Offprints From
Toward A Metric Of Science:
The Advent of Science Indicators
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Introduction

The Editors

Measure is a quality much admired in the abstract. However, our civilization values the ineffable as well as the quantifiable, finding utility in the tensions between such polar opposites. Specific attempts to measure particular things are, therefore, liable to encounter an ambivalent response. It has been over two millennia since Horace decreed, "There is measure in all things." Scholars uncomfortable with his perception have not displayed undue alarm. After all, they may effortlessly reach back a further four centuries and cite Protagoras' antithetical judgment, "Man is the measure of all things."

CONTEXTS OF THE SCIENCE INDICATOR REPORTS

The Horatian dictum knows its greatest successes in the field of natural science. Even there, the adoption of quantitative modes has not been especially rapid, complete, or devoid of controversy. Nonetheless, measurement has come to be perceived as vital to the character of

See p. iii of *Science Indicators 1972* (U.S. Government Printing Office, Washington, D.C., 1973). This volume will be referred to as *SI-72* throughout the present essays. However, our focus will not be on specific problems in the volume, but rather on those generic to the enterprise exemplified in *SI-72* and its successors (e.g., *Science Indicators 1974*, U.S. Government Printing Office, Washington, D.C., 1975).

the scientific enterprise and critical for its success. Because science and society are of a piece, it is not surprising that attempts to extend a metric from the natural to the social sphere and even to measure science itself have a rich, complex, and variegated history. In announcing its intention that the publication of "science indicators" become a regular part of its activity, the National Science Board was—whether consciously or not—placing itself within that history.

On a more immediate level, the National Science Board was also taking the critical step that linked two important intellectual movements of the past several years. The two movements in question—previously quite separate with respect to participants, ideas, and organization—are those of social indicators and of "unease with science." An example of the latter is in Theodore Roszak's *The Making of A Counter Culture* (1969), and its most central manifestation is in the Summer 1974 issue of *Daedalus*. The former has given rise to the impressively presented document entitled *Social Indicators 1972*. Much about the present state of knowledge of science indicators, about its strengths and weaknesses (both actual and potential), and not least, about the particular format of this book of essays, can be best understood in the light of this "disjuncture between," then "union of" two disparate intellectual currents.

The reality of social indicators, if not the neologism, has long been familiar in the Western world. William Petty's seventeenth-century exercises in *Political Arithmetick* come quickly to mind. Yet as a sustained intellectual movement, systematic concern with social indicators may be located primarily within the United States in the past several years. A variety of functions can be discerned from the burgeoning literature of that movement. Among these are:

1. Emulating the success achieved by economists in fashioning quantitative measures of significance to policy (e.g., unemployment, inventory accumulations, GNP, and allied "economic indicators")
2. Finding less ambitious, more empirical approaches to social science "problem solving" after the disappointed hopes of the Johnson years
3. Providing a means of discrimination within, and intellectual control of, the burgeoning information flows of "applied social science" (while creating cognitive forms appropriate to the social discourse of an expanded policy-forming apparatus)

In the nature of the case, science indicators are themselves social indicators and as such must be at least partially assimilable to the language, procedures, and assumptions around which the social indicator movement has taken shape.

A DEFINITION AND CLASSIFICATION OF SCIENCE INDICATORS

A definition is appropriate here. *Science indicators are measures of changes in aspects of sciences.* The purpose of this definition is to be heuristic, not final—a means of opening rather than closing discussion and debate. The definition suits the mood of this volume and the present state of "science indicator studies." That mood is one of disciplined eclecticism.

Science indicators will be produced, compared, and consumed by groups and individuals having varied priorities, programs, and preoccupations and dealing with a plurality of sciences. A rigid definition or an unswerving goal would have no great value (as has been slowly learned by those working in the broader field of "social indicators"). Eclecticism is as necessary as it is useful to the measurer of scientific change. Without it, there not only would be tedious wars between zealous factions but also a failure to take advantage of known, promising avenues available for the generation of measures of science. Those avenues are so various that we cannot hope for their being encompassed within any systematic, general theory of scientific change, at least in the foreseeable future.

To be useful eclecticism must be disciplined—that is, because a catholic, flexible, empirical approach is needed at this particular stage of understanding, it does *not* follow that "all measures are equal" and "anything goes" in our efforts to develop a better quantitative understanding of those processes by which science and society mutually condition each other's growth and transformation. Discipline is needed at every stage if we are to select for attention the most rewarding research sites and enable "science indicator studies" to fulfill their potential as a first example of possibilities in the *applied* historical sociology of scientific knowledge.

