

Cambridge University Press

978-0-521-11570-4 - Scientific Productivity: The Effectiveness of Research Groups in Six Countries

Edited by Frank M. Andrews

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## Part 1. Introduction

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# 1 The International Comparative Study on the Organization and Performance of Research Units: an overview

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## 1. Research on research and development

The need for an international and cross-cultural study of the performance-effectiveness of scientific research and experimental development (R & D) arose during the early 1960s out of Unesco's program of assistance in the field of science policymaking and research organization. Although the industrialized nations witnessed an exponential growth of R & D outlays during that period, and did not worry too much about the effectiveness of their ongoing research activities, nations that had barely reached the stage of political independence increasingly turned to Unesco for advice on how to reap maximum developmental benefits from the limited scientific and technological research capabilities that many of them had inherited from colonial times. Increasing their expenditures for R & D often was economically unfeasible, or exceeded the absorptive capacity of their available scientists and technologists.

So, the idea of taking a hard look at the performance-effectiveness of national R & D systems naturally came to the fore.

Since 1971, an International Research Team (IRT) of natural scientists, social scientists, and research managers has worked together with Unesco program specialists and outside consultants in order to: (1) delineate the problem and its possible approaches, (2) develop a well-defined methodology of work, (3) test this methodology in several countries with well-developed

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national R & D systems (six volunteer countries of Europe), and (4) propose modifications of the methodology based on results of these tests.

Although Unesco's initial motivation arose from the practical need of enhancing the performance of R & D through the improvement of its managerial environment and organizational setting, the International Research Team soon made the decision to go far beyond a mere testing of the traditional "rules of thumb" that have until now governed the planning, management, and logistics of scientific and technological research. The group committed itself to the ambitious hope of significantly extending a new field of research: the scientific management of R & D.

The methodological path chosen by the International Research Team was based on the procedures of modern empirical social science, and included hypothesis formulation, construction of measuring instruments, collection of data in standardized ways from large and heterogeneous populations of R & D personnel, and subsequent multivariate analysis of these data. This approach was well suited to the two major goals of the undertaking: description and prescription. With respect to *description*, it seemed important to develop a methodology that could broadly and accurately describe the current state of a complex R & D system. With respect to *prescription*, it was intended that the methodology, when suitably applied, would yield new knowledge of basic scientific relationships that could help guide science policymakers and R & D managers toward more effective and efficient ways of organizing research and development activities.

The purpose of this collective book is to present the international readership interested in the management of R & D with some of the scientific and methodological results that have emerged in the recent work of the International Research Team. The book is based on the analysis and interpretation of data collected in Round 1 of the International Study – the first major application of the methodology in six European countries.

In presenting the first results of the study in this book, the International Research Team is fully conscious of the fact that the new field of "research on research" is at an early stage of development. Fortunately, the way in which the International Study was designed permits an open-ended deployment of further effort, both by Unesco and by the international scientific community.

A separate methodological guidebook, describing in detail the recommended procedures for subsequent applications of the methodology developed by the International Research Team, is

also being published by Unesco.<sup>1</sup> This guidebook is addressed to science policymaking bodies and research institutions of those countries that may wish to launch—or to repeat—such a study on the performance of research units either on the whole of its national R & D system, or on a subset of research units selected therefrom.<sup>2</sup>

An attractive possibility for such future surveys is to design them right from the start to be fully compatible with the methodology that has been adopted by Unesco.<sup>3</sup> This permits the gradual building up of international, accessible, and cumulative archives, the *raison d'être* of which lies in the possibility of making international comparative analyses on the performance-effectiveness of research units as related to the organization of R & D and to the managerial practices adopted by different countries. It may also lead to the development of new theoretical concepts and approaches concerning the performance of research, the validity of which could be tested by reference to the archived data.

