry increased from $1,430 million (Table II) in 1953-54 to $6,310 million in 1961-62, a growth of 341 per cent. A comparison of these

TABLE I

FUNDS FOR RESEARCH AND DEVELOPMENT

(Millions of Dollars)

Year	Total Funds	Source of Funds by Sector				Performance by Sector			
		Fed. Govt.	Industry	Colleges Univ.	Other Non-Profit Org.	Fed. Govt.	Industry	Colleges Univ.	Other Non-Profit Org.
1953-54	5,150	2,740	2,240	130	40	970	3,630	450	100
1954-55	5,620	3,070	2,365	140	45	950	4,070	480	120
1955-56	6,390	3,670	2,510	155	55	1,090	4,640	530	130
1956-57	8,670	5,095	3,325	180	70	1,280	6,600	650	140
1957-58	10,100	6,390	3,450	190	70	1,440	7,730	780	150
1958-59	11,130	7,170	3,680	190	90	1,730	8,360	840	200
1959-60	12,680	8,320	4,060	200	100	1,830	9,610	1,000	240
1960-61 (prel.)	13,890	9,010	4,550	210	120	1,900	10,510	1,200	280
1961-62 (prel.)	14,740	9,650	4,705	230	155	2,090	10,870	1,400	380

Source: National Science Foundation, <u>Reviews of Data on Research and Development</u>, No. 41, Washington: Government Printing Office, 1963, p. 2.

TABLE II
PERFORMANCE OF RESEARCH AND DEVELOPMENT

Source of Funds
(Millions of Dollars)

	1953-54	1954-55	1955-56	1956-57	1957-58	1958-59	1959-60	1960-61	1961-62
Total	5,150	5,620	6,390	8,610	10,030	11,130	12,680	13,890	14,740
Fed. Govt.	970	950	1,090	1,280	1,440	1,730	1,830	1,900	2,090
Fed. Funds	970	950	1,090	1,280	1,440	1,730	1,830	1,900	2,090
Industry	3,630	4,070	4,640	6,540	7,660	8,360	9,610	10,510	10,870
Fed. Funds	1,430	1,750	2,180	3,330	4,330	4,760	5,640	6,080	6,310
Industry Funds	2,200	2,320	2,460	3,210	3,330	3,600	3,970	4,430	4,560
Colleges & Univ.	450	480	530	650	780	840	1,000	1,200	1,400
Fed. Funds	280	300	330	415	530	570	720	890	1,050
Industry Funds	20	20	20	25	30	40	40	50	55
College & Univ. Funds	130	140	155	180	190	190	200	210	230
Other Nonprofit Org. Funds	20	20	25	30	30	40	40	50	65
Other Nonprofit Orgs.	100	120	130	140	150	200	240	280	380
Fed. Funds	60	70	70	70	80	110	130	140	200
Industry Funds	20	25	30	30	30	40	50	70	90
Other Nonprofit Org. Funds	20	25	30	40	40	50	60	70	90

Source: National Science Foundation, Reviews of Data on Research & Development, No. 41, Washington: Government Printing Office, 1963, p. 4.

growth rates illustrates the change in orientation of industrially performed research and development--from seeking industrial benefits to performing federal research contracts--that occurred during the period. In 1961-62, 58 per cent of all R&D undertaken by industry was performed for a federal contract.

Colleges and Universities

During this 9 year period, the value of research sponsored by colleges and universities increased from $130 million to $230 million. This is a low increase in R&D funds compared to the other sectors. However, colleges and universities are the traditional performers of basic research. Because colleges and universities emphasize basic research, this level of expansion in their research and development appropriations cannot be judged too small on this basis alone.

On the other hand, performance of research and development by colleges and universities grew from $450 million in 1953-54 to $1,400 million in 1961-62. Federal government projects also sponsored the majority of research and development undertaken by colleges and universities. The share sponsored by the federal government also increased over the period. The $280 million that the federal government contracted for research and development to colleges and universities was 62 per cent of the total they performed in 1953-54. In 1961-62, the $1,050 million represented 75 per cent of the total undertaken by colleges and universities. Both industry and other nonprofit organizations also increased their research contracts to colleges and universities, and, as a result, the share of research and development sponsored intramurally by colleges and universities decreased from 29 per cent in 1953-54 to 16 per cent in 1961-62.

Other Nonprofit Organizations

The sector other nonprofit organizations had the largest rate of growth in R&D performance of the four sectors over the 9 year period although it remained the smallest. In 1953-54, this sector performed research and development, valued at $100 million of 1.9 per cent of the total. By 1961-62, the value of R&D performed by this sector had increased to $380 million or 2.6 per cent.

Although federal contracts to this sector increased from $60 million in 1953-54 to $200 million in 1961-62 or 233 per cent, the source of the rapid rate of growth in this sector can be traced to the growth in contracts from private industry and funds expended intramurally. Each source, industry and intramural, increased its sponsorship from $20 million in 1953-54 to $90 million in 1961-62, a growth of 350 per cent.

Although colleges and universities and other nonprofit organizations together perform only 12 per cent of the total research and development undertaken, these sectors have had very rapid rates of growth.

II. INTERSECTOR FLOW OF FUNDS FOR BASIC RESEARCH

A study of the flow of funds for basic research from sponsor to performer enables a comparison with the flow of funds for total R&D. It illustrates the similarities and the differences among the various sources and performers by type of scientific research. The most notable difference from this comparison is the dominance of colleges and universities in basic research performance.

This dominance by colleges and universities can be explained by the accumulation of basic research resources and some economic factors. These latter are the uncertainty associated with basic research undertakings and the absence of foreseeable, saleable basic research findings evident to the researchers. These factors limit the expansion of privately sponsored basic research.[14] They also limit the private performance of basic research findings sponsored by other sectors.

Basic research has expanded at a rate even greater than total research and development. In 1953-54, total basic research was estimated by the NSF at $432 million (Table III). In 1961-62, it was estimated at $1,488 million, a growth in basic research for the 9 year period of 244 per cent.

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[14] Cf. Richard R. Nelson, "The Simple Economics of Basic Scientific Research," The Journal of Political Economy, June 1959. Kenneth T. Arrow, "Economic Welfare and the Allocation of Resources for Invention," National Bureau of Economic Research, The Rate and Direction of Inventive Activity.

FIGURE 2

PERFORMANCE OF BASIC RESEARCH

BY SECTOR

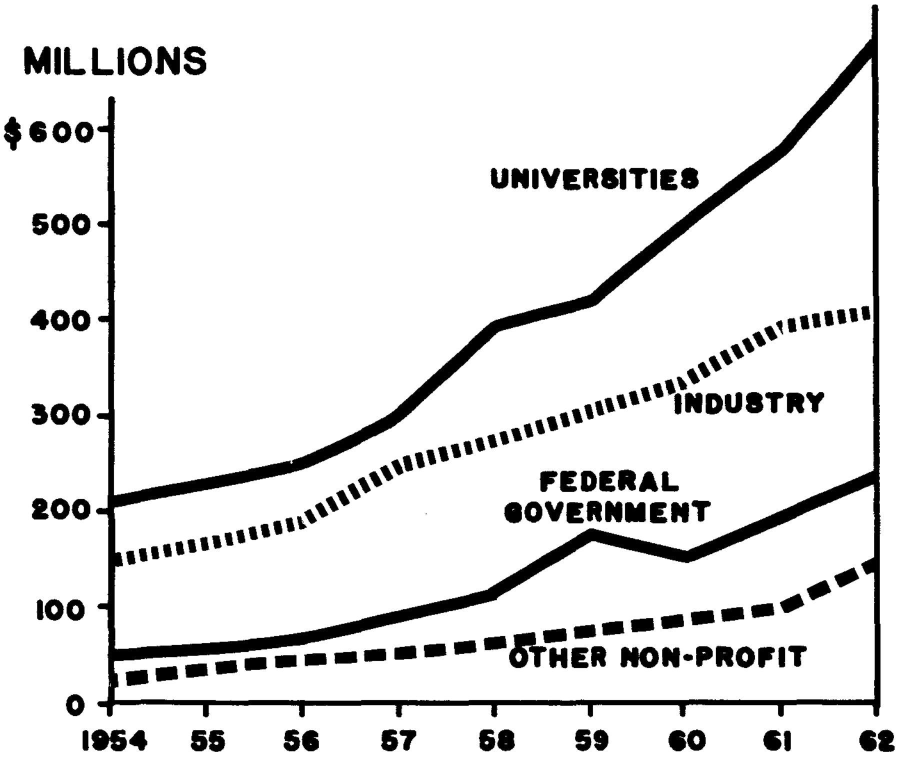

TABLE III

FUNDS FOR BASIC RESEARCH

Year	Total Funds	Source of Funds by Sector				Performance by Sector			
		Fed. Govt.	Industry	Colleges Univ.	Other Non-Profit Org.	Fed. Govt.	Industry	Colleges Univ.	Other Non-Profit Org.
1953-54	432	195	147	62	28	47	151	208	26
1954-55	485	n.a.	n.a.	70	35	55	166	230	34
1955-56	547	n.a.	n.a.	75	38	65	189	250	43
1956-57	694	n.a.	n.a.	90	46	90	253	300	51
1957-58	834	422	249	111	52	111	271	392	60
1958-59	975	524	275	118	58	180	305	420	70
1959-60	1,064	578	275	140	71	147	332	500	85
1960-61	1,256	684	328	161	83	193	388	575	100
1961-62	1,488	849	351	180	108	238	403	695	152

Source: National Science Foundation, <u>Reviews of Data on Research and Development</u>, No. 41, Washington: Government Printing Office, September 1963, p. 3.

Federal Government

As was the case with research and development, the primary sponsor of basic research has been the federal government, which in 1961-62 expended $849 million for basic research, sponsoring 57 per cent. This represented an increase for the 9 year period of 335 per cent.

At the same time, federal agencies greatly expanded their performance of basic research. In the 1953-54 period, federal government laboratories performed merely $47 million (11 per cent of total basic research). However, the value of basic research performed by federal government laboratories in 1961-62 had increased to $238 million (16 per cent). This was an increase in the performance of basic research by federal laboratories of 406 per cent.

Private Industry

Despite a 368 per cent increase in federal contracts to private industry for basic research over the period, industry's basic research continued to be sponsored primarily from within (Table IV). As was observed earlier this was not the case of total R&D. In 1961-62, private industry sponsored $351 million of basic research or 24 per cent of the total. However, industry performed $403 million (27 per cent of total basic research) of which $314 million was sponsored intramurally.

Colleges and Universities

Although the colleges and universities sector has been the principle performer of basic research, the source of these funds has been the other sector. The 1961-62 preliminary estimate of funds appropriated by colleges and universities for basic research was $180 million, or only 12.1 per cent of the total basic research. The intramural appropriations sponsored only one quarter of this sector's basic research. The reliance upon colleges and universities to perform basic research is clearly evident. Colleges and universities performed $695 million of total basic research in 1961-62 (47 per cent) showing a growth of 234 per cent. The source of the basic research funds is equally obvious. In 1961-62, $442 million of the college and university total (64 per cent) was sponsored by the federal government.

TABLE IV
PERFORMANCE OF BASIC RESEARCH

Source of Funds
(Millions of Dollars)

	1953-54	1954-55	1955-56	1956-57	1957-58	1958-59	1959-60	1960-61 (est.)	1961-62 (est.)
Total	432	485	547	694	834	975	1,064	1,256	1,488
Fed. Govt.	47	55	65	90	111	180	147	193	238
Fed. Funds	47	55	65	90	111	180	147	193	238
Industry	151	166	189	253	271	305	332	388	403
Fed. Funds	19	n.a.	n.a.	n.a.	41	53	84	91	89
Industry Funds	132	n.a.	n.a.	n.a.	230	252	248	297	314
Colleges & Univ.	208	230	250	300	392	420	500	575	695
Fed. Funds	119	129	144	173	240	256	305	350	442
Industry Funds	11	11	11	12	14	17	20	23	25
College & Univ. Funds	62	70	75	90	111	118	140	161	180
Other Nonprofit Org. Funds	16	20	20	25	27	29	35	41	48
Other Nonprofit Orgs.	26	34	43	51	60	70	85	100	152
Fed. Funds	10	15	20	25	30	35	42	50	80
Industry Funds	4	4	5	5	5	6	7	8	12
Other Nonprofit Org. Funds	12	15	18	21	25	29	36	42	60

Source: Nation Science Foundation, *Reviews of Data on Research & Development*, No. 41, Washington: Government Printing Office, September 1963, p. 5.

Other Nonprofit Organizations

The sector, other nonprofit organizations, was the smallest source of funds for basic research. It contributed $108 million in 1961-62 to the performance of basic research or 7 per cent of the total.

However, it grew sharply in performance of basic research by 485 per cent. The source of funds enabling this growth can be traced also to federal expenditures. In 1953-54, the federal government expended only $10 million for basic research with other nonprofit organizations, but in 1961-62, federal funds for basic research to this sector had increased eightfold to $80 million. In 1961-62, this sector performed $152 million or 10 per cent.

III. FEDERAL FUNDS FOR RESEARCH AND DEVELOPMENT

As noted earlier, the rapid expansion of federal appropriations for research and development and basic research has enabled the development of the science-based industry to the extent that it exists today. For this reason, the budget appropriations by federal agency for research and development are presented briefly in this section. In this way a link between the increase in federal appropriations for research and development and its effects is established. In order to detail further the impact of federal R&D expenditures, this section contains data showing federal appropriations by field of science, by intramural and extramural performers, and by standard industrial classification of performing industries.

Source of Federal Funds for Research and Development by Agency

> Four agencies - the Department of Defense, the National Aeronautics and Space Administration, the Atomic Energy Commission, and the Department of Health, Education, and Welfare - accounted for about 95% of total federal obligations for research and development in fiscal years 1961, 1962, and 1963.[15]

In 1954, when federal obligations for research and development and R&D plant totaled $3,038.8 million, the Department of Defense obligated $2,416.4 million (80 per cent) for R&D (Table V). The AEC had the second largest R&D

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[15] NSF, Federal Funds for Science XI, (Washington: Government Printing Office, 1963), p.6.

TABLE V

FEDERAL GOVT. OBLIGATIONS FOR RESEARCH, DEVELOPMENT AND R&D PLANT

By Agency, Fiscal Years 1954 to 1963
(Millions of Dollars)

	1954	1955	1956	1957	1958	1959	1960	1961	1962 (est.)	1963 (est.)
Total	3,039	2,747	3,269	4,381	4,908	7,121	8,078	9,606	11,239	14,448
Departments										
Agriculture	67	73	84	103	113	139	129	146	177	176
Commerce	8	16	18	19	19	30	33	47	73	102
Defense	2,416	2,084	2,431	3,250	3,480	5,237	5,825	6,688	6,835	7,477
H.E.W.	62	71	89	178	218	279	359	466	646	766
Interior	39	35	39	48	55	68	71	84	102	119
Atomic Energy Comm.	368	373	505	645	829	925	988	1,063	1,413	1,474
Fed. Aviation Agency	---	---	---	---	18	35	53	52	72	78
N.A.S.A.	57	65	66	83	97	300	487	906	1,697	3,939
Natl. Sci. Foun.	5	10	17	37	41	69	81	100	160	230
Veterans Admin.	5	6	7	10	13	17	19	23	31	33
All Other Agencies	11	15	14	9	26	22	32	30	34	55

Sums may not equal totals because of rounding off.

This table has been compiled from budget data. The totals include R&D plant which explains why these totals do not equal those in Table 1.

Source: National Science Foundation, Federal Funds for Science XI, Washington: Government Printing Office, 1963.

budget, $367.9 million, and the Department of Agriculture had the third largest, $67.2 million, in that year.

By 1963, the federal government obligations for research and development and R&D plant had grown to an estimated $14,447.8 million, and the Department of Defense obligations for research and development and R&D plant totaled $7,477.3 million. This was 52 per cent of the federal total. However, NASA's obligations for research and development and R&D plant during the period had grown to $3,939.2 million. This figure capped nearly a 7,000 per cent increase in research and development and R&D plant obligations. The $1,473.5 million expended by the AEC in 1963 for research and development and R&D plant was the third largest of the individual agencies and was 10 per cent of the total.

The Department of HEW, and the NSF are two agencies showing very rapid rates of growth of their R&D budgets. On the other hand, a slow growth by the Department of Agriculture also stands out.

