# SOCIAL RESEARCH AMONG THE ESTATES OF SCIENCE

Joel E. Cohen*
Consultant to The RAND Corporation
Santa Monica, California

SUMMARY

One of the clearest and most useful pictures in the vast literature on the dealings of a government with scientists is due to Don K. Price. The scientists in his picture of four estates are mostly natural scientists, however, and the change in government due to the discoveries of the natural scientists is slow enough at any particular moment that the government may be taken as static and given.

When social scientists join their natural colleagues, they immediately make the government itself an object of study. Like Keynesian economics, certain developed or embryonic social theories may affect radically the procedure and even the goals of the government which supports or encourages the development of these theories. Such theories deal, for example, with cost-benefit accounting, manpower flows, election predictions, and social and demographic effects of technological change.

If theoretical inventions in these social areas are analytical and predictive in form, are based on adequate data, and involve variables which are accessible to control or influence, then, unlike many inventions in the natural sciences, these theories (1) can affect directly and immediately virtually any other research, development, or action program in which people are involved; (2) can affect the structure, performance, and purposes of the very organization,

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the government, which allots the resources for their own future development; and (3) can take massive effect relatively quickly. The potency of social as compared to other kinds of technological inventions within cultural change is something like the potency of Lamarckian as opposed to Darwinian evolution.

At present the United States Congress both expects social sciences to help solve some of its most urgent problems and fears the potential power of social technologies. Congress is as suspicious of the possible use of social science to produce a "socialized, integrated, scientific world organization" as the scientist J. D. Bernal was hopeful of that use and outcome. However, no credible social theory is now comprehensive enough to pronounce universally in favor of monolithic unification as opposed to decentralized diversification.

The existence of certain social theories potent in effecting social change does suggest picturing the functional relations among scientists and government and Price's other estates as a nested set of feedback loops in which the different sciences affect and are affected by the shape of government at different rates and in different ways. From a certain point of view, this functional picture includes Price's picture of constitutional responsibilities, which emphasized the natural sciences.

## PRICE'S FOUR ESTATES

In his book on The Scientific Estate, Don K. Price distinguishes four broad functions in government and public affairs—the scientific, the professional, the administrative, and the political. (See Figure 1.) These functions, Price says,

> are by no means sharply distinguished from one another even in theory, but fall along a gradation or spectrum within our political system. At one end of the spectrum, pure science is concerned with knowledge and truth; at the other end, pure politics is concerned with power and action. But neither ever exists in its pure form.[1]

Of the estates between pure science and pure politics, Price says,

> The professions (for example, engineering and medicine) make tremendous use of the findings of the sciences, but they add something more: a purpose....Each is organized around a combination of a social purpose and a body of knowledge, much of it drawn from science ....[The general administrator's responsibility] is not restricted to some special aspect of an organization's affairs that is related to a special body of knowledge or a special type of training.... He is obliged to deal with all aspects of the concrete problems that his organization faces....

Price formulates a twofold principle of freedom and responsibility which is partly descriptive but also partly prescriptive of the constitutional relations among the four estates in the United States. It runs as follows:

> (1) [T]he closer the estate is to the end of the spectrum that is concerned solely with truth, the more it is entitled to freedom and self-government; and (2) the closer it gets to the exercise of power, the less it is permitted to organize itself as a corporate entity, and the more it is required to submit to the test of political responsibility, in the sense of submitting to the ultimate decision of the electorate.[3]

Price claims that the four estates will be found in any technologically advanced country because they are functions which the government must fulfill. Their respective quotas of freedom and responsibility in America are, Price says,

> plausible only on the basis of certain historic political assumptions[4].... although the way in which scientific knowledge is related to political purpose seems to require the existence of something like our four estates, it by no means requires the relationship among them that is conventional in the Western constitutional tradition.[5]

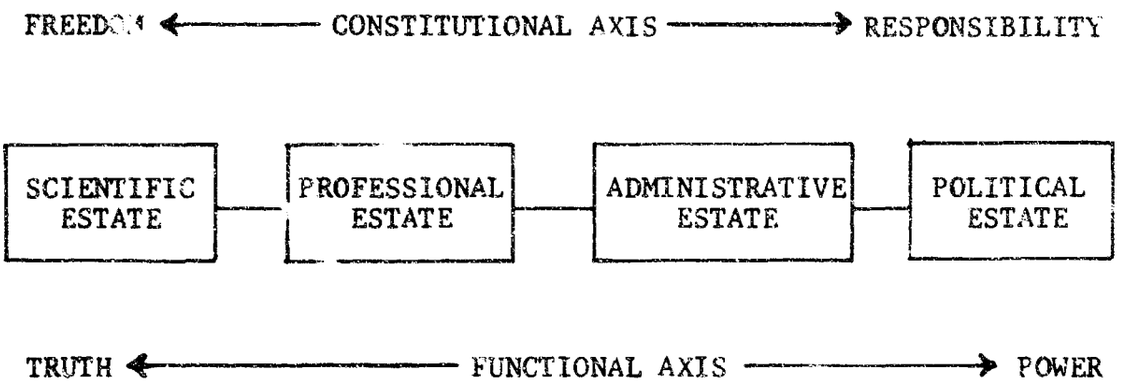


Fig. 1—Sketch of Price's Schema of the Four Estates

## DOMINANCE OF THE NATURAL SCIENCES

Price talks primarily about physical and biomedical science, with the emphasis on the former. The relatively greater scientific maturity of the natural sciences, their recent roles in support of national security, prestige, and welfare, and their contributions through technology to methods of production easily account for the predominance of the natural sciences in academic and political thinking about the social roles of science.

