American State Governments as Models for National Science Policy

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Abstract

In the 1980s state governments adopted an entrepreneurial stance and established an extensive array of programs targeted at encouraging university–industry research collaboration, the commercial development of new technologies, the start-up of new firms, and the technological modernization of existing firms. Although these state programs are frequently presented as laboratories of democracy, their relevance to national science and technology policy is open to question. State R&D strategies reflect contrasting theories about the linkages among academic research, technological innovation, economic growth, and administrative practices. Evaluations of state technology programs have essentially remained fixed at dead center, as unproven undertakings. State experiences have not been couched in analytical frameworks conducive to assessments of national science and technology policies.

INTRODUCTION

With an intellectual pedigree stemming from Lord Bryce and Supreme Court Justice Louis Brandeis, the analogy "laboratories of democracy" is often used to describe the influence of state initiatives on the formulation of national policies in America [Osborne, 1988]. This analogy has enjoyed a recent vogue in science and technology policy, where state government initiatives to foster technological innovation are increasingly seen as offering lessons for the formulation of national policies.

However, before the current array of state programs can be viewed as laboratories whose findings are relevant to national science and technology policy issues, at least three questions must be answered. First, what is the nature of the experiments? Second, how "successful" or "effective" have state programs been (given the multiplicity of state objectives)? Third, independent of the answers to the first and second questions, what is the relevance (if any) of recent state actions, either singly or collectively, for issues bearing on the formulation of national science policy?

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This article starts with a look at the setting for the recent use of the "laboratories of democracy" analogy by contrasting federal and state government support of scientific and technological innovation in the 1980s as a policy instrument directed at promoting economic growth. The next section expands an earlier characterization of the theories of technological innovation embedded in state programs. A third section addresses issues related to the evaluation of state programs and the processes by which evaluation findings shape consensus about feasible alternatives among policy network members; it considers the role of analogies as modes of thinking about policy problems, as well. The relevance of state programs to national science and technology policy debates is then examined.

A CONTRAST OF FEDERAL AND STATE SUPPORT OF TECHNOLOGICAL INNOVATION

Confronted in the 1980s with an erosion of America's "first place" standing in many aspects of technological accomplishment [National Science Board, 1985] and a deterioration of its international trading position in technology-intensive economic industries, broad cross-sections of America's government and industrial and academic communities began to present science and technology policies as paired instruments that could be used to promote technological innovation and in turn, economic competitiveness [Lambright and Rahm, 1989]. However, the stands taken by the Reagan and Bush administrations have limited the scope of federal action in this regard. Government encouragement of technological innovation has been limited to the support of basic research and the establishment of the appropriate market incentives (tax reduction, deregulation, monetary policy). An aversion to government encouragement of the development or commercialization of specific technologies, like high definition television, also has been evident. Direct federal responses to calls to accelerate the rate of technological innovation, such as the recasting of the National Bureau of Standards into the National Institute of Standards and Technology (NIST) and the U.S. Department of Defense's financial support of Sematech, are the visible exceptions [Smith, 1990].

An open season has been declared on the federal government's ability to formulate a coherent and effective set of policies that will promote technological innovation and manufacturing modernization, and on the content of these policies [Cordes, 1990]. According to Tornatzky and Fleischer, "There is no coherent innovation or technology policy in the United States" [1990, p. 241; compare Ergas, 1988; Roessner, 1987]. Similarly, the U.S. Office of Technology Assessment (OTA) [1990], after noting the slow change in the federal government's disinclination to support commercial advances in technology "as it became painfully obvious that one U.S. industry after another was losing technological leadership," writes:

> Some changes are occurring, and of these, some are real departures from the past. But they have been made in a piecemeal, ad hoc fashion. No comprehensive set of government policies has yet been adopted to promote the use of technology for better performance in manufacturing. [p. 173]

In striking contrast to the reluctant and organizationally dispersed nature of federal programs, state governments began to develop an extensive array of programs in the 1980s targeted at encouraging research collaboration between universities and industries, the commercial development of new technologies, the start-up of new firms, and, increasingly, the technological modernization of existing firms.

State support of economic development through subsidies, regulations, and other stimuli is readily traced to colonial roots [Clark, 1916]; over this long history, state support has been directed at many different strategic factors—infrastructure, infant industries, and diversification [Hansen, 1990]. Recent state endeavors are, however, notable both for their scale and their strategy. What has come to be termed the "new economic role of American states" [Fosler, 1988] involves an increased emphasis on new institutional arrangements entailing partnerships with the private sector and universities, and an active entrepreneurial role. Moving well beyond their traditional emphasis on what Peter Eisinger has termed "supply-side" inducements to economic growth (e.g., industrial revenue bonds, tax abatements) that serve to lower production costs within their borders, states are increasingly active in "demand-side" stimulation [Eisinger, 1988]. Newer state economic development efforts "are geared to enhancing existing state businesses, developing new indigenous companies and products, and expanding into international markets" [Clarke, 1986, p. xi]. Numerous programs are encompassed within this new role—venture capital funds, product development corporations, incubators, export development offices [John, 1987]. In these initiatives ". . the state has become a risk-taker, a path-finder to new markets, the midwife to joint public–private efforts to develop and test untried technology" [Eisinger, 1988, p. 9]—thus in the Schumpeterian sense, becoming the entrepreneurial state. Central to this entrepreneurial role has been the promotion of high-technology or advanced-technology firms and industries, followed more recently by programs designed to foster manufacturing modernization and technology transfer.