The Character of Federal Research Funds by Agency

The type of research sponsored by a federal agency is determined, of course, by the mission of the agency. The character of work of the research and development programs by the various administrating federal agencies in fiscal year 1963 will be discussed in order to focus more carefully upon the R&D product required by the Federal Government.

The primary observation of the total federal research and development in fiscal 1963 is that 64 per cent, $8,058.3 million, was spent for development but only 12 per cent, $1,486.4 million, was spent for basic research (Table VI).

Of the large expenditure of the Department of Defense for R&D in fiscal year 1963, 81 per cent, or $5,973.8 million, went for development of which the Department of the Air Force alone expended $3,333.9 million. This was 88 per cent of the total Air Force R&D budget. Of course, the Department of Defense has emphasized development because of its hardware requirements, but less than 3 per cent of the Defense R&D budget was spent for basic research.

TABLE VI

ESTIMATED FED. GOVT. OBLIGATIONS FOR RESEARCH AND DEVELOPMENT

By Agency and Character of Work, Fiscal Year 1963
(Millions of Dollars)

	Total	Research		Development
		Total	Basic	
Total	12,683.7	4,418.8	1,486.4	8,058.3
Departments				
Agriculture	171.1	165.0	57.2	6.1
Commerce	51.6	41.7	21.6	9.9
Defense	7,371.3	1,190.9	191.1	5,973.8
Army	1,380.5	264.5	35.3	1,071.6
Navy	1,597.7	224.1	77.7	1,332.7
Air Force	3,766.1	311.1	56.0	3,333.9
Adv. Res. Proj.	257.0	257.0	22.0	----
Dept. Funds	369.9	134.4	----	235.5
H.E.W.	703.1	699.6	235.8	3.4
Interior	109.7	93.2	38.1	16.5
A.E.C.	1,144.1	285.1	221.6	859.0
Fed. Avn. Comm.	70.4	13.3	----	57.1
N.A.S.A.	2,821.2	1,702.0	553.0	1,119.2
Natl. Sci. Foun.	160.3	159.6	159.6	.7
V.A.	27.7	27.0	4.0	.7

Sums may not equal totals because agencies with very small totals were omitted and because of rounding off.

Source: National Science Foundation, Federal Funds for Science XI, Washington: Government Printing Office, 1963.

> In 1963, although still the largest category, the missile program was expected to decrease to approximately 34 per cent of the Department's R&D effort.... The second largest area of support was military astronautics which accounts for... 19 per cent of the total anticipated in 1963.[16]

In contrast to Defense's emphasis on development, a large share of NASA's appropriations for research and development has been spent for basic and applied research. NASA's total applied and basic research, $1,702 million, was 39 per cent of the federal total. Of course, the mission of NASA accounts for the large expenditures for basic and applied research.

> Manned space flight projects and the development of large launch vehicles needed for manned space explorations account for approximately 39 per cent of the agency's estimated obligations for research and development in fiscal year 1962. Increases were planned in this area of more than $1 billion in fiscal year 1963, or an estimated 55 per cent of agencies R&D obligations for that period.[17]

The AEC was the expending agency for 15 per cent of the total basic research obligated by the federal government. The Department of HEW accounted for 16 per cent of the federally sponsored basic research as a result of programs undertaken by the National Institute of Health.[18] The NSF obligated over 99 per cent of its $160.5 million R&D budget in fiscal year 1963 for basic research.

Allocation to Sectors of Federal Funds by Agency

The allocation of federal funds by agency to performer indicates the impact of federal research upon the different economic sectors. That private industry is the dominate performer of federal R&D has been pointed out previously.

In fiscal 1963, of the $12,684 million of federal R&D, the Department of Defense alone expended $5,170 million with private industry (Table VII). In

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[16] Ibid., p. 8.

[17] Ibid., p. 9.

[18] Ibid., p. 10.

TABLE VII
ESTIMATED FED. GOVT. OBLIGATIONS FOR RESEARCH AND DEVELOPMENT

By Agency and Performer, Fiscal Year 1963
(Millions of Dollars)

	Total	Intra-mural	Extramural							
			Profit Organizations		Educational Insts.		Other Nonprofit Org.		Other	Foreign
			Proper	Res. Ctr.	Proper	Res. Ctr.	Proper	Res. Ctr.		
Total	12684	2462	7763.1	434.7	905.5	667.8	221.1	125.4	20.5	83.1
Departments										
Agriculture	171	120	.3	--	37.1	.1	.4	--	--	13.5
Commerce	52	44	2.7	--	2.6	(a)	.4	.2	.3	1.8
Defense	7371	1612	5169.6	95.9	225.9	122.2	47.6	76.1	(a)	22.4
Army	1381	564	739.6	4.9	39.0	12.2	10.3	7.0	(a)	3.2
Navy	1598	507	961.6	10.2	56.3	47.8	12.9	--	--	1.5
Air Force	3766	433	3087.0	76.4	73.7	21.2	5.4	64.2	--	5.3
Adv. Res. Proj.	257	36	137.5	4.4	24.6	41.0	9.8	1.8	--	2.4
Dept. Funds	370	72	243.6	--	32.3	--	9.1	3.2	--	10.0
H.E.W.	703	132	21.7	--	384.0	.3	121.3	.1	12.2	31.4
Interior	110	88	6.7	(a)	5.5	--	.9	--	7.2	1.1
A.E.C.	1144	16	368.4	328.8	66.6	312.8	8.7	39.5	.2	3.2
Fed. Avn. Agcy.	770	23	45.2	--	.6	--	.4	1.5	--	.1
N.A.S.A.	2821	371	2136.2	10.0	45.0	232.0	19.3	2.0	--	5.7
Natl. Sci. Foun.	160	10	.3	--	128.7	--	14.2	6.0	--	1.5
V.A.	28	27	.1	--	.4	--	.4	--	(a)	--

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a. Less than $50,000.

Sums may not equal totals because agencies with very small totals were omitted and because of rounding off.

Source: National Science Foundation, *Federal Funds for Science XI*, Washington: Government Printing Office, 1963 addition, NASA contracted $2,136 million in that year with private industry. Together these two agencies accounted for 94 per cent of federal R&D contracts to private industry.

The research products sought by NASA and Defense has affected greatly the distribution of R&D funds among industries. In 1962, the industry classified by NSF as aircraft and missiles undertook 56 per cent of the total federal R&D contracts to industry totaling $3,787 million (Table VIII). The second largest contracting industry for the federal government's R&D has been the electrical equipment and communications equipment industry. That industry performed $1,612 million of federal R&D in 1962 or 24 per cent. As might be anticipated of the total from the known expansion of space research, the share performed by the aircraft and missiles industry has been increasing in recent years. At the same time, the shares performed by the electrical equipment and communications equipment industry has decreased slightly.

The Department of Defense, $348 million; the Department of HEW, $384 million; the AEC, $379 million; and the NASA, $277 million were the dominate R&D contracting agencies of the federal contracts to educational institutions, totaling $1,573 million, in fiscal year 1963.

The Department of Defense spent $124 million with other nonprofit organizations in fiscal 1963. The Department of HEW spent $121 million with that sector. These two agencies together sponsored 71 per cent of the total federal R&D funds going to this sector.

Federal Funds for Scientific Research by Field of Science

The rapid growth of federal R&D expenditures by field of science was suggested in the previous discussions which characterized the applied and basic research demanded by federal projects. The engineering sciences have been the dominate field required by federal research. That field grew to 45 per cent of the total basic and applied research and equaled $1,995 million in the fiscal year 1963 estimate by NSF (Table IX). It was also the fastest growing field (Table X).

TABLE VIII
FED. GOVT. FINANCED R. & D. BY INDUSTRY AND CO. SIZE

	1957	1958	1959	1960	1961	1962
Total (Millions of Dollars)	4,336	4,759	5,638	6,127	6,313	6,729
Industry Group						
Food and kindred products	(a)	6	5	9	4	5
Paper and allied products	(a)	--	(b)	(b)	(b)	--
Chemicals and allied products	89	126	151	182	224	257
Industrial chemicals	80	110	114	128	137	158
Drugs and medicines	(a)	2	3	n.a.	3	3
Other chemicals	9	14	34	n.a.	83	95
Petroleum refining and extraction	11	12	25	26	19	20
Rubber products	37	21	39	37	36	31
Primary metals	6	15	14	16	16	14
Primary ferrous products	1	2	1	(b)	(b)	(b)
Nonferrous and other metal products	(b)	13	12	14	12	11
Fabricated metal products	38	57	43	33	33	32
Machinery	272	343	413	378	292	310
Electrical equip. and communication	1,196	1,337	1,597	1,603	1,533	1,612
Communication equip. and electronic comp.	518	615	810	884	784	867
Other electrical equipment	678	722	787	719	749	745
Motor vehicles and other trans. equip.	190	296	222	212	192	183
Aircraft and missiles	2,266	2,276	2,769	3,198	3,537	3,787
Professional and scientific instruments	109	137	166	202	176	224
Scientific and mechanical measuring instru.	80	93	116	138	109	131
Optical, surgical, photographic, and others	29	44	50	64	67	93
Other industries	108	133	191	229	252	253
Company Size (employees)						
Less than 1,000	168	233	(b)	(b)	(c)	(c)
1,000 to 4,999	226	202	263	310		
5,000 or more	3,942	4,324	5,091	5,511		

(a) Less than $0.5 million. (b) Not available, but included in total. (c) Not available.

Source: National Science Foundation

TABLE IX
ESTIMATED FED. GOVT. OBLIGATIONS FOR SCIENTIFIC RESEARCH

By Agency and Field Fiscal Year 1963
(Millions of Dollars)

	Total	Life Sciences			Psych. Sci.	Physical Sciences			Soc.	Other
	Res.	Biol.	Med.	Agr.		Phys.	Math.	Engr.	Sci.	Sci.
TOTAL	4419	204.1	703.0	76.4	83.9	962.8	67.0	1995.2	95.2	231.1
Departments										
Agriculture	165	17.2	13.8	1.7	--	28.4	.2	11.7	21.9	--
Commerce	42	--	--	.1	.1	26.1	.6	10.0	3.8	.9
Defense	1191	42.7	32.8	.5	20.4	467.1	41.2	356.1	.3	229.8
Army	265	21.6	25.4	.5	7.5	93.0	4.9	91.1	.3	20.1
Navy	224	7.8	6.8	--	9.0	84.4	20.6	86.8	--	8.7
Air Force	311	13.3	.5	--	3.9	137.0	15.7	140.6	--	--
Adv. Res. Projects	257	--	--	--	--	152.8	--	37.7	--	66.6
Dept. Funds	134	--	--	--	--	--	--	--	--	134.4
Health Educ. Wel.	700	25.2	589.4	.6	44.6	9.4	.1	2.6	27.6	--
Interior	93	23.9	.2	.9	--	40.9	1.1	24.1	2.3	--
Atomic Energy Comm.	285	39.2	18.7	1.5	--	187.6	5.0	33.1	--	.1
Federal Aviation Agency	13	.2	3.6	--	.4	2.5	.8	5.9	.1	--
N.A.S.A.	1702	9.0	16.0	--	10.0	130.0	5.0	1530.0	2.0	--
Nat. Sci. Foundation	160	45.7	3.0	--	6.2	68.6	12.4	16.5	7.2	--
Veterans Admin.	27	--	24.9	--	1.9	--	--	.2	--	--

Sums may not equal totals because agencies with very small totals were omitted and because of rounding off.

Source: NSF, Federal Funds for Science XI, Washington: Government Printing Office, 1963

TABLE X

FEDERAL GOVERNMENT OBLIGATIONS FOR SCIENTIFIC RESEARCH

By Field of Science Fiscal Years, 1959-63
(Millions of Dollars)

	1959	1960	1961	1962 (est.)	1963 (est.)
Total	1,390	1,927	2,337	3,185	4,419
Life Sciences					
Biological	88	106	133	168	204
Medical	268	342	441	608	703
Agricultural	64	68	63	74	76
Psychological Sci.	24	38	51	64	84
Physical Sciences					
Physical	288	421	654	782	963
Mathematical	16	24	45	52	67
Engineering	461	861	812	1,161	1,995
Social Sciences	31	35	44	65	95
Other Sciences	150	33	94	210	231

Source: National Science Foundation, Federal Funds for Science XI, Washington: Government Printing Office, 1963.

* * * * * *

NASA, the largest spender for basic and applied research with a $1,702 million budget, expended $1,530 million of this total for the engineering sciences. The Department of Defense also spent $356 million for the engineering sciences.

The physical sciences proper received $963 million of federal research expenditures in 1963. The Department of Defense expended $467 million for the physical sciences, 49 per cent of the federal research in that field; the AEC expended $187 million.

Although the medical sciences increased from $288 million in fiscal 1959 to $703 million in 1963, it decreased proportionately to the other fields of science. The Department of HEW spent $589 million in fiscal 1963 in the medical sciences. This amount supported 84 per cent of the total federal expenditures in this field of science.

The 319 per cent increase over the 5 year period of federal expenditures for mathematical sciences represented the second fastest growing field of federally supported science. Mathematical sciences were estimated, however, at only $67 million in fiscal year 1963, merely 1.5 per cent of the federal total. Of this total, Defense sponsored an estimated $41 million (62 per cent).

IV. INDUSTRIAL RESEARCH AND DEVELOPMENT: FUNDS AND PERFORMANCE

As discussed earlier, the private industry sector has been the largest performer and the second largest sponsor of research and development. This section discusses in more detail the organization by industrial classification, by company size, and by total number of scientists employed. The NSF data, covering a period from 1957-1962, show an increase from $3,459 million to $4,831 million of total company financed research and development. This was a growth of 40 per cent.

The chemical and allied products industry has been the largest sponsor of industrial R&D. That industry's R&D investment in 1962 was $894 million (Table XI); of this figure R&D investment by industrial chemical firms alone accounted for $572 million. In 1957, the chemical and allied products industry's expenditure for R&D totaled $646 million. This indicates a growth in R&D investment of 38 per cent in 5 years.

The electrical equipment and communications equipment industry was the second largest sponsor of industrial R&D, appropriating $887 million in 1962. This industry group was also the second largest performer of federal R&D.

The motor vehicles and other transportation industries spent $675 million for R&D in 1962; the machinery industry spent $633 million in that year. The aircraft

TABLE XI
SOURCE OF INDUSTRIAL R & D FUNDS AND MISSOURI INDUSTRY DATA

In Selected Manufacturing Industries

	R. & D. Funds 1962			Total Missouri	
	Total	Fed. Govt.	Company	Employment	Taxable Payrolls Jan.-March
Food and kindred products (Millions of Dollars)	108	5	103	49,953*	59,042*
Textiles and apparel	--	--	--	34,486*	25,365
Lumber, wood products, and furniture	--	--	--	13,690	11,291
Paper and allied products	65	--	65	12,290	12,880
Chemicals and allied products	1,151*	257*	894*	22,148	29,790*
Industrial chemicals	730	158	572		
Drugs and medicines	196	3	192		
Other chemicals	226	95	130		
Petroleum refining and extraction	302	20	281	2,489	3,453
Rubber products	126	31	94		
Stone, clay, and glass products	(a)	(a)	(a)		
Primary metals	166	14	152	13,048	18,586
Primary ferrous products	98	--	--		
Nonferrous and other metal products	68	11	57	11,528	16,620
Fabricated metal products	106	30	76	24,926*	31,032*
Machinery	924*	290*	634*	20,687	25,480
Electrical equipment and communication	2,498*	1,612*	887*	21,542	25,542
Communication equip. and electronic comp.	1,280	867	413		
Other electrical equipment	1,218	745	474		
Motor vehicles and other transportation equip.	858*	183	675*	22,539*	32,032*
Aircraft and missiles	4,199*	3,787*	412*	31,334*	46,879*
Professional and scientific instruments	455	224*	231	3,383	3,938
Scientific and mechanical measuring instru.	218	131	87		
Optical, surgical, photographic, and others	237	93	144		

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*Denotes one of five largest totals in respective columns

(a)Less than $0.5 million.

Source: National Science Foundation, Reviews of Data on Research & Development, No. 40, September 1963. U.S. Bureau of Census, U.S. Census of Manufactures: 1958, Vol. III, Area Statistics, Government Printing Office, Washington 1961.

and missiles industry, the dominant performer of industrially contracted federal R&D, was only the fifth largest sponsoring industry of R&D in 1962, allocating $412 million to R&D.

The data in Table XI are related to 1959 first quarter total employment and total taxable payrolls in Missouri in an attempt to show the relative size of the R&D leading industries in Missouri.