Thus J. D. Bernal discoursing in 1939 on The Social Function of Science declared: "The indirect effect of science through its inexorable influence on productive methods is now, and is likely for long to remain, its most important form of influence."[6] And, as recently as 1967, Eugene B. Skolnikoff could write in Science, Technology, and American Foreign Policy: "...the focus of interest in this analysis is the interaction of the physical and life sciences with foreign affairs.... Accordingly, the term science is not intended to include the social sciences."[7] There is only one index reference to the social sciences in the book. (While Skolnikoff, himself a social scientist, could leave aside the social sciences, he didn't want to talk himself out of the picture. So on the very next page he writes: "For this analysis, scientists are considered to be those individuals engaged in basic or applied research.... The term will be meant to encompass not only scientists in physical and life science fields, but also those in the social sciences."[8])

## ENTER THE SOCIAL SCIENCES

I think the rise of the social sciences may require a further development of Price's picture of the interactions among the four estates of government. It is not Price's description of the constitutional relations among the four estates—their allotments of freedom and responsibility—

but his account of how the estates function together that I want to reconsider.

In his history of Science in the Federal Government, Duprée records that "[o]ne change during the 1920's affected the government's scientific establishment out of all proportion to the money spent. The social sciences for the first time appeared as a distinct entity animating whole research activities."[9] Duprée cites the Bureau of the Census, the Bureau of Labor Statistics, and the Bureau of Agricultural Economics as early social science agencies. "But only after World War I did the social science of the country muster enough personnel, technical ability, and interest to tackle the federal government as an institution worthy of systematic study."[10]

After World War II, when the Air Force set up Project RAND, "those who organized RAND included in it at the outset a division of mathematics and within two years divisions also of economics and social science."[11] The critical importance of including the economists was that they developed the methods of cost-effectiveness analysis which were crucial to strategic choices of weapons.

Just as the early social scientists studies the government, so now the government is returning the compliment by suggesting that the economists' methods of cost-benefit analysis be applied to the government's research and development programs. In 1966, the House Committee on Government Operations reported its recommendations on the decision-making process in federal research and development programs. One of the Committee's recommendations was that the Executive Office should use the cost-benefit approach, wielded so successfully by the Pentagon, in evaluating major research and development proposals and "should initiate studies by economists and scientists to work toward improved cost-benefit analysis of research and development, both within programs and among competing programs."[12,13]

Reluctant as the natural scientists are[14] to be overrun by a sorcerer's apprentice of the social scientists' devising, a number of the most distinguished of the natural scientists have already, in another context, raised the question of the conscious and purportedly rational allocation of research resources. The 1965 study by the Office of Science and Technology of Biomedical Science and its Administration at the National Institutes of Health flatly declared:

> It is not clear to us that the approximate 2:1 funding ratio between mental health and neurology, or the 6:1 ratio between arthritis and dental science, for example, are so related both to national need and to scientific opportunity as to maximize the benefits of the overall expenditures in terms of improved health and longevity.[15]

This story of cost-benefit analysis reveals what engineers call a feedback loop. The government discovers in World War II that it needs the results of large-scale, institutionalized scientific research. It sets up a research institute. The researchers there provide the government with a tool for evaluating and comparing programs. Since one set of its programs is research, the government wants to apply that tool to research. If cost-benefit analysis is applied to research and development activities some discoveries will be made which might not have been made otherwise, and other discoveries will remain unmade which might have seen light under a different allotment of research resources. Among the discoveries which are made may be some which, when again cycled through the government, may again return in one way or another to affect or guide the discoverers.

As this feedback loop tightens, cost-benefit analysis may come to be applied to cost-benefit analysis: there may be policy choices where precise optimization is not worth the cost of information gathering and analysis. (Harvey Brooks points out privately that even in such cases cost-

benefit analysis may have a persuasive role, which can also be the object of analytical study.[21])

An important characteristic of cost-benefit analysis as an invention is that it is a procedure for manipulating symbols (not, like a computer, a mechanization of that procedure) which is based on and provides insight into the operation of a complicated system. It is not a solid-state device, or a clever miniaturization of circuits, a weapon or a cure.

## SOCIAL THEORIES WITH POSSIBLE FEEDBACK EFFECTS

Some examples of less well known social theories will emphasize the potency of such inventions in a feedback loop with government.

Doctoral education. Bolt, Koltun, and Levine[16] developed a model for the flow of men holding doctorates in science and engineering between and out of the two broad functional categories, or "estates," of graduate education and other professional activities. They showed how future stocks of doctorates in educational and professional functions could be predicted from difference equations involving as parameters (1) the rate of return of new doctorates into colleges and universities for employment; (2) the average productivity by faculty holding doctorates of new doctorates; (3) the rate of flow of faculty holding doctorates to employment outside colleges and universities; and (4) the rate of attrition in the stock of doctorates due to retirement, death and other causes. They estimated values for these parameters from recent American data and displayed the different strategies available to a policy-maker who wanted the country to be able, say, to produce twice as many doctorates per year in ten years as it does now. These strategies depend on influencing appropriately the values of the four parameters.