## 2. Some distinctive features of the International Study

Distinctive, and in some ways original, features of this Unesco-coordinated International Comparative Study on the Organization and Performance of Research Units include the following:

1. In harmony with the line of thought that evolved in the early 1940s and culminated in new conceptual approaches to human activity (such as control, communication, and cybernetics), it was decided to recognize purposeful *systems* as the new organizing concept of science-in-the-make, that is, of R & D.

2. Goal-seeking systems were defined as a set of interrelated elements that can display choice of either objectives or resources (or both). For the purpose of this study, Unesco selected—for a variety of reasons that later turned out to be generally valid—the lowest formal organizational grouping of research scientists and technicians—that is, the *research unit*—as the basic structural element of R & D systems. It was also decided that the R & D systems would be artificially limited, because of purely policy-making and managerial considerations arising from the principle of national sovereignty, to the set of research units belonging to a given nation, that is, the focus would be on the *national R & D system* (or a selected subset therefrom). This, of course, does not deny the essentially international character of modern science—and in some respects of technology also—whose basic characteristic of universality remains firmly founded on evidence arising out of verifiable experiment and observation.

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3. The boundaries of the system – short of a worldwide managerial utopia – have thus been chosen to coincide geographically with sovereign nation-states, not so much from the point of view of the objectives of the system, as from that of its resources in manpower, finances, information, and material base, which together form its manageable input.

4. As a consequence, Unesco contracted the appropriate science and technology policymaking organizations of the six European countries that volunteered to participate in the International Comparative Study. The contractual agreements included five basic conditions:

(a) that the contracting organization would select and finance the work of a national research team responsible for the scientific aspects of the study; and that the national team leaders of the six countries, together with the responsible program officers of Unesco and the international consultants, would form the International Research Team (IRT) entrusted with the design and management of the study;

(b) that a sample of approximately 200 research units per country (roughly 1,000 research scientists and technicians per country) would be approached by the interviewers of the national research teams in order to collect their answers to the international survey questionnaire, which was prepared under the aegis of Unesco with the assistance of front-ranking specialists in modern survey research, of scientific researchers, and of research managers;

(c) that the replies collected from individual scientists and technicians would be treated in complete confidentiality, in particular with respect to the hierarchy of the institutions to which they belonged and to the sponsoring science and technology policymaking organization of the country concerned;

(d) that the members of the International Research Team would adopt a common methodological approach for data management, statistical calculations, and multivariate analyses to be performed on the collected data; and

(e) that a complete set of *anonymized* data (cleaned to prevent the identification of individual respondents and single research units) would be made generally available through Unesco by depositing them, after an embargo period of two years, in archiving centers that volunteered for the task and were agreed upon by the International Research Team.<sup>4</sup>

5. The two-year embargo period on the survey data allowed the members of the International Research Team to analyze their own national data and to compare them with those of the other

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participating countries. This book, based on these explorations, is thus a collection of selective and mutually complementary analyses prepared by the members of the International Research Team.

6. The publicly archived survey data will allow further research on the performance-effectiveness of R & D by sociologists of science and R & D management specialists throughout the world. Moreover, national research teams belonging to countries that subsequently join the International Comparative Study under contractual association with Unesco will have at their disposal a set of baseline data permitting immediate national and international comparisons; they, in turn, will contribute their national data to the growing international archives of the study.

7. Given the rather modest scale of previous empirical research on R & D, Round 1 of the International Study is distinctive for both the magnitude of its data base and the breadth of its international perspective. With information from approximately 10,000 respondents regarding characteristics of over 1,200 research units in six nations, the study considerably extends the scope of empirical research on the organization and performance of R & D systems.

8. Moreover, the structure of the data (and of the data files) is such that *multilevel* analyses are both useful and feasible. Because the data were collected from several members of the same organizational entity—the research unit—and because many of the specific pieces of information concern that entity, it is logical to consider the data at both the respondent level and the unit level. Although much of the previous research on R & D processes and on R & D management has focused on individual scientists and engineers, sometimes within a laboratory setting, the conceptualization of R & D as the *collective* activity of a particular group has been much less common.