The aircraft and missiles industry, the largest industry performer of R&D, supports one of the largest payrolls and is one of the largest total employers among manufacturing industries in Missouri. The chemicals and allied products industry, the largest sponsoring industry of R&D and a large performing industry of federal R&D, supports one of the largest payrolls among Missouri manufacturing industries. The motor vehicles and other transportation equipment industry, a large industry for R&D, is one of the largest employers among manufacturing industries in Missouri and has one of the largest manufacturing payrolls in Missouri.[19]

As was observed in the data concerning federal R&D contracts to private industry, the company financed R&D has been concentrated in firms employing more than 5,000 persons.[20] Of course, the personnel and financial resources which are required for industrial R&D programs are generally found in large firms. Large firms with diversified product lines are more likely to find immediate use for unexpected research findings; thereby, the uncertainty in industrial research is mitigated by company size. On the other hand, some economists argue that competition will induce firms to seek research findings more actively and to employ them more quickly, and many of the most highly competitive firms are small. This issue of size in technological change remains unresolved.[21]

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[19] However, the motor vehicles industry in Missouri is engaged primarily in manufacturing and cannot be considered a significant source of R&D potential.

[20] NSF, Research and Development in Industry 1960, Washington: 1963, p. 15.

[21] Cf., W. R. McClauren, "Technological Progress in Some American Industries," American Economic Review, May 1954. Jacob S. Schmookler, Bigness, Fewness, and Research," Journal of Political Economy, December 1959. Edwin Mansfield, "Size of Firm, Market Structure and Innovation," Journal of Political Economy, December 1963, and "Industrial Research and Development Expenditure Determinants, Prospects, and Relation to Size of Firm and Inventive Output," Journal of Political Economy, August 1964.

CHAPTER III

EXPANSION OF SCIENTIFIC RESEARCH IN MISSOURI

The growth of scientific research activity in Missouri is difficult to measure because of the lack of reliable data concerning R&D inputs and outputs. There is a paucity of information relevant to regional scientific research. Any regional analysis of scientific research is limited by the data that do exist, and this analysis of Missouri's scientific research resources and performance must proceed upon that basis. The available data consist of a few indicators of scientific personnel in Missouri and some totals of federal R&D contracts let to Missouri organizations.

To complicate the analysis, the reliability of some of the existing data is limited. Some have vague definitional backgrounds; some are not amenable to wide application. These limitations which are confronted when studying Missouri, or any specific region, can be offset somewhat if the existing R&D indicators for Missouri are compared with selected states. Hopefully, a more detailed comparison with a few states will present a clearer understanding of Missouri's science-based industry than would a more cumbersome comparison of these indicators among all 50 states.

Five states were selected:

California, the performer of more than one quarter of all R&D;
Texas, a state recently to become important in space research with the Manned Spacecraft Center:

Illinois	states which are adjacent to Missouri, and therefore, have resource and climatic similarities.
Kansas	
Arkansas	

In order to insure proper interpretation the use of this comparative method warrants further explanation. The R&D data of the five states are not compared with Missouri in an attempt to determine whether or not an "appropriate" amount of R&D is performed in Missouri. Indeed, such analysis requires information far surpassing the meager knowledge available about R&D activity of Missouri. The regional disparities of R&D activity are not observed for the purpose of implying that R&D funds or resources are misallocated. This study's technique actually assumes the contrary; the spatial inequity of R&D performance is assumed to be optimum for the sake of analysis. If the existing pattern is assumed to be the "best" spatial allocation of R&D activity, this comparative study can proceed to determine why such a spatial allocation has resulted. It attempts to explain the factors that account for the spatial distribution of scientific research which exists.

The available data are used for this comparative analysis. Limited, but comparable data are available of the R&D facilities, educational facilities, and scientific labor resources in Missouri and the five selected states.

This chapter discusses the level of R&D expansion in Missouri in recent years and the resultant personnel effects. First, the level of federal R&D contracting by the Department of Defense and NASA for recent years will be compared. Second, data concerning laboratory personnel requirements and changes of personnel requirements from 1950 to 1960 will be observed in Missouri and California.

I. MAJOR FEDERAL RESEARCH AND DEVELOPMENT PROGRAMS IN MISSOURI AND SELECTED STATES

The level of federal research and development contracting with organizations in the state of Missouri are indicated by available prime contract data from the dominant agencies, Defense and NASA. However, these prime contract data have obvious pitfalls. Prime contract data do not show how much research work actually was performed in a state. There is considerable subcontracting in scientific research work. Missouri prime contractors let subcontracts to organizations outside of the state; other prime contractors let subcontracts to organizations in Missouri. Only for some NASA projects are limited subcontracting data available. Nevertheless, these data remain the best available indicators, andfor that reason they are discussed. The R&D prime contracting by these two federal agencies in Missouri will be studied separately.

Department of Defense

The Department of Defense estimated the net value of its contracts with organizations in the state of Missouri for "experimental, development, test and research work" to be $17.2 million in fiscal year 1962 (Table XII). Missouri was obviously a major scientific research performer for Defense as this figure represents 0.28 per cent of the total of these research contracts by the Defense Department for that period. The distribution of these contracts among Missouri organizations further shows the performance of Defense EDTR rests with Missouri's industry. The contracts were distributed in the following manner: business firms $15.5 million (89.7 per cent), other nonprofit institutions $1.1 million (6.3 per cent) and schools and their affiliates $683 thousand (4.0 per cent).

Despite the difficulties of prime contract data, some of the inherent problems can be mitigated by considering more than one time period. Although the exact level of performance cannot be ascertained, the various levels of prime contracting in a specific region seem to indicate whether the total federal R&D contracts in that region are expanding or contracting. For example, the prime experimental, development, test, and research contracts awarded to Missouri organizations in fiscal 1958 had been $9.6 million greater than they were in fiscal year 1962 (Table XIII). This contracting, valued at $26.9 million, was also a larger share of the national total (0.7 per cent). The following year, these contracts were estimated at $40.1 million, but, in each subsequent year, the total value of EDTR contracts let in Missouri declined. Therefore, although the precise level of EDTR performed in any one year in Missouri is not evident, the absolute and relative decline in prime contracts presents a clear impression of declining EDTR performance in Missouri.

The EDTR data for Missouri organizations stand out more clearly when the distribution among organizations in the comparative states is viewed. Schools and their affiliates in both California and Illinois received large contract awards. These totals were second and fourth in the U.S. respectively. The total for schools and affiliates in Illinois ($27.1 million) comprised 48 per cent of the EDTR awarded to Illinois organizations in fiscal 1962.

TABLE XII

MILITARY PRIME CONTRACTS

For Experimental, Developmental, Test and Research Work, Fiscal Year 1962

(Thousands of Dollars)

	Total	Schools and Affiliates	Other Non-profit Insts.	Business Firms
Alabama	12,694	341	481	11,872
Alaska	1,558	1,558	-	-
Arizona	18,894	482	95	18,317
ARKANSAS	323	-	-	323
CALIFORNIA	2,438,863	42,706	85,447	2,310,710
Colorado	229,339	5,201	940	223,198
Connecticut	65,005	625	223	64,157
Delaware	11,756	286	-	11,470
Florida	230,962	1,715	212	229,035
Georgia	4,686	1,366	81	3,239
Hawaii	652	169	-	483
Idaho	18	-	18	-
ILLINOIS	56,296	27,085	445	28,766
Indiana	39,405	3,317	-	36,088
Iowa	5,563	532	-	5,031
KANSAS	6,198	233	-	5,965
Kentucky	716	120	45	551
Louisiana	947	371	-	576
Maine	496	-	248	248
Maryland	190,581	50,123	7,184	133,274
Massachusetts	361,973	117,111	680	244,182
Michigan	58,850	10,877	49	47,924
Minnesota	52,082	2,104	343	49,635
Mississippi	501	438	25	38
MISSOURI	17,237	683	1,090	15,464

(Table XII continued)

MILITARY PRIME CONTRACTS

(Thousands of Dollars)

	Total	Schools and Affiliates	Other Non-profit Insts.	Business Firms
Montana	56	56	-	-
Nebraska	2,910	45	81	2,784
Nevada	65	-	-	65
New Hampshire	8,204	407	-	7,797
New Jersey	293,237	4,045	2	289,194
New Mexico	13,752	3,829	398	9,525
New York	664,844	24,741	10,560	629,543
North Carolina	37,046	3,530	71	33,445
North Dakota	-	-	-	-
Ohio	132,603	7,137	3,870	121,596
Oklahoma	4,402	961	24	3,417
Oregon	2,031	534	-	1,497
Pennsylvania	235,998	10,976	6,037	218,985
Rhode Island	6,312	2,612	-	3,700
South Carolina	338	51	-	287
South Dakota	401	65	-	336
Tennessee	33,583	552	280	32,751
TEXAS	73,231	5,233	10,737	57,261
Utah	119,192	1,419	-	117,773
Vermont	1,899	82	-	1,817
Virginia	34,572	1,255	2,225	31,092
Washington	492,787	3,009	58	489,720
West Virginia	61,660	55	-	61,605
Wisconsin	63,487	1,230	166	62,091
Wyoming	1,160	-	-	1,160
District of Columbia	23,783	6,606	7,508	9,669

TABLE XIII

MILITARY PRIME CONTRACTS

For Experimental, Developmental, Test and Research Work, Fiscal Years 1958 to 62
(Thousands of Dollars)

	1958	1959	1960	1961	1962
Alabama	-	25,966	20,435	7,640	12,694
Alaska	2,569	848	809	1,163	1,558
Arizona	12,701	14,377	17,791	23,858	18,894
ARKANSAS	476	450	346	414	323
CALIFORNIA	1,485,152	2,283,286	2,370,269	2,492,005	2,438,863
Colorado	97,577	4,943	177,676	293,528	229,339
Connecticut	56,120	105,105	91,979	123,295	65,005
Delaware	1,884	2,947	2,215	2,272	11,756
Florida	-	166,503	101,200	152,727	230,962
Georgia	-	12,647	5,264	6,011	4,686
Hawaii	-	165	57	21	652
Idaho	45	-	26	-	18
ILLINOIS	56,627	67,700	67,287	61,984	56,296
Indiana	45,799	54,058	34,065	29,488	39,405
Iowa	13,924	20,117	14,617	5,051	5,563
KANSAS	4,971	3,963	6,054	3,092	6,198
Kentucky	1,205	400	327	890	716
Louisiana	707	751	3,690	1,689	947
Maine	117	152	670	128	496
Maryland	136,002	160,141	127,380	198,483	190,581
Massachusetts	232,318	304,945	397,517	348,452	361,973
Michigan	71,655	117,542	84,503	92,313	58,850
Minnesota	53,436	64,826	59,968	51,378	52,082
Mississippi	292	529	577	894	501
MISSOURI	26,871	40,115	24,154	18,226	17,237

(Table XIII continued)

MILITARY PRIME CONTRACTS

(Thousands of Dollars)

	1958	1959	1960	1961	1962
Montana	71	27	74	16	56
Nebraska	28	11	22	5,011	2,910
Nevada	54	279	16	1,494	65
New Hampshire	2,365	7,109	8,842	10,664	8,204
New Jersey	200,382	161,274	434,654	228,280	293,237
New Mexico	13,003	14,343	13,861	13,249	13,752
New York	569,710	667,218	533,169	734,934	664,844
North Carolina	-	138,675	7,476	16,142	37,046
North Dakota	-	85	-	-	-
Ohio	138,615	173,595	179,349	137,502	132,603
Oklahoma	-	3,989	5,757	4,551	4,402
Oregon	689	806	1,421	1,377	2,031
Pennsylvania	276,692	256,444	189,385	224,239	235,998
Rhode Island	1,824	2,045	1,512	5,601	6,312
South Carolina	-	149	211	188	338
South Dakota	72	149	548	292	401
Tennessee	777	1,168	1,102	27,001	33,583
TEXAS	-	84,786	93,023	63,059	73,231
Utah	12,780	73,373	108,933	181,118	119,192
Vermont	2,905	1,800	3,030	1,386	1,899
Virginia	221	18,512	22,786	18,729	34,572
Washington	246,796	160,810	206,145	293,684	492,787
West Virginia	10	11,960	17,786	42,252	61,660
Wisconsin	4,424	5,005	64,079	74,239	63,487
Wyoming	-	-	230	3,475	1,160
Dist. of Columbia	19,022	21,376	19,148	24,010	23,783

Of the three adjacent states studied, only Kansas evinced an increase in EDTR contracting absolutely over the period. In addition, all three states showed a decline in the per cent of the national total of prime contracts awarded.

Texas declined proportionately as did the Midwestern group, however, California maintained the same proportion of experimental, development, test and research contracts over the period from fiscal 1958 to fiscal 1962. In fiscal year 1962, $2,438.8 million, or 39.9 per cent, of all EDTR prime contracts were let in California. Thus, there was approximately a 50 per cent increase in the value of contracts let to California organizations during the 5 year fiscal period.

Drawing conclusions from such data requires caution, but if prime contracts are reliable indicators, the performance of the Department of Defense experimental, development, testing, and research work has been a declining element of R&D activity in the state of Missouri. This decline occurred despite the large increase of EDTR nationally. Nevertheless, even if speculated future cuts in defense spending do not reduce experimental, development, testing, and research work, it does not appear to offer a source of growth to Missouri's scientific based industry.

National Aeronautics and Space Administration

NASA estimated the value of its R&D prime contracts in fiscal year 1963 to Missouri organizations to be $264.9 million (Table XIV). With this indicator Missouri's R&D appeared very strong, as Missouri was the third largest performing state of prime contracts for NASA in that year. Only California and Louisiana exceeded Missouri. Of course, this figure reflects primarily the R&D contracts awarded to McDonnell Aircraft Corporation of St. Louis for the Mercury spacecraft and the Gemini spacecraft of the manned space flight program.

Although this research and development performed at McDonnell, the states's largest employer with approximately 35,000 employees, is significant to the St. Louis and Missouri economy, its affect upon this R&D indicator must be appraised. The data problems of the R&D indicator, prime contracts, in this case are extreme. The total of Missouri's NASA prime contracts includes the total Mercury capsule

TABLE XIV

NASA R. & D. PRIME CONTRACTS

(In Thousand Dollars)

	Research and Development			Sal. & Exp.	Const.of Facil.
	Fiscal Year			Fiscal Year	
	1961	1962	1963	1963	1963
Alabama	$67,290	$133,110	$234,028	$70,370	$37,537
Alaska	607	980	1,805	--	--
Arizona	2,437	3,941	7,262	--	--
ARKANSAS	27	44	80	--	--
CALIFORNIA	274,993	459,289	830,704	29,207	87,856
Colorado	2,900	26,592	58,646	--	--
Connecticut	4,063	6,575	12,116	--	--
Delaware	49	76	140	--	--
Florida	58,641	94,857	174,799	6,500	361,963*
Georgia	3,244	5,247	9,669	--	--
Hawaii	178	294	542	--	--
Idaho	--	--	--	--	--
ILLINOIS	4,805	7,772	14,323	--	--
Indiana	1,370	2,221	4,092	--	--
Iowa	949	1,535	2,828	--	--
KANSAS	--	--	--	--	--
Kentucky	36	54	100	--	--
Louisiana	88	46,578	359,102	1,750	34,500
Maine	--	--	--	--	--
Maryland	23,125	47,463	78,480	43,425	24,780
Massachusetts	10,165	16,437	30,290	--	--
Michigan	8,079	13,074	24,092	--	--
Minnesota	2,301	3,200	5,898	--	--
Mississippi	--	--	--	2,500	92,500
MISSOURI	47,270	107,260	264,898	--	--

(Table XIV continued)

NASA R.&D. PRIME CONTRACTS

	Research and Development			Sal. & Exp.	Const.of Facil.
	Fiscal Year			Fiscal Year	
	1961	1962	1963	1963	1963
Montana	--	--	--	--	--
Nebraska	--	--	--	--	--
Nevada	55	87	160	--	40,000
New Hampshire	32	54	100	--	--
New Jersey	13,991	22,631	41,704	--	--
New Mexico	1,446	2,340	4,313	--	--
New York	51,181	82,785	152,553	--	--
North Carolina	150	239	441	--	1,300
North Dakota	--	--	--	--	--
Ohio	20,245	46,754	75,536	43,250	44,833
Oklahoma	374	610	1,123	--	--
Oregon	222	359	662	--	--
Pennsylvania	12,773	20,661	38,073	--	--
Rhode Island	92	152	281	--	--
South Carolina	--	--	--	--	--
South Dakota	--	--	--	--	--
Tennessee	1,054	1,709	3,149	--	--
TEXAS	14,653	44,243	73,225	30,304	31,755
Utah	31	54	100	--	--
Vermont	--	--	--	--	--
Virginia	35,170	58,653	102,030	43,632	25,774
Washington	110	174	321	--	--
West Virginia	1,500	2,500	1,500	--	--
Wisconsin	783	1,263	2,327	--	--
Wyoming	--	--	--	--	--
Dist. of Columbia	8,308	26,038	56,022	29,826	--
Other	--	--	--	--	34,000
TOTAL	$966,731	$1,827,750	$3,787,276	$300,764	$318,998

Sums may not equal totals because of rounding off.