The model is sufficiently convincing, and easy enough to present to nontechnical people, that it has been adopted

as a background for policy judgments within the government. While the model links previously fragmentary and unrelated manpower data, it also emphasizes gaps in those data. Bolt et al. conclude that "this and similar dynamic models of social systems can serve not only to aid in the development of policy but also to guide the collection of statistical information necessary to undergird policy with a solid factual base."[16]

Here the feedback loop is again clear. Bolt, the creator of the analytical model, is a former physicist turned M.I.T. political scientist. Working in and with the National Science Foundation, he does a piece of research which, through the government, affects strongly the future training of men in just those analytical skills which made his invention possible.

Voting predictions. Much has been said and written on the possible effects of publishing polls and predictions about election results. An announcement that 49 percent of voters say they will vote for candidate A and 51 percent say they will vote for candidate B may reverse an election's outcome if substantial sympathy for the underdog results, or may misleadingly widen A's margin of loss if voters jump on B's bandwagon. The problem has worsened lately with the use of computers to tabulate election returns on the day of the election and to project final outcomes before all votes are in. Since the television and radio networks broadcast the East Coast tabulations and projections to the West Coast, where voting stations remain open several hours later, the West Coast votes may be substantially affected. This problem, which has been especially acute in recent presidential elections, has generated much Congressional and judicial discussion about possible remedies.[17]

Unnoticed in the discussion is a bit of theory by Herbert A. Simon[18] which points to information relevant to a proper policy (presumably one that assures that elections turn out the way they would have without the interference of polls, predictions, and projections). Simon proves that if

the net effect of publication of a prediction or projection may be characterized as a bandwagon effect or an underdog effect (increasing or decreasing the actual percentage voting for the candidate predicted to win in comparison to the percentage voting for him without the poll's publication) then it is always possible to adjust the prediction before its publication so that the published prediction will in fact be correct. If a bandwagon effect is the consequence of publishing a prediction, Simon proves, then publication can have no effect on the (win-loss) outcome of the election, although alteration of the published prediction can but need not alter the outcome of the election. On the other hand, if an underdog effect is the consequence of publishing a prediction, failure to adjust the published prediction to take account of that effect can actually reverse the outcome of the election, while such an adjustment (accurately done) cannot reverse the outcome of the election.

From Simon's analysis, it obviously becomes crucial to know whether the effect on the American voting public of publishing predictions is bandwagon or underdog, and survey and opinion research centers exist at American universities to gather just such information.

Of course, Simon's model assumes an environment in which no politically significant events alter voters' preferences while they are making up their minds and while sample polls are announced. Like any other model, Simon's cannot be naively applied to a real world in which such events are inevitable.

Technological change and human ecology. A theory which linked economic and sociological changes consequent to the introduction of a new technology would be another area of theory of enormous potential importance. Harold A. Thomas, Jr. has developed such theory for a tribe of hunter-gatherers in southern Africa.[19] On the basis of data on the !Kung tribe gathered by Richard Lee,[20] Thomas constructs a production function of food. The two parameters of the production function refer to (1) efficiency of work, and (2) areal productivity

of land. Thomas estimates the shift in the production function which follows from the introduction of iron arrow tips. Assuming the tribesmen optimize a utility function which depends linearly only on their population size, their rate of work, and the average productivity of their work, Thomas predicts approximately the increase in food production, the decrease in the rate of work and the increase in tribal population. Better diet and greater longevity require calculable adjustments in the frequency of child-bearing (which is already rigidly controlled by abstinence, abortion and infanticide) if the population is to remain stable at its new level. Thus Thomas moves from arrowheads to sex life with an analytical model and a reasonable hope of prediction.

It remains to be seen whether further data on the !Kung will confirm the details of Thomas's analysis,and, more importantly, whether his procedures generalize to vastly more complicated interactions of technological innovation with human ecology. What is important in his attempt is its clear analytical style and its demonstration that such calculations are possible. Obviously, such calculations, were they reliable, would be crucial in guiding a government in the choice of large-scale technologies for support and development.

Two more examples of areas in which useful analytical theory is still more embryonic but of enormous potential importance are first, bureaucratic and administrative behavior and organization, and second, persuasion and influence, whether of individuals, small groups, or masses. The techniques of persuasion a government uses to build popular support for its space or welfare programs might also influence popular support for research, even research on the subject of persuasion. And the techniques might be most effectively employed by a bureaucracy whose structure was based on some fundamental understanding of bureaucratic structure: a bureaucracy could use its understanding of the theory of bureaucracy to increase its own effectiveness. Beginnings are being made in these directions.[21]

The theories that exist or are called for in these areas are what Merton[22] calls theories of the middle range, but they differ crucially from the verbal theories that seem pandemic in sociology. The variables involved in the theories mentioned above are not only measurable in the sense that their magnitudes can be inferred from some observations, but, unlike those of many current sociological explanations, they are, or will have to be, at least partially accessible to control.