### 3. Theoretical and practical foundations of the study

The theoretical and practical foundations of the approach adopted for the International Comparative Study derive from several sources. These include: (1) the theoretical perspectives of cybernetic modeling and systems analysis; (2) the concepts and findings from previous research in the fields of organizational psychology, sociology of science, sociology of organizations, creativity, and research on R & D; and (3) the experience gained from the continuing efforts of Unesco's Division of Science and Technology Policies to respond to the needs of national policy-

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making, planning, and program budgeting in the field of science and technology.

The study seeks to identify and assess the importance of numerous organizational, environmental, and other input factors that influence the performance-effectiveness of research units. Furthermore, critical to the effectiveness of national R & D systems as a whole are such questions as the following, which the study also seeks to address: (1) How do the basic structural elements of national R & D systems, that is, the research units, interact and work together, both within and across the boundaries of these systems? (2) What is the role and influence on the performance of research units of the higher organizational echelons within national R & D systems—such as the institutions and organizations to which the research units belong, and the national policymaking bodies concerned with science and technology? (3) What are the significant elements in human behavior and perception of situations that affect or reflect creativity and efficiency in the performance of R & D? (4) How do research units respond to the goals and purposes they are supposed to serve, or to the functions they are expected to perform?

Much preparatory work went into sharpening up the concepts underlying the performance and effectiveness of research units. Policymakers and planners dealing with R & D at all levels of government or private enterprise are naturally interested in maximizing output for given levels of input. But this cannot be reduced to simple economic cost–benefit analysis, as has been clearly shown during the past decades. Other factors nowadays increasingly come to the foreground when evaluating the performance of research units, such as product quality and originality, the applicability and social impact of R & D results, and—last, but not least in the minds of research scientists—the professional recognition and prestige accruing from breakthroughs in science or technology. Taken together, these perspectives have suggested a broader assessment of research-unit performance, and hence the study has explored total performance-effectiveness from a broad range of qualitative as well as quantitative reference points.

As is described in greater detail in Chapter 2, the dimensions of the criteria of effectiveness include recognition, extent of applications, social utility, general contribution to scientific or technological knowledge, plus effectiveness measures concerning R & D proper, training, and the management of the research work itself. Actual counts of such R & D products as books, articles, patents, and prototype devices are also available.

The social and organizational factors assessed by the study that

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might influence or relate to the performance of research units can be grouped into the following broad categories: R & D activities; research methods; scientific exchanges and contacts with other units; evaluation methods; planning of the work and choice of research themes; availability of resources; amounts and patterns of influence; supervision; remuneration and career advancement; working climate; and numerous demographic variables such as age, experience, staff size, staff turnover, institutional setting, and scientific discipline. The analytic possibilities posed by this rich array of information are vast, and the analysis-oriented chapters of this book, which provide a first exploration of the material, certainly do not exhaust its potential.

**4. Some general findings from the study**

Although this is not the place to present detailed summaries of statistical results, it may be useful to briefly sketch some of the general trends in the analyses that have been conducted to date. The kinds of trends we wish now to emphasize are those that emerge when one synthesizes the results of many individual specific analyses. These specific analyses are described in subsequent chapters of this book or in other studies for which examples will be cited.

One of the most important general findings of this International Study is that the R & D process seems to be responsive to *similar* psychological, social, organizational, and structural factors whatever the particular national setting (among these six countries) in which research units happen to be located. Although significant differences appeared in the survey data between the participating countries as regards R & D management practices, organizational settings, and climate of work, the *relations* that emerged between these factors and the performance of research units tend to show the same directional patterns. Furthermore, the major relationships observed in the present data from European countries tend to be consistent with findings from previous research on R & D, most of which has been conducted within the United States of America.<sup>5</sup> This cross-national replicability of major trends is, we believe, of major significance in that it opens the way for the development of a basic science of research-on-research that can be widely and generally applied for science policy purposes and the management of R & D.