Source: U.S. House of Representatives, Eighty-eighth Congress, Hearings before the Subcommittee on Manned Space Flight of the Committee on Science and Astronautics, Washington: 1963, pp. 466-469.

TABLE XV

SELECTED NASA SUBCONTRACTS

January 1, 1962-February 28, 1963
(In Thousand Dollars)

	Prime	1st & 2nd Tier Subcontracts		
	Contracts	Total	Small Bus.	Large Bus.
Alabama	$ 1,513	$ 436	$ 270	$ 165
Alaska	--	--	--	--
Arizona	--	4,022	73	3,949
ARKANSAS	--	172	26	145
CALIFORNIA	254,373	207,085	33,027	174,058
Colorado	--	1,846	70	1,777
Connecticut	--	12,717	1,197	11,520
Delaware	--	--	--	--
Florida	2,673	34,425	500	33,925
Georgia	--	82	59	23
Hawaii	--	--	--	--
Idaho	--	--	--	--
ILLINOIS	--	6,707	1,700	5,007
Indiana	--	1,017	92	926
Iowa	--	12,886	--	12,886
KANSAS	--	524	136	388
Kentucky	--	--	--	--
Louisiana	8,810	4,774	2,698	2,077
Maine	--	--	--	--
Maryland	--	12,345	279	12,066
Massachusetts	--	19,004	1,957	17,047
Michigan	--	3,650	1,103	2,547
Minnesota	--	26,238	701	25,536
Mississippi	--	28	13	15
MISSOURI	134,095	2,005	1,138	867

(Table XV continued)

SELECTED NASA SUBCONTRACTS

	Prime	1st & 2nd Tier Subcontracts		
	Contracts	Total	Small Bus.	Large Bus.
Montana	--	--	--	--
Nebraska	--	--	--	--
Nevada	--	1,099	1,099	--
New Hampshire	--	19	19	--
New Jersey	--	7,647	1,714	5,933
New Mexico	--	16	--	16
New York	17,847	36,331	2,420	33,911
North Carolina	--	509	--	509
North Dakota	--	--	--	--
Ohio	--	5,100	545	4,555
Oklahoma	--	452	273	179
Oregon	--	573	560	13
Pennsylvania	--	17,310	992	16,318
Rhode Island	--	69	33	35
South Carolina	--	--	--	--
South Dakota	--	--	--	--
Tennessee	--	78	--	78
TEXAS	4,554	2,081	165	1,916
Utah	--	257	10	247
Vermont	--	42	--	42
Virginia	--	114	24	90
Washington	--	74	28	46
West Virginia	--	725	80	645
Wisconsin	--	1,404	53	1,351
Wyoming	--	--	--	--
Dist. of Columbia	--	--	--	--
Other	--	--	--	--
TOTAL	$423,864	$423,864	$53,057	$370,807

Sums may not equal totals because of rounding off.

Source: U.S. House of Representatives, Eighty-eighth Congress, Hearings before the Subcommittee on Manned Space Flight of the Committee on Science and Astronautics, Washington: 1963, pp. 466-469.

contract. The Mercury capsule project alone encompassed approximately 4,000 subcontractors distributed among 37 states, Puerto Rico, and Canada.[22]

The extent of the Mercury Capsule's subcontracting can be measured somewhat from the data in Table XV. These data express a survey by NASA of its 12 major prime contractors, including McDonnell, and their first and second tier subcontractors for a period from January 1, 1962, to February 28, 1963. During this period McDonnell subcontracted $134.1 million.

These subcontract data place Missouri's space-related research in better perspective. They show little evidence of much space-related research other than that performed at McDonnell. The total value of the subcontracts performed by Missouri organizations for the 12 prime contractors was $2 million, distributed $1.1 million to small firms and $0.9 million to large firms. This total subcontracting was only 0.5 per cent of the total value of the subcontracts analyzed. By comparison, although California prime contractors subcontracted $254.4 million, at the same time $207.1 million was subcontracted to California organizations. Perhaps this relationship can be summed up effectively, but crudely, by comparing Missouri to all of the states. Missouri ranked third in prime contracts, but seventeenth in the total subcontracts studied. The actual ranking of space-related R&D performed in Missouri is somewhere between these two.

On the other hand, in spite of interpretation difficulties with prime contract data, there undoubtedly has been a large increase in R&D contract awards to Missouri organizations by NASA. The total for fiscal year 1961 was only $47.3 million which reflects nearly a sixfold increase in just 3 years in the prime R&D contracts against the approximately fourfold increase of total NASA R&D.

Although this study pertains specifically to the performance of research-related activities in Missouri, a nonresearch factor futher specifies the role of space related R&D activity in Missouri. One can observe, Table XIV, that there

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[22] U.S. Congress, House of Representatives, Hearings before the Subcommittee on Manned Space Flight of the Committee on Science and Astronautics, Eighty-eighth Congress, Washington: 1963, p. 467.

have been no expenditures by NASA for salaries or construction during the 3 year period in the state of Missouri. This is to say, the future of space-related research in Missouri most certainly rests with the winning of future R&D contracts by Missouri organizations.

The cases of Texas and California provide a contrast to the space-related R&D in Missouri. The value of R&D contracts by NASA to Texas organizations in fiscal year 1963 was $73.2 million which evidences nearly a fivefold increase during the 3 year period. In the same year NASA expended $91.8 million for the construction of facilities in Texas. In fiscal 1963, salaries and expenses by NASA in Texas totaled $43.6 million. These expenditures reflect, of course, the development of the Manned Spacecraft Center in Houston. California has been the dominant performer of R&D for NASA as well as for military EDTR. The prime R&D contracts for fiscal year 1963 were estimated at $830.7 million. In that same year $87.9 million was expended for the construction of facilities in California.

Although prime contract data are poor indicators at best, the apparent level of R&D contracting to NASA has been a rapidly increasing and important segment of R&D in Missouri. Not surprisingly, this is attributable to the function of the McDonnell Aircraft Corporation as a major supplier of space research and technology. Little strength in NASA prime contracting or subcontracting is evidenced in other organizations in Missouri.

Although Missouri firms, principally McDonnell, are important NASA R&D prime contractors, the state's involvement in space-related research and development turns on the performance of these contracts. Since no change in that relationship is likely, the future of Missouri's space research will require the winning of future R&D contracts by Missouri organizations. However, one can assert, if the past is a fair indicator of the future, that space-related research is likely to be an expanding element in Missouri science-based industry. Considerable expertise appears to have developed in Missouri, at least at McDonnell Aircraft Corporation.

II. EFFECTS OF R&D EXPANSION ON PERSONNEL REQUIREMENTS IN INDUSTRIAL LABORATORIES IN MISSOURI AND CALIFORNIA 1950-60

Even though a time-series cannot be developed reliably from the data published by the National Research Council, National Academy of Sciences in the series Industrial Research Laboratories of the United States, the different surveys represent a sampling of R&D laboratories at different periods.[23] The mix of personnel required by the respondent laboratories to the survey in one year can be compared to the mix of personnel required by the respondent laboratories to the survey of another year. In this way, the changes in personnel emphasis can be identified without comparing the absolute totals of the different surveys. Extreme caution must be taken in order not to use the data for more precise measurements than they merit.

Three different samples of laboratories are used in this study. The different percentages of scientists, engineers, technicians and auxiliaries in the three surveys show the changing personnel requirements over the 10 year period which is covered by these surveys. Thus, some effects upon the activities of Missouri's industrial laboratories which result from the increased industrial and federal research are evident in the changing personnel requirements of the respondent laboratories to these three surveys. In order to isolate personnel changes that apply specifically to Missouri's industrial laboratories, a comparison with the personnel changes in other states is warranted. For this reason, the growth of R&D and its effects upon the personnel requirements of the respondent laboratories are compared to similar data of respondent laboratories in California, a representative state because of its dominance in R&D performance and its obvious link with the rapid growth in R&D performance.[24] The growth of research in California doubtless has affected the

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[23] National Research Council, Industrial Laboratories of the U.S., Washington, 9th ed. 1950, 10th ed. 1956, and 11th ed., 1960. The compilers specifically forewarn against employing these data for statistical analysis because the questionnaire technique may have introduced many biases.

[24] The imprecisions of this measure and the manpower requirements for compiling these data preclude the comparison of Missouri data with any additional states.

personnel requirements of industrial laboratories in California.

In this way, the personnel requirements in Missouri's respondent laboratories can be compared to the personnel requirements of the laboratories in a state so prominant in the R&D expansion as California. The obvious similarities in personnel changes can be interpreted roughly as changes in personnel requirements generally; the distinct differences can be viewed as possible effects from the different levels of R&D. Fortunately, the available data are from significant periods: a year prior to the rapid growth of total R&D, 1950; a year just prior to the impetus of space R&D brought forth by Sputnik, 1956; and a recent year, 1960.

A definitional clarification of the terms used by the NRC study is necessary prior to the following discussion. For these surveys the respondents were instructed to distinguish among personnel who were:

(1) professionally trained members of the research staff
(2) other technical personnel of the research staff
(3) other research laboratory personnel such as administrative clerical and maintenance personnel.[25]

Changing Personnel Requirements in Industrial Laboratories

The 1950 survey and the 1960 survey identified respondent industrial laboratories in Missouri and in California. There were in fact several notable differences and several similarities between the respondents to the two surveys in the two states. Table XVI illustrates these comparisons.

The most notable change in the Missouri surveys was the marked reduction of the ratio of scientists to total personnel among the 1960 respondents from what it was among the 1950 respondents. In 1950, 29 per cent of all personnel employed by the Missouri respondent laboratories were scientists, but in 1960, only 12 per cent of the total personnel were scientists. A similar but less marked result occurred in the two separate California surveys of industrial laboratories. In the 1950 survey 23 per cent of all personnel listed were scientists. In 1960, scientists were 16 per cent of all personnel listed in the California respondent laboratories.

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[25] Natl. Res. Council, Natl. Academy of Sciences, Industrial Research Laboratories of the U. S., 9th ed., Washington D.C., 1950, Preface.

TABLE XVI

PER CENT OF PERSONNEL BY PROFESSION

In Industrial Laboratories, Missouri and California

	1950		1956		1960	
	Mo.	Calif.	Mo.	Calif.	Mo.	Calif.
Bacteriologists & Biologists	2.2	1.3	2.0	.5	1.1	.5
Chemists	23.3	13.1	16.6	8.8	7.5	5.7
Physicists	.9	3.1	2.2	2.6	1.4	3.8
Mathematicians	--	.2	.9	1.1	1.4	2.4
Medical Personnel	.7	.4	1.4	.2	.3	.3
Metallurgists	1.6	1.4	1.5	.9	.6	.8
Other Scientists	.2	4.0	.2	2.7	.1	2.2
Total Scientists	28.7	23.4	24.9	16.8	12.5	15.5
Engineers	16.7	26.8	28.8	30.3	31.2	27.3
Technicians	22.0	22.1	21.4	30.2	22.5	24.9
Auxiliaries	32.5	27.7	25.0	22.8	33.5	32.2

Sums may not equal 100 per cent because of rounding off.

Source: National Research Council, Industrial Laboratories of the United States, 9th ed., 10th ed., 11th ed.

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For both states the reduction in the percentage of scientists to total personnel employed by industrial laboratories can be traced readily to a lesser ratio of chemists to total personnel. In 1950, 23 per cent of the total laboratory personnel in Missouri's respondent laboratories were classified as chemists. In the 1960 survey only 8 per cent of all laboratory personnel were identified as chemists. In addition, the California results were quite similar. In the 1950 survey chemists comprised 13 per cent of total laboratory personnel in California. In 1960, only 6 per cent of total personnel were chemists. Nevertheless, despite these sharp relative reductions, chemists remained the largest group of scientists, by field, among the respondents for both states in 1960.

These results suggest a decline in emphasis upon chemical research by industrial laboratories in Missouri and California over this period, which does appear consistent with the national emphasis of the R&D growth that was discussed in Chapter II. These Missouri-California data because of their limitation appear more meaningful if viewed in this national context.

Physics and mathematics are the only fields of science which show relative increases when these two surveys in Missouri are compared. Indeed, these two fields were the only ones showing relative increases in California as well. The Missouri laboratories responding to the survey in 1950 listed no mathematicians among their personnel. In 1960, the respondent laboratories identified 1.4 per cent of their personnel as mathematicians. In addition, the 1950 survey in Missouri listed 0.85 per cent of all personnel as physicists; the 1960 survey in Missouri listed 1.4 per cent of all personnel as physicists.

Similarly, mathematicians and physicists were 0.2 per cent and 3.1 per cent respectively of all personnel employed in the respondent industrial laboratories in California in 1950; mathematicians were 2.4 per cent and physicists were 3.8 per cent of the total California personnel in 1960. The greater concentration of physicists and mathematicians relative to the other scientists in Missouri and California also appears to be consistent with the expansion by fields of science of the national R&D growth (Table X, page 32).

Although Missouri respondents evidenced a considerably heavier emphasis on chemists and lesser emphasis on mathematicians and physicists in both years than did the California respondents, the scientific personnel requirements of Missouri laboratories were similar to those of California. This similarity occurred despite California's clear dominance in research activity.

A factor which offset the apparent decline in the ratio of scientists to total personnel in Missouri and which was consistent with national expansion of engineering development was the relative increase in the employment of engineering talent. The Missouri industrial laboratories listed in 1950 employed twice as many scientists as they did engineers, however, by the end of the period this relationship had completely reversed itself. In 1960, the respondent laboratories employed more than 2 1/2 times as many engineers as scientists. Specifically, the percentage of engineers to total personnel was 17 per cent in 1950 and 31 per cent in 1960.

In contrast, the California laboratories appeared to maintain a constant ratio of engineers to total personnel over the period. The percentage was 27 per cent in both 1950 and 1960. Of course, because of the lesser ratio of scientists to total personnel observed in the 1960 survey, nearly two engineers were employed for every scientist among California's respondent laboratories in that year.

The ratios of technicians to total personnel and of auxiliaries to total personnel did not change much for the two different surveys in Missouri. The ratio of technicians to total personnel was 22 per cent in 1950, and 23 per cent in 1960. Among the 1950 and 1960 respondents the ratio of auxiliaries to total personnel was 33 per cent and 34 per cent respectively. Among the industrial laboratories of California slight relative increases in the employment of both technicians and auxiliaries were evident. The ratio of technicians to total personnel was 22 per cent in 1950, and 25 per cent in 1960. Similarly, the ratio of auxiliaries to total personnel among the respondents was 28 per cent in 1950, and it was 32 per cent in 1960.

Thus, in general the extremely rapid expansion of research and development in the U.S. has elicited a relative decrease in the employment of scientists, a relative increase in the employment of engineers in Missouri (a pro rata increase in California), and apparently a slightly higher requirement of technicians and even auxiliaries. Because of knowledge pertaining to the R&D expansion and the characteristics of the different job categories, the causes of these results can be pursued somewhat further.

These phenomena can be explained to some extent by two observations. First, as illustrated earlier, the increased federal R&D expenditures have purchased, in the main, development work. The field of science with the largest expansion has been engineering science (Table X, page 32). Thus, the observation that the engineer to scientist ratios had increased among the respondent industrial laboratories in Missouri and California over the period is not at all surprising. Such a result is consistent with the R&D expansion nationally.