In a polite but effective indictment of the utility of some sociological theories, a professor of public health looking for guidance as to the social etiology and ecology of disease found that

> If public health were to act upon the information thus obtained [from sociology], it would, among other things. have to upgrade social class, eliminate status incongruity and occupational stress, selectively control both geographic and social mobility, make cities into country farms, improve family incomes, shepherd groups through culture change, maximize the individual's acceptance of his life situation, prevent social isolation, and provid a value basis for choosing whether one's parents should or should not be church-going people.[23]

Mouthwash will not take the place of usable theory. Neither will sheer statistics. The necessity to develop social theory along with social information and "social indicators" is clearly appreciated by Raymond A. Bauer:

> General models of social systems exist, as to models of the American social system. It is safe to say, however, that all of them require considerable development and refinement before one could use them to plan developments in the noneconomic sector with any degree of precision.[24]

## HOW SOCIAL SCIENCES (AND SOCIAL THEORIES) CAN AFFECT GOVERNMENT

The familiar feedback loop between a thermostat and a home furnace which keeps the house at a steady temperature is stable. The information from the thermostat returns the

temperature to some constant state. The feedback loop between social science research and government is destabilizing. The information from government-supported or government-adopted research alters the structure and behavior of the government, which alters the research that gets supported ar adopted, and so on, around and around.

An understanding of social operation gained through social research may not only condition the success or failure of social programs, but may condition the goals of those programs, and must accompany any successful effort at control (barring pure luck).[25] Today the understanding of the practicing politician, the administrator, and the scientist attempting to influence government policy, is mostly implicit; as their goals become increasingly complicated and conflicting, their understanding will have to be more explicit.[26]

Three characteristics of the examples given in the preceding section are outstanding. First, the social scientific findings can affect directly and immediately a broad range of other research, development, and action programs. Second, they can affect the structure and performance of the very organization, the government, which allots the resources for their own future development. Third, they can take effect relatively quickly, so that a man's discoveries can return to influence his own future discoveries well within his working lifetime.

The other sciences in which the government is involved, the kinds in Price's scientific estate, do not seem to share all three of these characteristics. For example, the government's investment in land-grant colleges and agricultural research in the nineteenth century has, it is true, removed the problem of producing enough food in this country and freed most of the population from the soil, thereby making available resources for other programs; but this agricultural success has released resources to other programs only over a long period of time and has not greatly affected the procedure

by which future decisions regarding agricultural research are made.

The recent massive contribution of a freed agricultural population to urban problems of growth, congestion, and employment are consequences indirectly of agricultural science but most directly of failure to understand the social consequences of policies regarding welfare, minimum wages, and housing subsidy.

Similarly, while federal agricultural programs provided important examples of institutional arrangements for applied science which were later imitated, the social patterns created owed less to agriculture than to prescientific social experimentation.

As in agriculture, the discoveries in the physical sciences and technologies have affected a broad range of other research, development, and action programs for the most part indirectly or obliquely. Alvin Weinberg[27] has listed a number of ingenious "technological fixes" to social problems: for example, using atomic power to desalt ocean water to irrigate land to provide more food to sidestep or allay an exploding population. Such a device, Weinberg admits, is mainly good for buying time; and since time may be important in convincing people that they want to limit the number of children they have, such a device may be crucial. Yet this technological approach does not say what is a desirable range of population sizes, nor how to convince people to have less children during the time that it buys; nor does it affect, except through providing time, the ways a government makes decisions about its population control or atomic energy programs.[28] The influence of the knowledge of the laws of physics on the structure of the social institutions which apply those laws is very indirect.

## A BIOLOGICAL ANALOGY

A biological analogy may be suggestive. An animal species, such as man, and its environment, including other

species, form a coupled system. The environment selects certain members of the species to survive long enough to reproduce and influences the way the species will evolve. But the species also affects the way the environment will change by what it does to the other species, what it puts into or extracts from the atmosphere, the soil and the seas. Ordinarily, this interaction is rather slow-paced and indirect, because according to Darwinian theory and much evidence the environment's only means of affecting evolution is by determining who reproduces and who does not. Think how much faster change could occur if, as Lamarck supposed, animals could adapt within their lifetimes and pass on their adaptations to their offspring. Anthropologists are familiar with the cliche that man has progressed from biological evolution to cultural evolution, that man's tremendous capacity to learn and to transmit culture over generations enables him to modify his life faster than Darwinian selection ever could. Within the process of cultural change, I suggest, the action of physical laws on the social structures which apply them is usually of the Darwinian sort; whereas the action of an understanding of social functioning is more likely to be of the Lamarckian sort.

## PRESENT RELATIONS OF GOVERNMENT AND SOCIAL SCIENCE

In order to speculate on possible future relations between government and social science in this country, it seems reasonable to start with some view of their present relations. Among the many aspects of those relations which the following sketch will exclude are those relating to the founding of a National Social Science Foundation,[29] the roles of social scientific findings in judicial decisions on the Constitutionality of racial segregation and tracking (segregation by performance on standardized tests) in public schools, and the roles of many recent "social scientific" reports in prompting, or failing to prompt, executive action

on social problems. Massive case studies of each of these and other excluded aspects would, I think, reinforce the general conclusions drawn below.