A second general finding has to do with the criteria of R & D performance. The study confirms the International Research Team's expectation that the performance-effectiveness of re-

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search units is a multidimensional concept, encompassing a variety of distinct aspects. Although it is tempting to think of research units as falling somewhere along a simple good–bad or effective–ineffective dimension, the data show that this is a much too simplistic conception. On the contrary, units that “look good” by some criteria may—or may not—rate highly on other criteria.<sup>6</sup> Furthermore, the factors that predict to high levels of certain kinds of effectiveness are frequently different from the factors that predict to high levels of other aspects of effectiveness. Of course, this is not to say that all research units “average out” to be equally effective. Rather, it leads to the conclusion that if one wants to understand and/or enhance the performance of R & D units, one has to be clear about the particular aspects of performance that are of primary concern.

A third general finding has to do with the kinds of factors that showed notable relationships to various aspects of effectiveness. These include sociological characteristics (e.g., a person’s position in the social system of the research unit), organizational characteristics (e.g., the size of a research group), social-psychological characteristics (e.g., communication between research scientists or between research units), psychological characteristics (e.g., scientists’ morale, motivation, and satisfaction with supervision and with resources), and various characteristics of the way the technical work itself is planned, configured, and conducted.<sup>7</sup> Whereas the demonstration of a relationship between factors such as these and certain aspects of performance does not prove that a causal connection exists, the identification of such relationships opens up numerous possibilities for ways in which research-unit effectiveness, *might* be enhanced through improved management techniques.

A fourth general finding, related to what has just been described, is the rather consistent and somewhat surprising *absence* of notable relationships between indicators of economic or physical resources and the effectiveness of research units. The reasons for this lack of relationship are not completely understood, but it seems quite clear that once the resource base is sufficient to keep a research unit viable (and hence eligible for inclusion in a study such as this one), there is no necessary linkage between material endowment and quality of research performance. In short, a unit can be poor but make great contributions—or be rich but ineffective. Although no one expected a tight linkage between resources and quality, the apparent absence of any linkage, if this continues to appear in further analyses, holds great import for science policy.<sup>8</sup>

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A fifth general finding is of a more methodological kind. Although many notable relationships have already been identified in the data from the International Study, almost without exception they tend to be of rather modest strength. Several considerations converge to suggest that one should *not expect* massively strong relationships (and should be highly suspicious of any that appear) between any single characteristic of research units and performance: (1) The effectiveness of research units is almost certainly determined by *many* factors; hence, no one factor by itself will account for a large part of the variation between units in effectiveness. (2) The actual data about research-unit characteristics and performance provide only imperfect indications of the true characteristics and performance levels. There is no reason to believe that the quality of measurement in the International Study is unusually poor – on the contrary, the use of standardized instruments and data-collection procedures, and of broadly based performance indices (described in Chapter 2), almost certainly enhanced the quality of the measures. Nevertheless, it would be naive to assume that the data are totally without error or bias.<sup>9</sup> (3) The performance measures developed by the International Research Team probably depend only *partially* on the organizational, managerial, and psycho-sociological variables that have been assessed in the present study. Some members of the International Research Team gradually developed the feeling that independent variables, differing in kind from those tested during the Round 1 surveys, played a significant part in the performance-effectiveness of research units. These factors are probably linked with the cognitive structure of modern scientific thought and are usually somewhat loosely referred to under the concept of intuition. In any event, such a line of research seems worthy of further exploration, with appropriate and distinct methodological tools.

## 5. Possible misinterpretations

Readers and those who analyze these data in the future should be cautioned regarding possible misinterpretations of statistical results. The modest size of the important relationships, just discussed, combined with several subtle aspects of the structure of the data, require considerable sophistication when dealing with this material. The following points should be borne in mind:

1. The finding of a statistical relationship between X and Y (e.g., morale and performance) does not prove that X causes Y. Although this might be the case, it is also possible that Y causes X, or that both X and Y are influenced by other factors.