The second observation is a condition of the brisk labor market for industrial laboratory personnel during the period. The abrupt expansion of R&D caused a scarcity, at least at prevailing market prices, of trained personnel during the period. The many expanding research facilities were trying to add staff members at the same time. This shortage induced a rise in salaries of scientific personnel, particularly of scientists and engineers. Under these conditions of rising costs, the administrators of industrial laboratories who were desiring to minimize operation costs would be expected to employ engineers in some research jobs formerly performed by higher cost scientists. Naturally, such substitution is desirable if the cost of a given research activity is to be minimized. Similarly, the employment of technicians in support of the higher cost scientists and engineers, which releases them for additional research work, is desirable. Of course, better support for the scientists, engineers, and technicians with the assistance afforded by auxiliary personnel who perform clerical help, library research, maintenance, and other support tasks frees the scientific personnel for technical research activities.

Aside from helping to explain changing personnel requirements of industrial laboratories, this second observation also leads to an important conclusion regarding the personnel requirements of industrial laboratories. This conclusion seems particularly appropriate in the face of overall expanding research and development.

From the analysis of the scientific personnel market, technicians and auxiliaries can be considered important prerequisites if the available scientists and engineers are to be employed in their most productive alternative. This point which is of obvious importance to a regional study of scientific research will be discussed further in the following chapter when the mobility of scientific talent is considered.

CHAPTER IV

AN ANALYSIS OF SCIENTIFIC TALENT IN REGIONAL R&D EXPANSION

Because of the unique importance of scientific talent, the success of research depends upon it, closer scrutiny of the role of scientific talent in the regional expansion of R&D is warranted. This chapter discusses some characteristics of this unique input and investigates the relationship of scientific education to regional scientific research activity.

I. EXPANSION OF REGIONAL R&D AND MOBILITY OF SCIENTIFIC TALENT

As discussed in the previous chapter, the rapid growth of R&D in recent years has caused the scientists, engineers, and technicians who have specialized in the fastest growing areas of research to be highly demanded. Administrators of new or expanding research facilities in seeking additional personnel have been forced to bid against administrators of other expanding research facilities, thus creating a brisk, nation-wide market for scientific personnel.[26] The effects that this expanding national market for scientific talent have had upon regional scientific research organizations are of concern to this study.

A new or expanding research organization in a particular region may be able to hire additional personnel from the local scientific labor force. Even if a rapid expansion of scientific research demands a net increase in the total number of scientific personnel in the region, the additionally required scientists, engineers, and technicians may be available from local educational institutions. However, if the

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[26] There has been some disagreement as to the extent of the shortage of scientists and engineers during this period. For differing opinions see A.A. Alchion, Kenneth J. Arrow, and W.M. Capron, An Economic Analysis of the Market for Scientists and Engineers, RAND RM-2190-RC, Santa Monica, 1958; David M. Blank and George I. Stigler, The Demand of Scientific Personnel, Natl. Bureau of Economic Research, New York 1957; Bureau of Labor Statistic Long-Range Demand for Scientific and Technical Personnel, (Washington: Government Printing Office, 1961.)

local supply of existing and newly trained scientific personnel proves insufficient, the necessary personnel can be acquired only from without the region.

In this latter case, the degree of spatial mobility of scientific personnel obviously is important. This mobility indicates the ease with which additional scientific personnel can be obtained from without the region. Viewed differently, the degree of spatial mobility of scientists indicates the ease with which scientists trained or employed in one region can move to another for employment. Obviously, the education of scientists within a region does not insure their employment in that region, nor, similarly, does it insure the expansion of local R&D activity. Only after establishing the mobility of scientific talent are these matters relevant.

The mobility of scientific talent, as one can discern readily, is not a priori obvious. As would apply to the transfer of any person spatially, there is a myriad of factors affecting the mobility of scientists and engineers among regions. There are considerations underlying job opportunities themselves, such as salary, professional advancement, and nature of work. There are environmental factors such as climate, recreation, and other social amenities. There are ties to particular regions such as family, friends, and business or home investments. Of course, this list of factors is incomplete, but it does illustrate the diversity of factors, complicated by the strata of skills, which underlie the spatial mobility of scientific labor.

In addition, the significance of the mobility of scientific talent is amplified when one views how frequently scientific education is cited as "the," rather than merely "a," prerequisite of science-based industry. Such contentions allege that a research-laboratory location near a university or college benefits the laboratory by the proximity of the science faculty, the university scientific facilities, and the stream of science graduates. If the stream of science graduates is a prerequisite, the proximity to the source of graduates must be the cause. The validity of this contention depends also on the degree of mobility of scientific talent, i.e., it rests upon the mobility of newly graduated scientific talent between geographical points of education and employment.

The following section studies the mobility of scientific talent and questions whether, in the main, scientists have moved to states with concentrations of R&D projects or whether, in the main, the projects have been undertaken by organizations in states with a heavy investment of scientific talent in education. Subsequent to studying this question, the level of investment of scientific talent in education in Missouri is compared to the five comparative states. The final section of this chapter compares the scientists employed in industrial laboratories in Missouri to the comparative states.

II. SCIENTIFIC MOBILITY AND R&D LOCATION

A Study of the Mobility of Scientists

There is evidence that the mobility of scientists and engineers is high. The labor market for these talents is obviously national in scope. For example, employing organizations often advertise for scientists and engineers in regional media in distant regions of the country. In addition, employing organizations frequently send representatives to distant regions of the country to recruit scientists and engineers. These activities are clearly evident, underscoring the national scope of the market, but there is one study of the mobility of scientific talent that illustrates more convincingly the ease with which scientists may move from the location of education to the location of employment and then among various places of employment. This was a study by the Bureau of Labor Statistics published in 1953 that analyzed specifically the mobility of scientific talent.[27] The findings establish the degree of mobility of scientists at the time of the study and provide a touchstone for the analysis to follow. The relevant results of the BLS study will be presented briefly.

This study analyzed the work and education history of 1,222 Ph.D. chemists, physicists, and biologists which was about 5 per cent of the total number of scientists in their fields at that time. From that sample the Bureau of Labor Statistics concluded

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[27] Bureau of Labor Statistics, Occupation Mobility of Scientists, Bulletin No. 1121, Washington: 1953.

that "Ph.D. scientists are one of the most mobile segments of the population."[28] Specifically, it found that more than 40 per cent of the group had worked in at least three different states during their careers, and at the time of the study only one third was employed in either the state of his baccalaureate or his Ph.D.[29]

Furthermore, the BLS study reached one conclusion which is particularly applicable to this regional analysis and consistent with the previous observations concerning a national scientific labor market. The study stated that:

> Geographic location need not be a limiting factor in planning research and development programs, at least with reference to the recruitment of scientists, particularly Ph.D's. Scientists are usually willing to move to a new locality in order to advance their economic or professional interests.[30]

The study further observed a net regional shift of scientists in this group from the states where they were educated to the states where they were employed.[31] This is to say, as one would expect, that the number of scientists moving into some states was insufficient to compensate for the number of scientists moving from those states.

Thus, at that time, scientists clearly were responsive to the location of job opportunities in regions other than their place of education. This proposition seems adequately supported given the complexity of the mobility of scientific talent. Then, in order that this analysis of regional R&D can move forward, scientists and engineers are assumed to be quite mobile throughout the following analysis.

At this point a digression is warranted in order to compare the regional requirements of scientists and engineers with other technical skills. From the data exhibited in Table XVI, page 52, and the following analysis, technicians and auxilaries were shown to be important personnel requirements if personnel were to be employed efficiently. This conclusion added the categories of technicians and auxilaries to scientists and engineers as personnel prerequisites of scientific research. If these skills are not available from sources within the region, they must be acquired from without the region.

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[28] _Ibid._, p. 4.

[29] _Ibid._, p. 48

[30] _Ibid._, p. 49.

[31] _Ibid._, p. 52.

Since the auxiliary category is ambiguous and broad, encompassing several different levels of skill and training, it cannot be discussed satisfactorily in general terms. However, the technician category has more definite qualities. It suggests a certain semi-professional level of skills that are obtained only with training that requires an elapse of time. Therefore, the indigenous supply of technicians, as well as scientists and engineers, cannot be increased without a period of waiting.

Therefore, the number of technicians available for the expansion of R&D within a region, as in the case of scientists and engineers, depends upon the locally supplied technicians or the ease with which technicians can be acquired from without the region. But, there is not the same indication that the market for technicians is national in scope as there is for scientists and engineers. If the net increase of technicians required for regional scientific research expansion is not obtainable, there is not the same indication that they can be attracted to the region from without as there is for the scientists and engineers. If the mobility of persons with these skills is considerably less, and these observations indicate that it may be, an indigenous supply of technicians is an inescapable prerequisite of scientific research. Unfortunately, data are not ample to pursue this proposition further.

The BLS study describes, however, a period prior to the recent expansion of federal and industrial R&D. Specifically, the very rapid growth of federally sponsored research is not represented, and thereby, neither are any accompanying regional shifts of scientific talent.

Whether the very rapid growth in research and development in the period since this study has increased or decreased the net regional shift of scientists is not obvious, a priori. That depends, of course, upon the spatial distribution of the expanding scientific research projects. If the new projects are more dispersed geographically than is scientific education, assuming scientific talent has remained as mobile, the net regional shifts of talent from scientific education to scientific employment probably has increased. On the other hand, if the new projects have been located, in fact, near sources of scientific education, despite the mobility of scientific talent, net regional shifts of scientific talent from locations of education to employment probably have decreased. This relationship of scientific education and scientific employment is investigated in the following section.

An Analysis of the Effects of Federal R&D on Scientific Mobility

The proposition that scientific education has attracted concentration of scientific research activity in recent years, as opposed to scientific talent moving from the place of education to job locations elsewhere, can be tested empirically only very crudely because of inadequate data. Since scientific talent is an unique input of research and development, this question obviously is significant. However, the data difficulties incurred by any empirical analysis of it are considerable.

A method of analysis was developed which, nevertheless, utilized the available indicators of R&D. This method involved correlating data of federal R&D expenditures, population, and relevant scientific employment data for the 50 states and the District of Columbia. A sum of the Department of Defense and NASA research and development expenditures for fiscal year 1960 was used as the dependent variable. State population size, the number of scientists employed in educational institutions, and the number of scientists employed in governmental, industrial and nonprofit laboratories were used as the independent variables.

Rationale of the Study

The use of these particular data require further explanation, but the rationale of the correlation technique, which also requires further explanation, will be discussed first.

The functional distinction between scientific talent employed in scientific education that trains scientists for the future and performs most of the basic research (Chapter II) and the scientific talent employed in laboratories of the federal government, industry and nonprofit organizations that performs the bulk of the total scientific research, principally applied research and development, separates the scientific community easily into two parts.[32] The degree of spatial mobility that was established in the previous section of this chapter is assumed to prevail throughout the period investigated.[33]

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[32] Cf., Fritz Machlup, The Production and Distribution of Knowledge in the U.S., (Princeton, New Jersey: Princeton University Press, 1962) p. 204.

[33] Bureau of Labor Statistic, op. cit., pp. 66-67.

If R&D projects and thereby the research and development jobs in governmental, industrial, and nonprofit laboratories have located in regions apart from regions with heavy scientific education, it will be readily apparent from the following correlations. The correlation of R&D expenditures with scientists employed in governmental, industrial and nonprofit laboratories will be relatively high because the scientists will have moved from the point of education to the job locations. Additionally, the correlation of scientific education with the R&D expenditure data would be expected to be relatively low. The correlation of scientists employed in education with scientists employed in the governmental, industrial, and nonprofit laboratories would be expected to be relatively low also.

On the other hand, if the R&D projects and thereby the research jobs in governmental, industrial, and nonprofit laboratories have been located in regions with considerable scientific education, somewhat different results would be expected. The correlation of R&D expenditures with scientists employed in governmental, industrial, and nonprofit laboratories would be expected to be relatively high. The correlation of scientific education with R&D expenditures, and the correlation of scientists employed in education with scientists employed in other organizations would be expected to be relatively high. These correlations would occur in this manner if scientific education provided an attraction to the R&D projects, and thereby, the scientific research jobs were available in the same locality.

By using data that indicate the expenditures upon R&D in a region, the scientific education in a region, and the number of scientists employed in governmental, industrial, and nonprofit laboratories, this technique can be performed.

Even though the rationale of the correlation technique was easy to establish, the selection of the data used requires further explanation. The technique was dictated by the limited relevant data.

Rationale of the Data Used

Further explanation is required concerning the selection of the dependent variable. The federal R&D prime contract data of the Department of Defense and NASA were not used as the dependent variable because this study was concerned with federal research alone, but because expenditure data for industrially sponsored research within the various states are not available.[34] Nevertheless, approximately one half of the total R&D performed in the U.S. in 1960 was contracted by these two agencies. The dependent variable thereby represents a major portion of all R&D activity, and it remains the best measure of spatial R&D allocation available. Unfortunately, the results of this study apply only to the R&D allocation of these two agencies and are not applicable generally. But, to the extent that their research projects are similar to research projects sponsored by other organizations, the findings of the study can be interpreted more broadly.

The number of scientists employed in educational institutions was used as a variable representing scientific education.[35] These data represent the level of scientific talent invested in education. Although dollar investment figures in scientific education, if they were available by state, might be a better indicator inasmuch as they suggest a quality level of scientific education, the number of scientists invested in education obviously is an appropriate indicator of a concentration of scientific education.

The number of scientists employed in industrial, governmental, and nonprofit laboratories indicates the number of jobs in these organizations in the various states.[36]

The population variable was used in the analysis to remove any influence of population size upon the other variables.[37] In comparing the simple correlations the other three variables are each correlated with the population size of the state. In the multiple linear correlation the population variable is used to remove the effect of population size from the dependent variable. Using this variable in the multiple linear correlation specifically acknowledges that a variation in allocation of research

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[34] The dependent variable is a sum by state, of the DOD experimental, developmental, testing and research prime contracts fiscal year 1960 (Table XIII, page 41) and of the NASA R&D prime contracts fiscal year 1961 (Table XIV, p.44).

[35] Table XVII, Column (1), page 71.

[36] Table XVII, Columns, 2,4,5, and 6, page 71.

[37] U.S. Department of Commerce, Statistical Abstract of the United States, 1963, Washington, D.C.

and development funds among states exists, but it suggests that much of this variation can be accounted for by population size (the two most populous states, California and New York, are the largest contractors of federal research).

Naturally data which are so hard to assemble and which must describe such diverse activities as scientific education and research are likely to have undesirable qualities. That is indeed the case with these. There are some imprecisions in the data used that may result in misleading findings. These are the following:

(1) Neither the scientists employed in educational institutions nor scientists employed in laboratories are homogenous inputs. Naturally, some scientists are more capable than others. Two scientists of different skills actually represent two different inputs, but this distinction cannot be handled quantitatively with these data. Hence, neither the quality of scientific education nor the quality of scientific research are portrayed by these data, and surely the competence of the scientific talent in education and research is a factor in spatial allocation.

(2) The R&D activity demanded by NASA and DOD is extremely specialized by field of science. The scientific personnel data used as independent variables include all fields of science and do not reflect this specialized demand. Therefore, neither the scientific education variable nor the scientists employed in laboratories variable reflect this specialized demand.

(3) The available data of federal R&D contracts awarded by these two agencies identify prime contracts only. Since subsequential contracting is not identified, the precise location of R&D performance is not represented in the dependent variable which naturally was the assumption underlying the use of these data.

In spite of these difficulties with the employed data, their use is meaningful. Using these variables enables them to be compared with one another, and the importance of each variable, relative to each of the others, can be ascertained from the analysis. One must keep in mind, however, the data difficulties incurred. They do limit the conclusions which can be made from these data.

Results of the Correlation Problem

Some simple correlations among these variables show relationships that shed some light on the importance of the scientific education in the allocation of federal R&D expenditures. Furthermore, the inner correlation among the independent variables affects the results of the multiple linear correlation that follows.

The simple correlations of the population variable with each of the other three variables is useful. It indicates in turn the following:

(1) a correlation of population with the scientists employed in educational institutions indicates the per capita concentration of science education

(2) a correlation of population with the scientists employed in other organizations indicates the jobs for scientists per capita

(3) a correlation of population with the expenditure data indicates the two agencies' R&D contracts per capita.

These three correlations are compared in order to isolate relevant relationships among the variables.

The coefficient of simple linear correlation of population with the sum of NASA and DOD prime R&D contracts is .60. Thus, according to this relationship the population variable explains only 35.9 per cent of the total variation of the allocation of R&D funds by NASA and the Defense Department.[38]

This correlation acquires more significance if the chauvinistic repercussions in a region that surrounds the R&D contract activities of these two agencies are acknowledged. The attraction of research and development projects or the reduction of research and development projects of these two agencies in a region generally raises keen interest. These events attest to the regional concern and the political pressures which surround these agencies' R&D projects. However, this low correlation seems to assert that pressures derivable from population size are not too effective.