In the second progress report (1966) of the Subcommittee on Science, Research, and Development of the House Committee on Science and Astronautics, the members of Congress, or at least their staff, manifested a curiously ambivalent lusting after the favors of social science and a fear of her power. On the positive side, the subcommittee noted with pride that it had

> recommended adequate representation of industry, nonprofits, small colleges, and social scientists on the National Science Board [of the National Science Foundation]....Dr. Ralph W. Tyler, director for advanced studies in the behavioral sciences at Stanford University, was elected as Vice Chairman of the Board, representing the first time in the Board's history that a social scientist has held that post.[30]

Further, in its statement of requirements on government in the future, the subcommittee concluded:

> We are further convinced that governmental effectiveness in coping with the big issues of the future will require two special attributes:
>
> (1) An ability on the part of the Government, and particularly the Congress, to see and cope with each problem in its entirety—to deal with each as a complete system and to treat the entire syndrome rather than isolated phases of it. A current example is pollution, a large ecological systems problem, which must depend for its solution not only on science and technology, but on political considerations, judicial and legal situations, economic and tax factors, public relations, interstate and international cooperation and industrial evolution, together with the involvement of social scientists in certain preliminary stages of planning.
>
> (2) A willingness to encourage and support approaches to the problems of the future which will join the social sciences with physical sciences and engineering, and which will make use of their combined powers. The necessity for this appears obvious when one looks closely at the difficulties facing modern society. Few of them will be eliminated by the

> application of technology alone. In many instances, in fact, we need to know a great deal more about the behavior and motivations of humanity—individually and collectively—than we now know in order to apply our growing technology with accuracy and maximum results.[31]

Six pages later, the same subcommittee looked at another side of the social sciences:

> We are concerned about the inroads against personal liberty which may be inherent in [the] application [of social sciences and electronic techniques of observation]—and about their constantly increasing potential for the invasion of personal privacy. This means more than invading the person or the senses. It also means invading the mind and personality by unconscious exposure to or direction by the machine or certain social science techniques....[32]

BERNAL'S VIEW

If that is not the United States Congress speaking, it is at least the Congress letting a staff member of one of its subcommittees speak for it. Congressional hopes for, and fears of, the social sciences reflect a very strong and potentially influential appreciation of what the social sciences can do for and to government. Like the U.S. Congress, J. D. Bernal also hoped society would take advantage of science's integrating and systematizing power.[33] But the U.S. Congress and the Marxist Bernal feel vastly different about the political framework within which the social sciences will best come to fruition. The members of Congress would not easily accept Bernal's claim that "Only in a socialized economy effectively concerned with providing maximal welfare can the full development of the social sciences be expected, for there they needs must become in practice and theory an integral part of the machinery of communal life."[34] Not all the members of Congress might favor this assertion by Bernal:

> The freedom of the nineteenth century was a seeming thing. It was an absence of a knowledge of necessity. Its basis lay in social relations through a market. In liberal theory every man should be free to do what he liked with his own, buy or sell, work or idle. In fact he was tied by the iron laws of economics; laws socially

> produced but taken as laws of nature because they were not understood. In an integrated and conscious society this conception of freedom is bound to be replaced by another—freedom as the understanding of necessity.[35]

The Congress may often vote the tax changes suggested through the President by the Keynesians in the Council of Economic Advisers, but it prefers to exercise choice without thinking of "iron laws of economics." Certainly in the domain of social laws and social control, the Congress is not attracted by the prospect of central integration through the social sciences that so attracts Bernal: "Science implies a unified and coordinated and, above all, conscious control of the whole of social life ... Henceforth society is subject only to the limitations it imposes on itself... The socialized, integrated, scientific world organization is coming."[36] Bernal here assumes in advance that social science will show that globally coordinated unification is the best social organization for all future political choices.

If the Congress supports the development of the social sciences, must it also acquiesce to a society so centrally integrated that the freedoms of the citizen and of the Congress are endangered? No credible social theory yet exists to answer that question. For certain purposes, decentralized political choice and scientific research may be highly desirable. A diversity of societies and cultures, and a diversity of social scientific endeavors coupled to them is, for example, the evolutionary version of not putting all your eggs in one basket; and this is often a better strategy than monolithic uniformity in a rapidly and unpredictably changing environment.[37] But in insisting that social life and social organization be approached more self-consciously, Bernal desires the inevitable, if political choice and social sciences continue to be coupled.

## A FLOW CHART OF INFLUENCE

Evolutionary biologists and comparative cultural anthropologists know that species and so-called primitive societies solve apparently similar ecological problems in a variety of ways. If an extrapolation to more complex societies has any validity, it is likely that technologically advanced societies can arrange the relations between their natural and social scientific endeavors and their political functioning in more than one way. Here it is necessary to return to Price's picture of the four estates.

When Price labels the axis from science to politics as the axis from freedom to responsibility, it is clear that he wants to describe informally the constitutional arrangement, that is, the assignment of social responsibility, of the four estates in the United States. He makes explicit that this allocation of social responsibility is in no sense necessary, and points out that other, notably socialist, countries have very different constitutional arrangements.

When Price relabels the line from science to politics as moving from truth to power, he seems to suggest a sort of epistemological or functional schema, according to which quantities of truth and influence move in the proper directions from one estate to the next.

The examples given above suggest that the strong coupling of political choice and the social sciences into a feedback system makes a linear picture inadequate to represent the system of mutual influence.

In a picture (see Figure 2) fully as rough and approximate as Price's, imagine a circular loop with arrows pointing in a clockwise direction. At the 12 o'clock position stands the political estate. At the 3 o'clock position stands the administrative estate, which translates what the political estate wants to understand to the scientific estate (standing at 6 o'clock) and supplies it with resources to find out.