By way of illustration of the need for discipline in approaching science indicators, it is fruitful to reflect upon some of the distinctive categories into which such indicators can be grouped. The most important distinction is between *explicit* and *tacit* indicators. As the name suggests, *explicit science indicators* are measures of change in science, developed in detail appropriate to their context. We may further distinguish between the *discovery* and *invention* of such explicit science indicators. That the great bulk of work on science indicators in *Science Indicators 1972 (SI-72)* belongs in the "explicit-discovered" category of indicators then becomes apparent. The reasons for this are not far to seek. In the comparatively recent past many agencies, principally but not exclusively government agencies, have for their own purposes compiled annual and short-run statistical series on, for example, research expenditure, patent production, the number of Ph.D.'s awarded. Such measures are today routinely and unobtrusively produced by the system. Their use as indicators awaits only their discovery.

To depend entirely on such "explicit-discovered" indicators would be to

commit the field of indicator studies to an interim empiricism of a kind apparent in *SI-72*. Thus our approaches should extend at least to "explicit-invented" indicators. Such indicators—measures that we deliberately set out to construct—will usually be "theory-laden" measures of normative interest. Examples of such explicit-invented indicators might be the citation/publication ratios of scientific literature for different fields and countries or (an as-yet-uninvented explicit indicator) the percentages of university presidents possessing Ph.D.'s in a given field of science. Finally, we can only mention the two other possible categories—implicit-invented indicators and implicit-discovered indicators—leaving their fuller discussion to some other occasion.

Enough has been said to suggest that only within a rich framework of historical and sociological understanding can an effective stance toward science indicators be developed. That stance must cope with the varieties in type and use of possible indicators and must also steer between a spurious objectivism ("the facts dictate . . .") and the sort of despairing subjectivism fashionable in the recent past. To recognize the social embeddedness of a social construct such as "science indicators" is at least to open the way toward a more distanced, dispassionate analysis. Necessary perspective may be achieved by philosophical, psychological, sociological, or historical means. All are discussed, and the last two are more fully developed in the essays in this volume. Here we can only hint at some implications of a perspective from the sociology of knowledge.

A PERSPECTIVE FROM THE SOCIOLOGY OF KNOWLEDGE

Whether pursued with scientific rigor or deliberately cast in the modes of humanistic understanding, any indicator of the state, character, or direction of change in science will necessarily reflect not only the *Ding an sich* it seeks to capture, but also the historical experience, fundamental assumptions, and present visions of the group or groups that gave it birth. Neither liberal optimism nor dismal agnosticism is permissible as the organizing framework of discourse at the administrative centers of Western nations. Instead, responsible leaders appreciate the cultural significance of science within the modern tradition and the real if intangible linkages between scientific knowledge, industrial innovation, economic prosperity, and military power. Such leaders also recognize the labyrinthine complexity of the political process, the widening range of interests demanding accommodation within that process, and the corresponding difficulty in achieving either consensus or decision on appropriate forms, levels, and characteristics for the support of science. "Indicators" may thus serve in this generation in

ways not wholly dissimilar from the less quantitatively tuned optimism and pessimism of early days. That is, indicators in general and science indicators in particular may serve as modes in which to shape knowledge, to mediate perceptions, to order values, and to handle ambition.

Powerful traditions within the scientific community foster a view of science in which it is seen as primarily a matter of "results"—whether those results reside in theories, hypotheses, laws, or established facts. According to this view, science possesses great internal autonomy. Interaction with the larger society is primarily in terms (a) of decisions whether and on what scale to fund the necessarily esoteric, specialized practitioners of research, and (b) of intellectual and societal impacts of the "results" of that research. This view of science underlies much of the analysis in *SI-72*.

However, to view science as a mode of culture and hence of cognition, education, socialization, and control may be analytically more fruitful. The work of many anthropologists reminds us that different social systems yield characteristically different styles of culture, cognition, and "cosmology" (beliefs about nature and its relationships to man). Each of these characteristic modes carries with it appropriate patterns of education and socialization. These patterns maintain and reinforce the basic culture as well as its underlying social patterns. Now *science*, in the sense that we use the term (belief in natural law, empirical investigation, consensible results, and progressive understanding), is itself a belief-system characteristic of a social order that can be and has been described. According to Ernest Gellner's brilliant aphorism, "Science is the mode of cognition of industrial society," while "industry is the ecology of science."