Of course, this low correlation does not rule out the possibility of political pressures issuing from other sources and affecting the allocation of the R&D funds. However, it does support the earlier assumption of this study concerning federal R&D allocation.[39] The federal R&D funds were assumed to be allocated to the organization that would supply the best research products. That is to say,

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[38] All simple correlations were tested for significance at the .05 level.

[39] p. 38 and p. 43.

the funds were allocated so as to maximize the anticipated value, hopefully discounted, of the research findings of a given agency's R&D budget. Indeed, assuming a level of efficiency in R&D project allocation is consistent with the mission of the respective agencies. It seems to be a reasonable assumption.

The simple correlation of population with the number of scientists employed in educational institutions was .95. This very high correlation results from the obvious functional relationship of population size and educational requirements. However, the functional relationship between scientific jobs and population size is less certain because of the mobility of scientific talent. One cannot assume that the number of scientists employed in governmental, industrial, and nonprofit laboratories are distributed according to population size nationally. Nevertheless, the correlation between the population variable and the variable of the number of scientists employed in governmental, industrial, and nonprofit organizations was .90.

With the very high correlation of each of these two variables to population one would expect them to be highly correlated to each other and they are. The simple linear correlation between scientists employed in educational institutions and scientific job variables was .90. Thus, following the rationale for this study, this relationship shows a definite link between the location of scientific education and the location of the total scientific jobs available.

The simple correlation of scientific education with the NASA and Defense research and development expenditures was .69, thereby explaining 47.6 per cent of the total variation of the expenditures variable. When compared to the .60 simple correlation of population and the dependent variable, the scientific education variable obviously is a better predictor of NASA and Defense R&D programs. Again the .68 correlation between the scientific jobs variable and the dependent variable was not distinctively different from the correlation of the scientific education variable and the dependent variable. No redistribution of total scientists from the point of their education to job location elsewhere because of NASA and DOD research programs was evident. However, more detailed data that specify fields of science, especially the fields of science which are highly demanded by projects of these agencies, probably would have somewhat different results.

A multiple linear correlation using the population variable and the scientific education variable as the independent variables and the NASA and DOD R&D expenditures as the dependent variable enables a further comparison of these variables. Additionally, the coefficient of partial correlation of scientific education, with the population variable held constant at its mean, can be tested for significance. This would show whether or not the scientific education variable is a significantly different, better predictor of the dependent variable.

The multiple linear correlation using both of these independent variables produced a coefficient of multiple correlation of .70, thus explaining 49.2 per cent of the total variation. When introduced after accounting for the population variable, the variable scientists employed in educational institutions still explained 20 per cent (coefficient of partial correlation of .46) of the remaining unexplained variation in the R&D prime contract data. This result tested significant at the .05 level. Despite the high correlation between these two independent variables, the scientific education variable, even after accounting for population, still significantly explained 13.3 per cent of the total variation of the R&D expenditures. The scientific education variable is a significantly better predictor of these R&D expenditures than the population variable.

This conclusion rests tenuously on data that show a relationship between scientific education and the location of these federal R&D prime contracts. The relationship obviously is too nebulous to argue that scientific education, per se, is the primary prerequisite of federal R&D. Even though the partial correlation coefficient of scientific education was .46 after the population variable had been introduced, these variables together explained only 49 per cent of the total variation of the dependent variable. The remaining 51 per cent of unexplained variation looms as an important unanswered question about the allocation of federal R&D prime contracts.

The consequence of this questioning may be mitigated somewhat by reconsidering some of the imprecisions outlined earlier regarding the data used in this correlation. The quality of scientific talent surely is a more potent predictor of the location of federal R&D projects than a total of all scientists. If the heavy emphasis of federal R&D in certain fields of science had been accounted for in measuring the investment of scientific talent in education, then undoubtedly a better predictor of federal R&D contracts would have resulted. In addition many factors other than population affect the allocation of these federal R&D funds. Nevertheless, despite the large unexplained variation, this study concludes that scientific education is a relevant determinant of these federal R&D projects. However, one obviously cannot conclude from this limited position that scientific education is either a necessary or a sufficient precondition for federal research activity.[40]

The results of this analysis enable some speculation about the role of scientific education in locating research and development activity, but, before doing so, two seemingly inconsistent positions held in this study should be reconciled. The two positions requiring further explanation are:

(1) that scientists are highly mobile spatially
(2) that scientific education is a relevant locational determinant of the scientific research projects of these federal agencies.

Under certain reasonable, logically supported conditions, these positions are not inconsistent. If the apparent relationship of research and development activity to scientific education occurs for reasons other than the indigenous source of new scientific talent, there is no inconsistency in these two positions.

Thus, one should re-examine the three inherent inputs of local scientific education that account for its reputation as a locational prerequisite of R&D activity.[41] These inputs are:

(1) a steady stream of science and engineering graduates which is available from a university for personnel expansion

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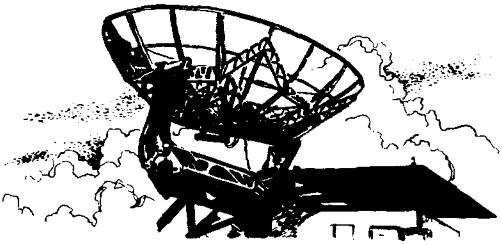
[40] There are several states heavily endowed with federal R&D contracts that have a strong base of scientific education. California and Massachusetts are the most obvious examples. However, there are several states heavily endowed with federal R&D contracts that conspicuously lack much scientific education. California and Massachusetts may be more appropriately an argument for high quality scientific education.

[41] p. 57

(2) the scientific facilities of a university which are available for post graduate work, library reference, and occasional laboratory testing

(3) the science faculty which is available for part-time consulting.

The high degree of spatial mobility of scientific talent accepted by this study reduces the significance of the first reason. Science graduates probably are available from without the region. On the other hand, since some relationship of scientific education and federal R&D was held from the correlation analysis, perhaps one should look to the other two reasons. These two, the availability of the science facilities for occasional use and post graduate study and the availability of a competent science faculty for occasional employment by research projects near a college or university, may be the real link of science-based industry and scientific education. In addition, these inputs are indivisible, and after locating are less mobile. The university environment is stimulating and communication is easy. Thus the university generates technological external economies obtainable by the scientific research projects in the region. These two facets of scientific education that attract a research project are clearly consistent with the clustering of research projects discussed earlier.[42]



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[42] pp. 12 & 13.

CHAPTER V

SCIENTIFIC TALENT RESOURCES IN MISSOURI AND SELECTED STATES

The relevant data published by the National Science Foundation and the relevant data published by the National Research Council will be reviewed in this chapter in order to show the concentration of scientific talent in Missouri and the five comparative states. The caution that was expressed in the previous use of these data should be applied again. The data can be interpreted only as general indicators. Thus, when the concentration of scientific talent in Missouri and the comparative states is appraised, the figures will be compared briefly with the relevant national data from the earlier discussion when appropriate.

The NSF data that were used in the analysis in the preceding chapter can be employed as one measure of the scientific talent resources in Missouri. These data show that 3,437 scientists were employed in Missouri in 1960 (Table XVII), which represented 1.7 per cent of the total number of scientists in the U.S. Since a per capita measure of scientists is a more convenient notation for expressing the concentration of scientists, it will be used throughout the remainder of this chapter. This notation facilitates the comparison of Missouri with the five comparative states and the U.S. averages after accounting for the total population size. For example, these above figures represent 80 scientists per 100,000 persons in Missouri in 1960, as opposed to 112 scientists per 100,000 persons in the U.S. as a whole in 1960.

Among the comparative states, California stands out considerably above the U.S. average with 144 scientists per 100,000 total population (Table XVIII). The Arkansas figure, 46 scientists per 100,000 persons, is noticeably below the U.S. average and Missouri. These figures are consistent, of course, with the concentrations of prime contract data (Table XIII, page 41, and Table XIV, pages 44 and 45).

However, merely computing these aggregate figures does not provide detailed information about the scientific community or the scientific activity in Missouri. Obviously, if the effects upon the scientific community of the level and the type

TABLE XVII

SCIENTISTS BY EMPLOYER AND STATE, 1960

Geographic location	Total	Educational institutions 1	Federal Government 2	Other government 3	Military and Public Health Service 4	Nonprofit organizations 5	Industry, business, or self-employed 6	Other, including no report 7
All locations	201, 292	55, 663	21, 623	10, 741	4, 772	8, 855	90, 986	8, 652
Alabama	1, 638	420	337	86	88	72	602	33
Alaska	443	45	196	59	45	6	81	11
Arizona	1, 302	446	260	76	33	23	415	49
Arkansas *	815	298	115	50	13	8	301	30
California *	22. 788	6, 017	2, 188	1, 735	420	1, 516	10, 189	723
Colorado	3, 587	794	932	147	130	97	1, 359	128
Connecticut	3, 530	997	119	179	18	92	2, 007	118
Delaware	2, 237	150	19	23	6	20	1, 997	22
District of Columbia	5, 508	501	3, 657	78	446	303	387	136
Florida	3, 088	1, 130	349	289	112	75	1, 005	128
Georgia	2, 025	680	313	139	136	37	683	37
Hawaii	522	136	89	76	49	26	121	25
Idaho	849	196	246	71	14	11	284	27
Illinois *	10, 512	3, 495	577	554	132	734	4, 646	374
Indiana	3, 958	1, 691	123	196	20	50	1, 778	100
Iowa	1, 986	1, 208	101	148	3	36	421	69
Kansas *	2, 045	890	106	149	45	61	694	100
Kentucky	1, 275	487	105	70	60	16	497	40
Louisiana	3, 071	780	250	114	35	19	1, 818	55
Maine	605	207	39	98	15	46	177	23
Maryland	5, 838	1, 115	2, 406	204	571	218	1, 169	155
Massachusetts	7, 913	2, 875	528	204	119	667	3, 205	315
Michigan	6, 909	2, 536	245	526	39	209	3, 137	217
Minnesota	3, 301	1, 302	229	248	18	108	1, 311	85
Mississippi	973	270	204	52	18	3	402	24
Missouri *	3, 437	1, 083	396	189	68	156	1, 465	80
Montana	960	238	265	83	31	8	311	24
Nebraska	987	445	169	66	72	16	184	35
Nevada	368	103	83	40	17	8	110	7
New Hampshire	527	281	35	42	13	16	118	22
New Jersey	10, 604	1, 410	349	250	61	282	8, 048	204
New Mexico	2, 032	402	397	135	109	385	524	80
New York	21, 659	6, 015	640	1, 069	168	1, 500	11, 631	636
North Carolina	2, 435	1, 133	228	172	42	46	746	68
North Dakota	474	203	69	66	6	8	94	28
Ohio	9, 134	2, 223	655	508	229	520	4, 716	283
Oklahoma	2, 930	624	165	62	43	43	1, 911	82
Oregon	2, 223	755	672	235	21	38	439	63
Pennsylvania	11, 984	3, 251	611	466	60	564	6, 695	337
Rhode Island	676	347	39	32	21	19	203	15
South Carolina	988	306	81	65	35	4	468	29
South Dakota	439	223	90	48	10	6	42	20
Tennessee	2, 717	708	335	194	11	242	1, 097	130
Texas *	10, 292	1, 874	504	280	278	165	6, 848	343
Utah	1, 522	514	316	70	31	14	524	53
Vermont	299	177	21	41	----------	11	39	10
Virginia	2, 944	763	494	242	176	57	1, 114	98
Washington	3, 433	1, 082	434	250	62	45	1, 446	114
West Virginia	1, 322	297	87	72	5	13	821	27
Wisconsin	3, 433	1, 642	210	321	19	108	1, 011	122
Wyoming	775	141	155	54	1	3	408	13
Foreign	3, 187	652	369	117	589	99	1, 215	146
No report	2, 793	105	21	1	9	26	72	2, 559

Source: National Register of Scientific and Technical Personnel, 1960

American Science Manpower 1960 (Washington: National Science Foundation, 1962) pp. 72-3.

TABLE XVIII

SCIENTISTS BY EMPLOYER PER 1960 POPULATION

(Per Hundred Thousands)

	United States	Mo.	Ark.	Kan.	Ill.	Tex.	Calif.
Total	112	80	46	94	104	107	144
Educ. Inst.	31	25	17	41	35	19	38
Fed. Govt.	12	9	6	5	6	5	14
Other Govt.	6	4	3	7	5	3	11
Military and Pub. Health Service	3	2	1	2	1	3	3
Nonprofit Org.	5	4	--	3	7	2	10
Industry, Bus.,or Self-employed	51	34	17	32	46	71	64
Other	5	2	2	5	3	4	5
Total all others except Educ. Insts.	82	55	29	54	68	88	107

Sums may not equal totals because of rounding off.
Sources: National Science Foundation, American Science Manpower 1960, Washington: 1962.

U.S. Bureau of the Census.

* * * * * *

of R&D in Missouri are to be ascertained more detailed information concerning the scientific talent employed in these various states is then required. The data in the following discussion will be expressed in more meaningful detail whenever possible.

This more detailed investigation of the supply of the scientific talent in Missouri can be directed somewhat by the conclusions drawn from the analysis in Chapter IV. This is to say, that the dichotomy between the employment of scientific talent in educational institutions and the employment of scientific talent in all other organizations is appropriate for this more detailed study of scientific talent in Missouri and the comparative states. The level of scientific education in Missouri should be studied since the link between scientific education and scientific job location has been established. However, the graduation of scientists and engineers in Missouri by no means assures that they will be employed in Missouri due to the high degree of spatial mobility of scientists acknowledged in this study.

Based on these observations this section will be divided into two parts. The first part is a comparison of scientific education in Missouri with the selected states. The second part is a comparison of the scientists employed in laboratories in Missouri and the comparative states.

In both parts of the following study the data will be identified by field of science in order to enable a subsequent comparison with the projected growth of R&D by field of science. Thereby, it will be evident whether or not adequate scientific talent resources in the most rapidly growing scientific fields exist in Missouri relative to the comparative states and if the most rapidly growing fields of science are emphasized presently by the universities within Missouri.

I. COMPARISON OF SCIENTIFIC EDUC. IN MO. AND COMPARATIVE STATES

The NSF data, (Table XVII, page 71) show that there were 1,083 scientists employed by educational institutions in the state of Missouri in 1960. This figure represents 25 scientists per 100,000 persons employed in educational institutions in Missouri in that year which is significantly less than the comparable national average of 31 scientists in educational institutions per 100,000 persons (Table XVIII).

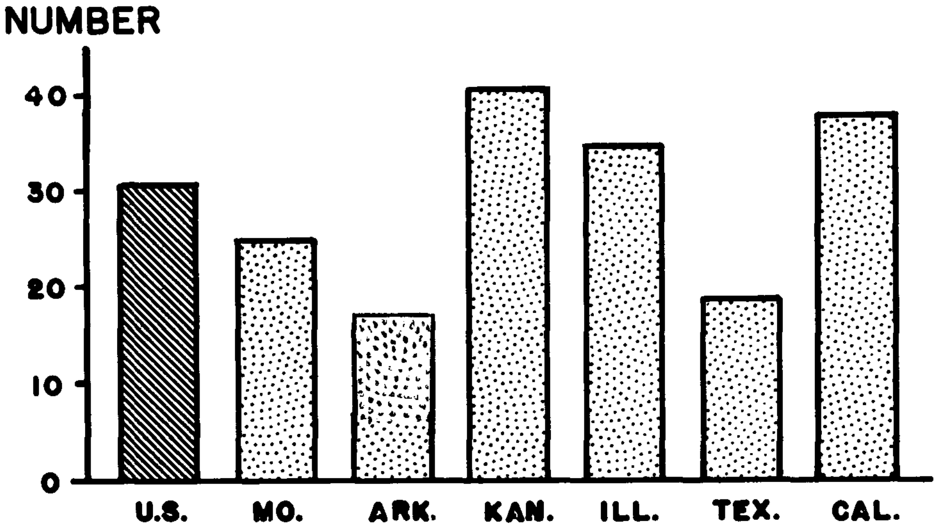
Of the five comparative states, the figures for Kansas, 41 scientists employed in educational institutions per 100,000 persons; California, 38; and Illinois, 35, were greater than the U.S. average figure. The figures for Texas, 19 scientists per 100,000 thousand persons employed in educational institutions, and Arkansas, 17 were less than the Missouri figure.