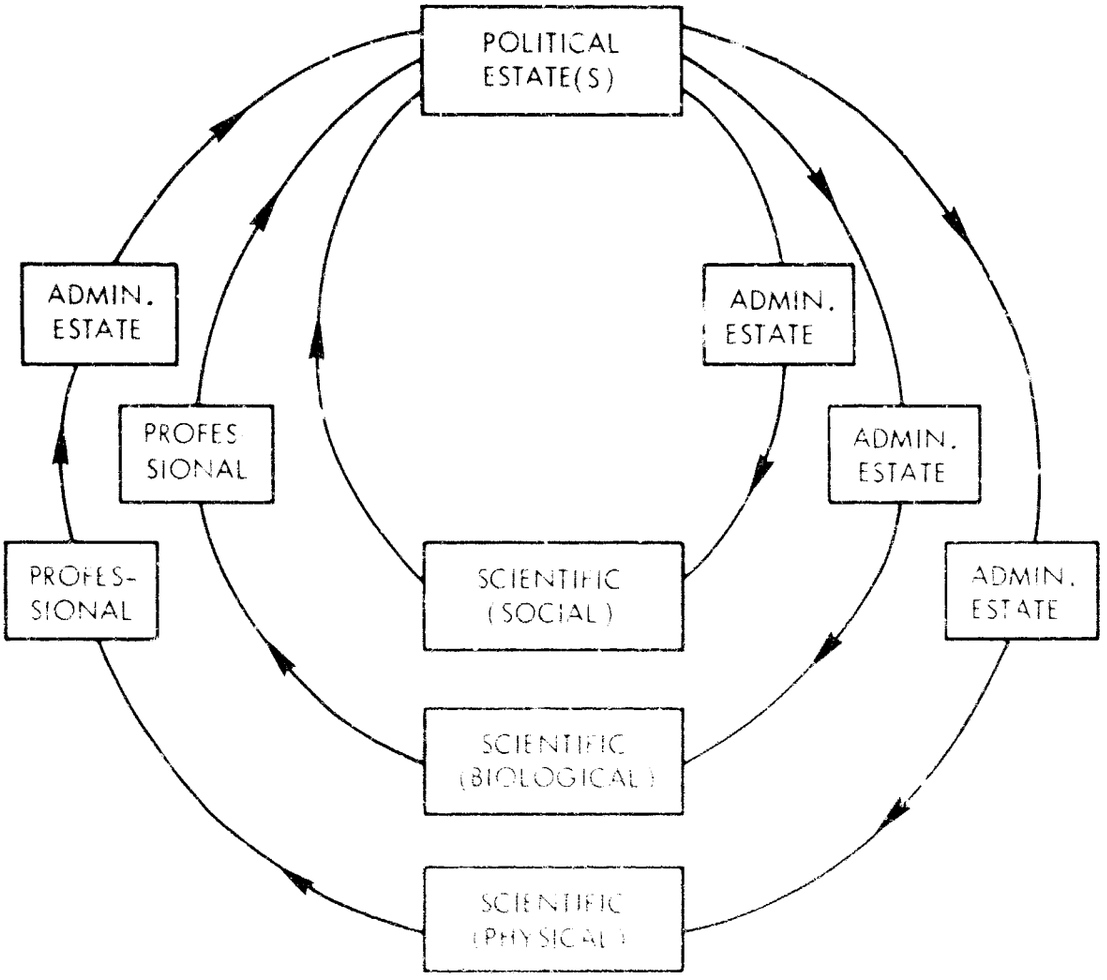


Fig. 2 - Proposed functional schema: a nested set of feedback loops

The scientific estate investigates where resources are available and feeds the results directly back to the government, as in the case of cost-benefit analysis.

Around this first circle is a larger circle tangent to it as the 12 o'clock position, thus going through the same political estate. At the 3 and 6 o'clock positions are respectively administrative and scientific estates, as in the first loop, but in addition at the 9 o'clock position is the professional estate. If the social applications of the science generated in this loop are clear in advance, the new findings are forwarded immediately to the professional estate and put into practice: as, for example, when someone at NIH finds a cure for a disease and passes the word to the medical profession. The findings of the scientists at 6 o'clock affect the purposes and forms of politics at 12 o'clock through the activities of the professionals. The engineers who made possible the massive pollution of the East Coast and the physicians who contributed to the public expectation of reasonable health, including clean air, were among the forces producing new interstate political alliances to control pollution.[38]

Around both of these circles is a still larger one tangent to both of them at the 12 o'clock position, again going through the same political estate. Administrative and science have their usual posts at 3 and 6 o'clock. At 8 o'clock are the professions, and, at 10 o'clock, another bunch of administrators again. From the point of view of the scientist at 6 o'clock in this loop, the 3 o'clock administrators are afferent, or input, affecting which problem areas will get support, while the 10 o'clock administrators are efferent, or output, determining how his scientific findings and the skills of the professionals will be used to carry out the initial political purposes.

The point of view of the politician in this outer loop is not quite so simple, for the administrators on both sides

of him are supposed to carry out his purposes. The 3 o'clock administrators facilitate large scale changes in basic understanding. The administrators at 10 o'clock carry out purposes with the principles and skills made available by the scientists and professionals. The administrators at 10 o'clock produce large-scale changes in the society and influence the political framework in which future choices are made.

In the science of this outer loop belong, I think, most of the physical scientific and technological research that Price has in mind for his scientific estate. I put it on the outside to suggest that the time this science requires to effect a change in the structure and purpose of the political estate may be relatively longer than that of the science on the inner loop, and that its influence is mediated through other estates. (This is the Darwinian kind of selection mentioned earlier.) In the science of the inner loop I would place the social sciences, including economics, whose effects can be most immediate.