The work of Mary Douglas suggests the possibility of constructing a typology that systematically relates social structure to varieties of cosmology. Her work also suggests ways of understanding how cosmology changes as social structure changes. For example, preferred modes of science in an industrial society may be found to be physics and chemistry. In an agrarian society the favored modes may be geology, natural history, and meteorology; in an increasingly service economy, the social, psychological, and biological (medical) sciences may be preferred. The perceived or argued "utility" of each of these modes *is part of* the cultural constellation in question. Again, there are social systems in which the prevailing cosmology and culture are not positively oriented to science at all. Equivalently, there are sectors of our own society for which scientific modes of cognition either have no meaning or have only negative implications.

Thus, if we wish to develop indicators of the state of science, we shall have to attend at least in part to the sociology of knowledge. What basic changes are taking place in our social system? Which of these changes carry implications for science as a mode of culture? To answer these questions,

greater emphasis must be placed on understanding public attitudes toward science, on seeing how "images of science" in different social and professional groups relate to other aspects of their cultural experience, and on the manner of socialization in the ways of science through formal education and informal popularization.

Analysis of this kind also comes upon the difficulties inherent in a focus on "science indicators" rather than some comprehensive category such as "knowledge indicators." For instance, *SI-72* reports the growth in the numbers of natural science Ph.D.'s. Yet, as O. D. Duncan points out in his paper in this volume, such information takes on quite different aspects in a larger frame. Natural science Ph.D.'s awarded show a steady increase, suggesting a "healthy" state. However, such Ph.D.'s *decrease* relative to social science Ph.D.'s—information that indicates quite different and possibly more significant aspects of the change. Again, information on the absolute number of undergraduate science degrees holds little significance without measures of both the size and the actual alternative choices of the age cohort in question. The widening ripple of repercussions from the simple perception that "student shortage" will be the pattern of the next two decades is only the latest indication that the financing of university science must be understood within the context of the place of universities in the larger society. Finally, the funding of the academic mission of the NSF alone is a less informative indicator of the value placed on scientific knowledge than one that also includes (in both collected and disaggregated forms) the statistics for the several varieties of knowledge supported by NIH, NEH, and so on.

In short, *SI-72* rests upon an assumption of autonomy for the natural sciences that may better reflect the statutory jurisdiction of the NSF than the social reality in which the sciences actually function. The problematic nature of that assumption points toward the urgent need for better theoretical understandings of science from the perspectives of the sociology of knowledge. Were more of those understandings available, we would be able to state with greater confidence what sorts of *social and cognitive* data provide reliable indicators of coming shifts in the place of particular sciences in society, as of the whole scientific enterprise. Such understandings might also clarify the difficult questions of when a particular discipline could be examined apart from the rest of learning and when science indicators should properly yield place to knowledge indicators.

The decision to create a series of science-indicator reports came about in answer to somewhat different (but no less real or immediate) concerns than those discussed above. The National Science Board is charged by Congress to oversee the work of the National Science Foundation. Its activities lie at the interface between the ambitions of the community of academic natural scientists and the changing realities of national life, as expressed by Congress

and by the Office of Management and Budget. By the early 1970s the National Science Board was understandably concerned with the relative decline in funding of the natural sciences. This decline coincided with an apparent turn away from major universities, graduate training, and pure research as foci for such support as was available. Also important was a much-reported public disenchantment with the social dislocations and possible environmental damage perceived to flow from an uncritical nurturing of the "science-technology" complex within American society. Against this background the National Science Board undertook to present as its annual report for the year, *Science Indicators 1972*.

The laudable goal was a systematic objective report on the overall state of American science. In view of the lack of previous work toward such an end and the little attention paid to the natural sciences by the social-indicators movement, the first of the biennial science-indicator reports succeeded to a surprising extent. However, the success was far from unqualified. As will become apparent from the essays that follow, *SI-72* was not only an imaginative, ambitious, and innovative venture, it was also a hurried, uneven performance. It pointed forcefully to a significant new way of conceptualizing and appraising the scientific enterprise for selected public purposes. But in places it also mixed advocacy with social reporting; conflated science with technology in confusing fashion; moved uncertainly between the presentation of available time series, the polling of opinion, and Delphic utterance; and on occasion it made insufficient use of economic and statistical techniques of analysis necessary to its stated ends. In sum, although a commendable first effort, this report on science indicators is variously flawed, the flaws making abundantly plain the need for basic improvement in the ongoing series of *science indicator* reports.

The aim of *Toward a Metric of Science* is to begin laying part of the groundwork, not the specific techniques, for such improvement by providing critical discussion of science indicators, as concept and as practice—a discussion involving historians, sociologists, political scientists, and economists of science; physical, life, and social scientists themselves; and experts drawn from the antecedent social-indicators movement.