Whereas the data of scientific talent employed in educational institutions do not illustrate the various fields of science emphasized in the educational institutions in the selected states, the data of Ph.D.'s graduated from universities in the states do. The number of Ph.D.'s granted in the various fields of science illustrate the fields stressed.

Figure 3

SCIENTISTS EMPLOYED IN EDUCATION

Per 100,000 Persons



Data indicating the number of Ph.D. scientists by field of science graduated from U.S. colleges and universities have been published by the U.S. Department of HEW.[43] From these, the number of graduates from the University of Missouri, St. Louis University, and Washington University, the three universities offering the Ph.D. degree in the sciences in Missouri in that year, were compiled (Table XIX). These data cover a 10 year period, 1948-49 to 1958-59. The expressed figures represent the 10 year total.

The various fields of science in which Ph.D.'s are offered by the universities in these six states should be interpreted broadly as indicators of the emphasis of scientific education in specific fields of science. This interpretation is reasonable. In order to award the Ph.D. degree in any field of science, a college or university must have a faculty capable of providing the graduate coursework and supervising research as well as laboratory-library facilities sufficient for performing the required research. Clearly a considerable concentration of scientific resources is a prerequisite for the university or college that awards the Ph.D. degree in a field of science.

Furthermore, the cluster of scientific resources required to award the Ph.D. degree is consistent with the observed nucleus of an R&D cluster. This observation has special meaning to this analysis. The number of Ph. D.'s awarded may be a reasonably good indicator of the inherent R&D attraction of an educational institution.

The three universities in Missouri together granted 229 Ph.D.'s in the biological sciences, the largest total of the fields surveyed during this period. In the biological sciences, Washington University alone granted 99 Ph. D.'s. The two next largest fields of science in which Ph. D.'s were granted in Missouri during this period were chemistry, 160 Ph. D.'s, and physics, 131 Ph.D.'s.

However, the ratio of total Ph.D.'s to the 1960 population for Missouri did not compare favorably with the ratios from the five other states (Table XXIII).

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[43] U.S. Department of HEW, Degrees in the Biological and Physical Sciences, Mathematics, and Engineering, Washington: 1963.

TABLE XIX

PH.D.'s GRANTED IN THE PHYSICAL SCIENCES

1948-49 to 1958-59

	Astronomy	Chemistry	Geology	Meteorol.	Physics	Biological Sciences	Math. &Statistics	Engineering	Total
Missouri	--	160	28	--	131	229	39	81	668
Missouri University	--	60	13	--	27	58	12	35	205
St. Louis University	--	45	6	--	34	72	18	2	177
Washington University	--	55	9	--	70	99	9	44	286
Arkansas	--	21	--	--	--	2	--	--	23
Kansas	--	141	15	--	33	180	19	10	408
Illinois	24	1,047	156	22	359	727	221	600	3,156
Texas	--	273	26	--	175	264	58	159	955
California	39	789	204	15	686	1,177	261	513	3,684

Source: U.S. Department of Health, Education, and Welfare, Degrees in the Biological and Physical Sciences, Mathematics, and Engineering, Washington: 1963.

Missouri was fourth behind Illinois, California and Kansas. Illinois was significantly larger than the other five states. In fact the Illinois ration of Ph.D.'s conferred in 1960 to population was the largest of all six states for five of the six fields of science identified. Only Kansas in one field of science, the biological sciences, had a ratio of science Ph.D.'s to population that exceeded any of the Illinois' ratios. The ratio of Ph.D.'s granted in Missouri per 1960 population was never in a higher position than third or fourth within the six states for every field of science considered.

Assuming that these data are appropriate indicators of scientific education, Missouri shows little noticeable strength relative to the comparative states. An exception is the per capita figure for physics Ph.D.'s in Missouri, a notable field because of its rapid growth. It is comparable to that of Illinois and California, and perhaps this shows Missouri's scientific education strength relative to expanding R&D requirements. The figures per capita of the other two fastest growing fields, mathematics and engineering, are not comparable to the Ph.D. per capita figures for Illinois and California.

II. SCIENTIFIC TALENT IN OTHER THAN EDUCATIONAL INSTITUTIONS

Following the rationale of the analysis in Chapter IV of scientific education and R&D in the U.S., the scientists employed in laboratories indicate the existing job opportunities for scientists in Missouri. When these data are compared with the selected states, the type of scientific activity in Missouri is contrasted with the other states in this group.

An Aggregate Analysis of Missouri's Scientific Resources

There were 55 scientists per 100,000 persons employed in organizations other than educational institutions in Missouri in 1960. This figure is less than the 82 scientists per 100,000 thousand persons employed in that sector in the U.S. as a whole in 1960 (Table XVIII, page 72). Similarly, the deviations of the other five states about this national average figure were large. Of the group of states studied, the figures for California, 107, and for Texas, 88, were the only ones larger than

FIGURE 4

SCIENTISTS EMPLOYED IN NON-EDUCATIONAL ORGANIZATIONS

PER 100,000 PERSONS

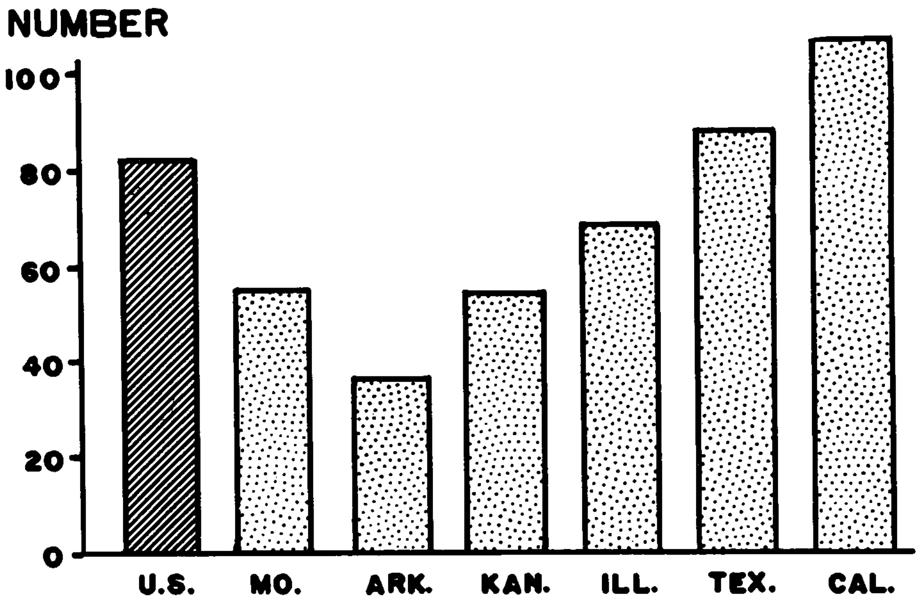

TABLE XX

PH.D.'s GRANTED IN THE PHYSICAL SCIENCES

1948-49 To 1958-59 Per 1960 Population
(Per Hundred Thousands)

	Astronomy	Chemistry	Geology	Meteorology	Physics	Biological Sciences	Mathematics & Statistics	Engineering	Total
Missouri	--	3.7	.6	--	3.0	5.3	.9	1.9	15.4
Arkansas	--	1.2	--	--	--	.1	--	--	1.3
Kansas	--	6.5	.7	--	1.5	8.3	.9	.5	18.4
Illinois	.1	10.4	1.5	.2	3.6	7.2	2.2	6.5	31.4
Texas	--	2.8	.3	--	1.8	2.7	.6	1.6	9.8
California	.4	5.0	1.3	.1	4.3	7.4	1.6	3.2	23.3

Sources: U.S. Department of Health, Education, and Welfare, *Degrees in the Biological and Physical Sciences, Mathematics and Engineering,* Washington: 1963

U.S. Bureau of the Census.

the national average. The figures for Illinois, 68, Kansas, 54, and Arkansas, 29, of scientists per 100,000 persons in this sector in 1960 were all below the national average.

The scientific personnel employed in Missouri by field of science demonstrate somewhat the type of research performed in the industrial, federal government, and nonprofit organizations. These NSF data indicate generally the type of scientific jobs that exist in Missouri presently. But, they do not permit the exclusion of scientists by field of science who are employed in educational institutions.

From Table XXI one can observe that 980 of the total 3,437 scientists in Missouri in 1960 were chemists.[44] This is a ratio of 23 chemists per 100,000 persons in the 1960 Missouri population(Table XXII). Although chemists comprised the most heavily concentrated field of science in Missouri, the U.S. chemists per capita figure was greater yet, 29 per 100,000 persons in 1960.

These data further reveal that Missouri's 161 sanitary engineers, 108 meteorologists and 83 medical scientists each reflected larger concentrations per capita than the comparable U.S. average figure in 1960. It also shows, however, that the number of psychologists, physicists, mathematicians, and earth scientists per capita in Missouri was considerably lower than the national average.

The mobility assumption of scientific talent and its effect upon regional R&D, should be considered again with these new data. The assumption of mobility is supported by the education and employment figures for the physicists and mathematicians in Illinois. These figures emphasize that scientific education alone does not induce R&D activity. The number of physicists and mathematicians per 100,000 persons employed in Illinois in 1960 was even smaller than the national average for these fields. This occurred despite the emphasis in their education as indicated by the large number of Ph.D.'s per capita granted in Illinois in these fields, (Table XX, page 77). In comparison, the number of Ph.D.'s per capita conferred in California was quite similar to that of Illinois; however, the 16 mathematicians and the 22

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[44] For more recent data see National Science Foundation, Scientific Manpower Bulletin, No. 20, March 1964.

TABLE XXI

SCIENTISTS BY FIELD OF SCIENCE AND BY STATE, 1960

Geographic location	Total	Agricultural sciences	Biological sciences	Medical sciences	Psychology	Earth sciences
All locations	201, 292	13, 140	23, 901	3, 287	15, 257	17, 642
Alabama	1, 638	237	160	30	76	45
Alaska	443	127	53	4	5	88
Arizona	1, 302	219	162	11	70	175
Arkansas *	815	205	102	9	58	101
California *	22, 788	1, 106	2, 213	278	2, 151	1, 862
Colorado	3, 587	384	278	44	193	1, 132
Connecticut	3, 530	104	392	59	301	89
Delaware	2, 237	27	97	7	64	19
District of Columbia	5, 508	270	570	130	422	542
Florida	3, 088	379	508	43	327	186
Georgia	2, 025	439	382	52	147	57
Hawaii	522	53	92	4	49	33
Idaho	849	302	82	4	28	58
Illinois *	10, 512	332	1, 362	245	911	385
Indiana	3, 958	214	634	63	286	153
Iowa	1, 986	214	376	44	217	88
Kansas *	2, 045	112	282	27	223	399
Kentucky	1, 275	110	181	20	93	80
Louisiana	3, 071	274	279	28	113	952
Maine	605	121	96	6	67	35
Maryland	5, 838	243	1, 325	235	307	184
Massachusetts	7, 913	133	799	177	632	283
Michigan	6, 909	498	892	120	634	243
Minnesota	3, 301	343	426	85	336	159
Mississippi	973	221	130	6	33	246
Missouri *	3, 437	190	417	83	235	186
Montana	960	311	105	5	23	250
Nebraska	987	145	142	17	83	70
Nevada	368	76	26	1	23	56
New Hampshire	527	88	106	6	31	23
New Jersey	10, 604	138	743	94	614	162
New Mexico	2, 032	194	94	8	46	397
New York	21, 659	404	2, 375	531	2, 618	641
North Carolina	2, 435	336	417	50	180	78
North Dakota	474	88	58	5	45	90
Ohio	9, 134	233	775	119	709	301
Oklahoma	2, 930	125	192	26	104	1, 061
Oregon	2, 223	885	253	27	138	126
Pennsylvania	11, 984	370	1, 299	230	917	427
Rhode Island	676	26	70	5	67	27
South Carolina	988	189	104	4	42	21
South Dakota	439	129	73	3	24	47
Tennessee	2, 717	190	331	36	149	84
Texas *	10, 292	414	698	66	422	3, 474
Utah	1, 522	217	206	23	84	313
Vermont	299	51	72	7	33	8
Virginia	2, 944	249	288	47	193	149
Washington	3, 433	572	370	61	230	231
West Virginia	1, 322	120	95	9	60	73
Wisconsin	3, 433	389	571	48	257	114
Wyoming	775	136	42	2	22	364
Foreign	3, 187	201	309	38	134	1, 003
No report	2, 793	7	1, 797	5	31	272

(Table XXI continued)

Meteor-ology	Geog-raphy	Mathe-matics	Physics	Astron-omy	Chem-istry	Chemical engineer-ing	Sanitary engineer-ing	Other engineer-ing	Other specialties
3, 829	1, 072	15, 511	20, 882	630	53, 071	6, 563	5, 226	17, 526	3, 755
46	5	143	141	3	472	58	51	147	24
47	3	7	11	1	15	3	17	60	2
54	10	90	97	23	152	7	42	176	14
13	6	36	22		162	20	32	47	2
401	97	2, 501	3, 549	119	4, 299	581	515	2, 745	371
107	21	187	256	20	384	55	53	441	32
51	14	343	457	18	1, 192	115	71	260	64
4	3	53	98	1	1, 450	208	18	136	52
248	100	539	899	62	881	36	148	460	201
150	21	213	252	11	512	65	148	226	47
70	5	133	116	3	336	39	110	113	23
45	6	16	22	2	84	6	33	67	10
18	2	30	69	1	122	24	14	85	10
208	114	729	957	16	3, 594	341	332	714	272
23	27	311	335	17	1, 316	149	103	259	68
23	10	178	145	6	451	29	76	103	26
27	8	163	113	2	376	38	57	192	26
15	6	77	81	1	381	71	42	104	13
30	18	126	89	3	615	137	46	326	35
16	2	39	28	1	122	10	23	33	6
142	29	574	714	16	1, 318	148	126	396	81
213	45	821	1, 490	61	2, 205	172	188	508	186
74	49	523	557	22	2, 127	243	191	553	183
43	22	282	267	4	900	88	90	199	57
9	3	43	33		98	15	18	116	2
108	19	232	191	4	980	147	161	410	74
32	3	37	18	1	64	7	11	87	6
69	16	103	66		152	7	37	69	11
14	3	12	25	1	59	9	9	49	5
12	7	39	52	2	109	3	14	26	9
64	21	766	1, 320	16	4, 972	573	145	757	219
64	4	207	456	22	267	26	25	203	19
208	96	2, 077	2, 781	43	6, 279	804	519	1, 634	649
61	11	209	156	1	634	43	76	141	42
9	4	35	16		60	9	21	27	7
81	38	596	850	25	3, 568	417	311	897	214
37	13	142	100	3	554	118	69	362	24
43	10	78	124	4	257	15	67	167	29
72	46	770	1, 359	21	4, 365	513	312	1, 041	242
12	4	53	114	2	211	6	17	55	7
25	3	49	78	1	308	74	35	44	11
15	3	21	19		55	2	19	23	6
27	14	175	281	2	971	183	63	180	31
172	23	459	596	12	1, 866	442	241	1, 322	85
40	7	82	98	2	205	26	19	183	17
3	4	21	18		55	1	6	15	5
90	15	255	306	12	740	119	109	326	46
104	18	255	315	4	640	113	108	361	51
5	3	39	38	5	591	137	30	105	12
49	38	257	277	20	935	79	108	224	67
11	1	12	12		72	12	7	77	5
323	18	369	173	13	169	19	110	256	52
2	4	4	245	1	369	1	33	19	3

Source: National Register of Scientific and Technical Personnel, 1960

American Science Manpower 1960 (Washington: National Science Foundation, 1962) pp. 72-3.

TABLE XXII

SCIENTISTS BY FIELD OF SCIENCE PER 100,000 POPULATION

1960 Data

	United States	Mo.	Ark.	Kan.	Ill.	Tex.	Calif.
Total	112	80	46	94	104	107	144
Agri. Sci.	1	4	11	5	3	4	7
Biol. Sci.	13	10	5	3	14	7	14
Med. Sci.	2	2	1	1	2	1	2
Psychology	8	3	3	10	9	4	14
Earth Sciences	10	4	6	18	4	36	12
Meteorology	2	2	1	1	2	2	3
Geography	1	--	--	--	1	--	1
Mathematics	9	5	2	7	7	5	16
Physics	12	4	1	5	9	6	22
Astronomy	--	--	--	--	--	--	--
Chemistry	29	23	9	17	36	19	27
Chem. Engin.	4	3	1	2	3	5	4
Sanitary Engin.	3	4	2	3	3	2	3
Other Engin.	10	9	3	9	7	14	9

Sources: National Science Foundation, American Science Manpower 1960, Washington 1962.