To show how nonrigorous this assignment of sciences to inner and outer loops is, here are two counterexamples. The discovery by physical scientists of new means of detecting violations of a test ban treaty immediately opened new political possibilities to the American and Russian negotiators of a test ban treaty. Here is physical science with immediate social effects. Yet this physical discovery was a consequence of a social decision, after the initial negotiations, to invest in research in the area. (It could also be argued that since the discovery did not really alter the ultimate intent or procedure of the negotiators, it still belongs on the outside loop.) On the other hand, if government-supported studies of public education affect differentially who gets educated and with what quality, within a generation or two there will be a differential effect on the personnel in the government and on the kind of scientific and action programs they are inclined to support. (There will also, incidentally, be a differential

effect on the pool of people from whom educational sociologists are drawn.) Here is a slow (outer loop) effect of social science.

The separation of activities into these three loops is meant to suggest differences in subject matter, time scale, and degree of institutional differentiation (whereas a social scientist may be a fundamental researcher, interpreter to politicians, and administrator of a resulting project, these jobs are perhaps more often divided among different men on the outer loop).

But also, since the estates are, in Price's conception, delineations of different functions, the separation of activities into these three loops is meant to suggest this functional difference: social research can alter quickly and drastically the structure and behavior of the government with which it interacts, while the natural sciences more often act ecologically, through their effects on the environment or populace at large.

From the theory of control systems it is known that in a nested set of feedback loops the rate of change of the whole system is limited by the rate of change in the slowest-changing loop. Before the rise of the social sciences, and to a considerable extent even now, the rate of change of the inner loop was nearly zero, so that the inner loop was invisible and the government was nearly static in its interactions with estates on the outer loop.

Once the inner loop picks up enough steam scientifically to surpass the outer loops in rate of substantial change (a distant prospect) then the physical sciences set the limits on the society's rate of change. This arrangement is entirely reasonable if the physical sciences are viewed as mediating between the society and its physical environment, and if the society can adapt to its environment much more rapidly than the environment can change. At the moment such adaptation is far from common; social change is in fact

the prime limitation on the system. Adequate social sciences offer a possibility of improving the situation.

The lumping of the entire political estate into one box emphasizes the different functions of different sciences. It is not meant to deny that there are camps, perhaps equally functionally significant, among the politicians. The special interactions of the Congressional Joint Committee on Atomic Energy, the Atomic Energy Commission, and the federal laboratories can easily be distinguished within the workings of the outer loop, for example; the failure to make such a distinction is intended to suggest that, while the personalities and issues involved may be special, the functioning is not necessarily so. Similarly there are those in Congress and the executive branch who have N.A.S.A. as their preferred client, some who have N.I.H. as theirs, and some who have no taste for science or scientists. Doubtless senators from states with much federal research money often feel differently towards science than those without. But emphasis here is on the different roles and effects of sciences.

The suggested allotments of different kinds of science to different loops is not meant to deny that biology can be directly affected by advances in physics and chemistry, nor that social and behavioral sciences can be directly affected by the progress of biology, without the intervention of politicians. The reason for neglecting this interaction here is that it is scientifically "in-house"; the political estates benefit from it, but don't have to deal with it directly.

If an administrator moves far off to the right in the 3 o'clock direction in Figure 2, the outer semicircle from science to politics on the left appears to lose its curvature and approximates the spectrum from truth to power of Price. I would guess that Price wrote from this point of view (the social sciences then being virtually invisible), and combined that aspect of the functional schema with what he

clearly saw was the constitutional schema. Unless there is some social scientific finding to the contrary, there is no obvious reason why all the administrators performing various functions in various loops in this functional schema cannot be given the apportionment of freedom and responsibility described by Price; similarly for the scientists, professionals, and politicians.

One surprising (to me) aspect of this schema is the preponderance of administrative functions. I can imagine friends of mine in pure research asking, "What politician and what administrator supported the thinking that led to the theory of relativity?" I can only answer, "None," and readily admit that the schema is incomplete in at least two major respects. First, science will probably always benefit from the gratuitous discoveries of men free to think for themselves. Another way of saying this is that politicians (like scientists) don't always know what they want to understand, and sometimes it is only after a fundamental advance in understanding that they realize that it was just what they wanted. Moreover, the terms and contexts in which scientists couch their understanding may be very different from those in which the politicians state their problems. It seems fair to estimate, though, that the fraction of all scientific activity in America which is described by this schema has been steadily increasing. Second, political choice will probably always be conditioned by things other than knowledge of the direct and indirect implications of natural and social laws. But as the inner two loops of this schema are filled in, the fraction of all political choices conditioned, if not determined, by the natural and social sciences will, I would guess, rise spectacularly.

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NOTES

1. Don K. Price, The Scientific Estate (Cambridge, Mass.: Harvard University Press, 1965). p. 135.

2. Ibid., p. 133.

3. Ibid., p. 137.

4. Ibid., p. 138.

5. Ibid., p. 139.

6. J. D. Bernal. The Social Function of Science (London: George Routledge and Sons, 1939). p. 386.

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8. Ibid., p. 19.

9. A. Hunter Dupree, Science in the Federal Government (Cambridge, Mass.: Harvard University Press, 1957). p. 335.

10. Ibid., p. 336.

11. Bernard Brodie "The Scientific Strategists," in Robert Gilpin and Christopher Wright (eds.), Scientists and National Policy Making (New York: Columbia University Press, 1964). p. 246.

12. U. S. Congress. House 89:2 Committee on Government Operations, Federal Research and Development Programs: The Decision-Making Process (Washington: GPO, 1966). p. 4.

13. Ibid., p. 34.

14. U. S. Congress House 90:1 Committee on Government Operations, Federal Research and Development Programs: The Decision-Making Process (Comments by the National Academy of Sciences and the Bureau of the Budget) (Washington: GPO, 1967). pp. 12-14.

15. U. S. Office of Science and Technology, NIH Study Committee. Biomedical Science and Its Administration (a report to the President) (Washington: GPO, 1965). pp. 11-12.

16. Richard H. Bolt, Walter L. Koltun, and Oscar H. Levine, "Doctoral Feedback into Higher Education." Science 148:918-926, 14 May 1965.

17. Thomas H. D. Mahoney, "Computers, Congress, the Constitution, and the Courts: the Problems of Early Broadcasting of Reports, Projections, and Declarations." Harvard University Seminar on Science and Public Policy, mimeo, 1967.

18. Herbert A. Simon, "Bandwagon and Underdog Effects of Election Predictions," Public Opinion Quarterly 18, 1954. Reprinted in Simon's Models of Man (New York: John Wiley, 1957). pp. 79-87.

19. Harold A. Thomas, Jr., "Human Ecology and Environmental Engineering," Harvard University Center for Population Studies, unpublished manuscript, 1968.

20. Richard B. Lee, "Subsistence Ecology of !Kung Bushmen." Ph.D. dissertation, University of California, Berkeley, 1965.

21. For attempts to understand large organizations, see Beatrice and Sydney Rome, "Leviathan," System Development Corporation Magazine 8(4):17-25, April 1965. The presence in the 1966 Arts of Persuasion in Litigation Handbook of a monograph called "Persuasion and Behavioral Change" by James V. McConnell, a psychologist whose research has primarily been in the area of persuading flatworms, may indicate a nascent awareness of the social potential of theoretical understanding of persuasion.

22. Robert K. Merton, On Theoretical Sociology (New York: Free Press, 1967). Chapter 2: "On Sociological Theories of the Middle Range."

23. Edward S. Rogers, "Public Health Asks of Sociology ..." Science 159:506-508, 2 February 1968.

24. Raymond A. Bauer, "Application of Behavioral Science," in Applied Science and Technological Progress (a report to the Committee on Science and Astronautics, U.S. House of Representatives, by the National Academy of Sciences, June 1967) (Washington: GPO, 1967). p. 134.

25. "Technical knowledge is a necessary but not a sufficient requisite for the scientist who seeks to play the

catalyst in the conversion of scientific discovery to social action." By itself medical evidence on the effects of smoking failed to produce appropriate legislative response. The quote is from Stanley J. Reiser, "Smoking and Health: the Congress and Causality," in S. A. Lakoff (ed.), Knowledge and Power (New York: Free Press, 1966). pp. 293–311. See also Kingsley Davis, fn. 28 below.

26. See John W. Finney, "Institute Set Up to Aid the Cities," New York Times, 27 April 1968, p. 1.

27. Alvin M. Weinberg, "Social Problems and National Socio–Technical Institutes," in Applied Science and Technological Progress, pp. 415–434.

28. "The study of social organization is a technical field; an action program based on intuition is no more apt to succeed in the control of human beings than it is in the area of bacterial or viral control. Moreover, to alter a social system, by deliberate policy, so as to regulate births in accord with the demands of the collective welfare would require political power, and this is not likely to inhere in public health officials, nurses, midwives, and social workers. To entrust population policy to them is 'to take action,' but not dangerous 'effective action.'

"Similarly, the Janus–faced position on birth–control technology represents an escape from the necessity, and onus, of grappling with the social and economic determinants of reproductive behavior." Kingsley Davis, "Population Policy: Will Current Programs Succeed?" Science 158:730–739, 10 Nov. 1967.

29. Luther J. Carter, "Social Sciences: Where Do They Fit in the Politics of Science?" Science 154:488–491, 28 Oct. 1966.

30. U. S. Congress, House 89:2 Committee on Science and Astronautics, 2nd Progress Report of the Subcommittee on Science, Research, and Development, Inquiries, Legislation, Policy Studies Re: Science and Technology: Review and Forecast (Washington: GPO, 1966). p. 16.

31. Ibid., p. 20.

32. Ibid., p. 26.

33. Bernal, op. cit., p. 411.

34. Ibid., p. 342.

35. Ibid., p. 381.

36. Ibid., p. 409.

37. In a study of "Scientific Productivity and Academic Organization in Nineteenth-Century Medicine," Joseph Ben-David attributed the rise in productivity of medical science in Germany and America in the last half of the 19th century to the presence of academic decentralization and competition, and the simultaneous fall in productivity in France and England to de facto or de jure academic centralization. In Bernard Barber and Walter Hirsch (eds.), Sociology of Science (New York: Free Press, 1962). pp. 305-328. See also Joseph Ben-David, Fundamental Research and the Universities (Paris: Organization for Economic Cooperation and Development, 1968).

38. For a brilliant intimation of the long-term social implications of biology, see Robert S. Morison, "Where is Biology Taking Us?" Science 155:429-433, 27 January 1967.