U.S. Bureau of the Census.

* * * * * *

physicists per 100,000 persons employed in California were much larger ratios than the comparable U.S. averages (Table XXII).

Although physics and mathematics were two rapidly growing fields of science during the period of rapid R&D expansion, only Arkansas, among the six states studied, had a lower per capita concentration of scientists in these two fields than did Missouri. Nevertheless, one should recall that these two fields were the only ones observed to increase relative to the others in the industrial laboratory personnel requirements in Missouri laboratories during the period.

A Detailed Analysis of Missouri's Scientific Resources

The type of noneducational organizations employing the scientific talent further explains the type of scientific activity in Missouri. These more detailed data describing the scientific-talent resources in Missouri are available from the surveys by the National Research Council.[45] These data enable a tabulation of industrial laboratory data by field of science and by owner of laboratory, and a subsequent comparison of the personnel resources of Missouri's industrial laboratories to the industrial laboratories in the comparative states.

Of the 92 industrial laboratories listed for Missouri in the 1960 survey by the National Research Council, 78 had been established by profit-making organizations. Of this group, the majority, 52 laboratories, declared that they performed research for owners of the laboratory only. Only 18 laboratories owned by profit-making organizations stated that they performed research or consulting for others on a fee or contract arrangement.

The 78 company-owned laboratories identified in this survey in Missouri employed 740 (77 per cent) of the employees identified as scientists, 2,333 (97 per cent) of the engineers, 1,670 (96 per cent) of the technicians, and 2,427 (94 per cent) of the auxiliary personnel (Table XXIII). Clearly, they were the dominant performers of research among the industrial laboratories in Missouri. However, in some of the other states studied the company laboratories employed an even larger share of the scientists. The company-owned laboratories in California employed 88 per cent of the scientists listed. The company-owned laboratories in Kansas employed 84 per cent of all of the scientists, and in Texas 79 per cent.

Thirteen of Missouri's laboratories listed in 1960 were independent laboratories. All but one of these undertook research projects for others on a fee or contract basis. Only one Missouri laboratory, the Midwest Research Institute of Kansas City, was identified by this survey as a nonprofit laboratory.

The predominant fields of science in company-owned industrial laboratories in Missouri illustrate the research activity undertaken, and thereby, demonstrate

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[45] National Research Council, op. cit.

TABLE XXIII

INDUSTRIAL LABORATORY PERSONNEL

By Profession and Owner of Laboratory Missouri, 1960

	Company Labs.	Independent Labs.	Non-profit Labs.	Total
Number of Respondent Labs.	78	13	1	92
Bacteriologists and Biologists	59	21	8	88
Chemists	425	81	70	576
Physicists	94	1	15	110
Mathematicians	93	3	14	110
Medicial Personnel	23	1	0	24
Metallurgists	41	6	0	47
Other Scientists	5	0	0	5
Total Scientists	740	113	107	960
Engineers	2,333	14	51	2,398
Technicians	1,670	44	20	1,734
Auxiliaries	2,427	67	85	2,579
Total Laboratory Personnel	7,170	238	263	7,671

Source: National Research Council, Industrial Laboratories of the United States, 11th ed. Washington, 1960.

* * * * * *

whether or not the industrial laboratories, by classification of owners are in the fastest growing areas of R&D. As mentioned previously, physicists and mathematicians each represented 1.4 per cent of total personnel employed by these laboratories in Missouri. Although 77 per cent of all scientists identified by this survey were employed by company-owned laboratories, these laboratories employed an even larger per cent of physicists and mathematicians. Company-owned laboratories employed 85 per cent of the physicists and 84 per cent of the mathematicians identified by the respondent laboratories in the 1960 survey in Missouri (Table XXIV). Midwest Research Institute alone employed 14 per cent of the physicists and 13 per

TABLE XXIV

PER CENT SCIENTISTS BY FIELD OF SCIENCE AND OWNER OF LABORATORY

Missouri, 1960

	Company Labs.	Ind. Labs.	Nonprofit Labs.
Bacteriologists and Biologists	67	24	9
Chemists	74	14	12
Physicists	85	1	14
Mathematicians	85	3	13
Medicial Personnel	96	4	--
Metallurgists	87	13	--
Other Professionals	100	--	--

Note: Sums may not equal 100 per cent because of rounding off.

Source: National Research Council, Industrial Laboratories of the United States, 11th ed. Washington: 1960.

* * * * * *

cent of the mathematicians which encompassed most of the remainder employed in Missouri in that year.

The 13 independent laboratories listed for Missouri in 1960 employed 12 per cent of the scientists, and as in the case of the company owned laboratories, their personnel listings describe their research activities. Twenty-four per cent of the biologists and bacteriologists, 14 per cent of the chemists, and 13 per cent of the meteorologists identified by this survey in Missouri were employed by the independent laboratories. On the other hand, they employed less than 1 per cent of the total physicists and less than 3 per cent of the total mathematicians listed among the Missouri respondents.

TABLE XXV

INDUSTRIAL LABORATORY PERSONNEL BY PROFESSION

Per Cent of Total, 1960

	Mo.	Ark.	Kan.	Ill.	Tex.	Calif.
Bacteriologists & Biol.	1.1	--	9.8	2.2	.4	.5
Chemists	7.5	17.1	3.3	10.8	11.1	5.7
Physicists	1.4	--	3.3	1.6	4.5	3.8
Mathematicians	1.4	--	3.3	.7	1.7	2.4
Medical Personnel	.3	--	.5	.4	.3	.3
Metallurgists	.6	--	1.1	1.4	.6	.8
Other Professionals	.7	--	.6	2.9	3.2	2.2
Total Scientists	12.9	17.1	24.0	20.1	21.9	15.5
Engineer	31.2	32.1	47.3	24.1	28.5	27.3
Technicians	22.5	25.7	11.9	25.1	17.7	24.9
Auxiliaries	33.5	25.0	16.8	30.5	33.9	32.2

Note: Sums may not equal 100 per cent because of rounding off.

Source: National Research Council, Industrial Laboratories of the United States, 11th ed. Washington: 1960.

* * * * * *

Thus, the company-owned laboratories clearly were the principal employers of scientists in Missouri as reported in the 1960 survey. Furthermore, the company laboratories had hired more than a proportional amount of the engineers, physicists, and mathematicians, which were the fields showing the large national increases during the period and the only fields showing a proportional increase in Missouri over the period.

The data from industrial laboratories in Texas and Illinois illustrate an emphasis very similar to that evident in the Missouri industrial laboratories (Table XXV).

However, as one could expect from the R&D contract and employment data already studied, California laboratories emphasized somewhat different areas of research. Although the company-owned laboratories employed 89 per cent of all of the scientists listed, they employed 79 per cent and 81 per cent of the mathematicians and physicists respectively. On the other hand, the independent laboratories employed 17 per cent of the mathematicians and 15 per cent of the physicists.

III. GEOGRAPHICAL DISTRIBUTION OF SCIENTIFIC TALENT IN MISSOURI

The available data of scientific talent in different locations in Missouri are very sparse. Nevertheless, by piecing together the existing data the geographical distribution of scientific talent in Missouri can be indicated. This distribution of talent can be used as a measure of the location of R&D activity. Inasmuch, as the scientific activities appear relatively low for Missouri these data can indicate whether or not this is the case throughout the state.

The relative size of the scientific communities in Kansas City and St Louis are available from NSF data, and they both appear smaller than their population size might indicate. St. Louis, the ninth largest city in the U.S. by population, was sixteenth in total scientists in 1960 with 1,749 scientists.[46] Kansas City, the twenty-second largest city in the U.S. by population, with 748 scientists was not among the largest 25 cities in population of scientists.[47]

Of the 92 industrial laboratories identified by the 1960 survey of the National Research Council in Missouri, 51 were located in the St. Louis area, 32 in the Kansas City area, and only 9 in the remainder of the state(Table XXVI).[48] These data showed marked differences in the R&D activities undertaken in these industrial laboratories in the two cities in spite of their proximity.

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[46] National Science Foundation, Scientific Manpower Bulletin, No. 18, November 1962, p. 1.

[47] Ibid.

[48] National Research Council, op. cit., The Metropolitan figures apply to the Missouri portion of the St. Louis and Kansas City standard metropolitan statistical areas.

TABLE XXVI

INDUSTRIAL LABORATORY PERSONNEL BY PROFESSION AND LOCATION

Missouri, 1960

	Total	St. Louis	Kansas City	Other
Num. of Respondent Labs.	92	51	32	9
Bacteriologists & Biol.	88	33	45	10
Chemists	576	276	268	32
Physicists	110	75	34	1
Mathematicians	110	81	28	1
Medical Personnel	24	20	3	1
Metallurgists	47	32	13	2
Other Scientists	5	3	1	1
Total Scientists	960	520	392	48
Engineers	2,398	1,929	429	40
Technicians	1,734	1,237	449	48
Auxiliaries	2,579	1,920	626	2,579

Source: National Research Council, *Industrial Laboratories of the United States,* 11th ed. Washington: 1960.

* * * * * *

For example, marked differences were evident in the total scientist to engineer ratios in the laboratories of the two cities. Although St. Louis employed 54 per cent and Kansas City 41 per cent of the scientists in Missouri in 1960, St. Louis employed 80 per cent and Kansas City 18 per cent of the total number of engineers listed.

In addition, there was a marked difference between the fields of science emphasized in the data from the two cities; but, in some cases the source of this difference in the fields of science was readily identifiable. For example, the scientific talent employed by the McDonnell Aircraft Corporation in St. Louis affected greatly the

Missouri and the St. Louis totals. McDonnell not only employed 16 per cent of the total scientists listed in Missouri in 1960, but McDonnell also was the employer of 60 per cent of all physicists and 59 per cent of all mathematicians as identified by the respondent laboratories in Missouri in 1960.

The available NSF data (Table XXVII) concerning the location of scientists in Missouri can be compared meaningfully to the National Research Council data. For the most part, the NSF data corroborate the geographical distribution of scientists illustrated by the respondent laboratories. For all employers, more than one half the total scientists in Missouri in the fields of chemistry, engineering, biology and physics were employed in St. Louis in 1960.

Some indication of the geographical location of the various types of employers is also available from the NSF data (Table XXVIII). Of all scientists employed in educational institutions, 592 were employed in Kansas City and outstate Missouri, and 491 were employed in St. Louis. Of the scientists in industry, business, or self-employed, 962 were employed in St. Louis and 503 in the remainder of the state.

Seventy-five (68 per cent of the total in Missouri) physicists were employed in St. Louis in industrial laboratories and 34 (31 per cent) in Kansas City. Eighty-one (74 per cent of the total in Missouri) mathematicians were employed in St. Louis in industrial laboratories and 28 (25 per cent) in Kansas City. There were 45 (51 per cent of the total in Missouri) bacteriologists and biologists employed in Kansas City and 33 in St. Louis.

TABLE XXVII

TOTAL SCIENTISTS IN MISSOURI AND ST. LOUIS

By Field of Science, 1960

	Kansas City and Outstate Missouri	St. Louis
Agricultural Sciences	171	18
Biological Sciences	154	263
Psychology	121	114
Earth Sciences	126	60
Meteorology	78	30
Geography	5	14
Mathematics	118	114
Physics	94	97
Astronomy	0	4
Chemistry	362	618
Sanitary Engineering	119	42
Other Engineering	232	325
Other Specialities	24	50

Sources: National Science Foundation, Scientific Manpower Bulletin, No. 18, November 1962.

National Science Foundation, American Science Manpower 1960, Washington: 1962.

TABLE XXVIII

TOTAL SCIENTISTS IN MISSOURI AND ST. LOUIS

By Employer, 1960

	Kansas City and Outstate Missouri	St. Louis
Educational Institutions	592	491
Federal Government	233	163
Other Government	148	41
Military and Public Health Service	50	18
Nonprofit Organization	111	45
Industry, Business or Self-employed	503	962
Other, Including no Report	51	29

Sources: National Science Foundation, Scientific Manpower Bulletin, No. 18, November 1962.

National Science Foundation, American Science Manpower 1960, Washington: 1962.

CHAPTER VI

CONCLUSIONS RELEVANT TO SCIENTIFIC RESEARCH IN MISSOURI

From the theoretical appraisal of the performance of scientific research in a regional economy, and from the sparse, diverse data that relate scientific research to the Missouri economy used in this study, the conclusions can be only general. These conclusions can be summarized in two general statements:

> (1) Despite the dominance of an individual state industrial contractor, McDonnell Aircraft Corporation, in space research, there appears to be little overall strength in research and development at this time in Missouri.
>
> (2) If a viable scientific research industry is sought for Missouri, the role of catching up indicates that a considerable quantity of scientific resources, with some specific characteristics, must be made available.

The absence of overall R&D strength in Missouri was evident from the data studied. Evidence of R&D strength was lacking for nearly all of the regional R&D indicators studied. For the most part, the leading manufacturing industries in Missouri are not ones which are currently heavy performers of R&D in the U.S. as a whole, however, the transportation equipment and chemical industries may be exceptions to this in Missouri. The comparison of personnel data for Missouri and selected states indicated that Missouri has a relatively low concentration of scientific talent employed in research laboratories. The comparison indicated also that there is a relatively low concentration of scientific talent employed in Missouri's educational institutions, and that there is a relatively low concentration of Ph. D. scientists graduated in Missouri. These low personnel observations prevail also for the most rapidly expanding fields of science.

Missouri emerged considerably stronger from a comparison of federal prime R&D contract data. This strength can be traced directly to the sizable space prime research contracts awarded, and the importance of this R&D activity to the state economy is obvious. However, the available subcontract data clearly indicate that space research is not strong throughout the state. Other Missouri organizations definitely are not significant performers of federally sponsored space R&D. Additionally, the federal prime military research contracts to Missouri organizations have been declining in recent years.

Given that the overall R&D based industry in Missouri is relatively low, then the theoretical structure of R&D performance illuminates some general preconditions if a relative increase of R&D is a goal for Missouri.[49] Indeed, this study cannot and should not judge whether Missouri's resources, public or private, should be devoted to developing a cost-competitive, self-sustaining R&D performing industry. That decision requires an appraisal of all alternatives available to Missouri resources. However, the observations in this study of R&D locational determinants isolated some factors applicable to expanding regional R&D performance if such a development is desirable.

The winning of federally sponsored R&D and the undertaking of industrial R&D generates the regional demand for scientific resources. If this increase of demand is forthcoming because of expanding R&D undertakings from either sponsorship, there are several locally supplied resources that would generally aid the development of a viable R&D oriented industry. For example, scientific research and scientific education were shown to be related, and presumably expanded scientific education will aid the development of regional R&D. However, the high spatial mobility of scientists causes one to look beyond the educational institution as a source of scientific talent to explain this relationship. The characteristics of much R&D location provided a further basis for directing regional scientific education if developing a regional R&D industry is an accepted goal. The indivisibilities which cause the clustering of many R&D projects is this basis. A warranted expansion of the lumpy inputs of R&D, high-quality scientists and research capital equipment, in educational institutions will aid the regional R&D expansion. The overall expansion of scientific talent probably will generate technological external economies available to other research projects in the region.

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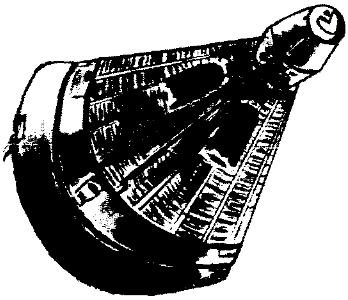
[49] This statement implies an increase relative to the R&D expansion of other states.

Despite the mobility of scientists, persons with the skills of technicians probably are not so mobile, and technician skills which are immobile must be supplied locally. Therefore, a supply of less mobile persons with demanded technician skills must be available for regional R&D expansion.

Thus, if Missouri establishes a strong scientific research performing industry as a state goal, a considerable quantity of scientific resources must be attracted to the state. This may mean acquiring resources which actually would be more productive in another locale, and in these cases Missouri's catching up effort is at a market disadvantage. Finally, there is no guarantee of success. However, the lack of transfer costs which exists in R&D implies that there is a possibility of developing a stronger R&D performing industry in Missouri.



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