State technology programs have roots in the state science and engineering foundations of the 1960s [Long and Feller, 1972], but the programs of interest here began in the early 1980s as Rust Belt states responded to severe economic dislocations in core manufacturing industries during the 1981–1982 economic downturn and came to perceive that traditional industries were experiencing secular, not cyclical, decline. Confronted by the Reagan administration's refusal to adopt any semblance of an industrial or regional economic policy, state governments had to act if economic recovery initiatives were to be undertaken; they acted [Fosler, 1989; Osborne, 1988, Schmandt and Wilson, 1987, 1989].

Technology development programs are all but ubiquitous among U.S. states. A survey conducted in November 1987 by the Minnesota Department of Trade and Economic Development (the most widely cited of the several such surveys) reported that 43 states had at least one program that specifically encouraged technological innovation [Minnesota, 1988; see also Burton, 1989; Lambright and Teich, 1989; OTA, 1984], and that the states were allocating over $550 million for science and technology initiatives during FY1988. The emphasis in these initiatives is on technological innovation, with slightly over two thirds of the funds being allocated to this objective. According to the Minnesota survey, 41.2% of state funding was allocated to technology or research centers to promote research and development, and 27.3% to research grant programs (up from 18.1% in FY1986). The remainder was apportioned among venture and seed capital programs (6.8%), research parks and incubator facilities (6.7%), technology transfer programs (8.3%, up from 1.2% in FY1986), and technology offices, boards, and commissions, technology training programs, and information/networking programs (7.7%). Emphasis on technology development in turn has (to date) made universities "pivotal institutions in state high-tech policy for economic development" [Eisinger, 1988, p. 275].

Targeting and accountability are integral features of state technology development programs. The clear intent to target these funds toward economic development is reflected in the fact that although most of the grant awards are made to universities, they are administered by state science and technology offices (75%) or by departments of commerce or economic development (20%). Only three states administer these funds through boards responsible for higher education.

Against this backdrop, the analogy of states as laboratories of democracy is plausible and indeed rhetorically persuasive on multiple levels. It recalls the state experimentation that led to New Deal reforms that presaged U.S. economic recovery and international economic hegemony (an especially compelling association in this period of pessimism about America's international economic competitiveness). Moreover, the concept of laboratories has positivistic associations with hypothesis testing and programmatic evaluation. It suggests that effective and ineffective policies are being sorted out, and that this social learning will yield a best-case prototype for federal adoption. Indeed, from fledgling operations spawned in part by an absence of federal programs, state programs have advanced to national prominence through a series of overlapping steps. These steps have included seeking improved federal–state coordination, in part to avoid being swamped by related federal initiatives such as the Engineering Research Centers program of the National Science Foundation (NSF); efforts to garner the benefits of complementary actions, such as resubmitting to state agencies proposals that originally had been entered into NSF competitions; and efforts to secure federal funds for state programs [Hamaty, 1989–1990; Jones, 1989; Tanski, 1989–1990]. By the late 1980s, state programs were increasingly presented as experiments that the federal government could learn from and build upon [Plosilla, 1989–1990].

Federal inaction, however, does not provide a theoretical lens through which the effectiveness of state initiatives can be examined; nor is state action, successful or not, necessarily relevant to the overlapping but not identical set of objectives, scale, or scope of federal science and technology policies.

What is missing in particular is an analysis of the theories of research, invention, innovation, and diffusion subsumed within state technology development and technology transfer programs. This type of analysis is needed to formulate answers to questions about the apportionment of public R&D funds among basic, applied, and commercialization programs; variations in the effectiveness of governmental efforts to commercialize technologies across technologies and industries; the effectiveness of set-aside R&D programs directed at small business firms; the existing and potential capabilities of universities and quasi-public institutions to take on expanded or new responsibilities for technological innovation and technological modernization; and relationships between and core support for targeted academic research and educational programs.

STATE TECHNOLOGY DEVELOPMENT AND TRANSFER STRATEGIES

State technology development programs draw from the common pool of propositions that shape almost all diagnoses of the sources of America's eroding economic competitiveness and technological slippage, and from the common pool of contemporary policy prescriptions. These include concern about the ability of American firms to "commercialize technology or to achieve mass markets for new products after succeeding in the early stages of innovation" [Smith, 1990, p. 18]; institutional rigidities that stifle cooperation between and among government, industries, and universities; the disproportionate emphasis of faculty at research universities on basic research; and the slow and uncertain pace with which research findings generated within academic institutions are converted into commercial products by American firms. Accordingly, state programs typically emphasize research activities within the "generic/applied/developmental" band of a stylized R&D continuum, and closer government–industry–university partnerships in R&D-related activities, with the state's role perceived as that of a catalyst or broker in bringing firms and universities together. In addition, to ensure that the research supported by the program has a commercial rather than an academic orientation, most state programs require that university proposals for state funding include cost-sharing by industrial firms and/or provide for industry representation on the state boards that make awards.

Beneath these similarities, allowing for the presence in many state programs of multiple elements, are significant differences among programs in their theories of technological innovation, and in the effective points for public-sector intervention in these processes. These differences include assumptions about interrelationships among basic, applied, and developmental research and assumptions about technology transfer processes, particularly those that relate to the conversion of academic research into commercial products. Moreover, although most state officials speak of the long-term, circuitous relationships between state-funded technological programs and economic growth, there are manifest differences in the length of time they are willing to allow for tangible outcomes to become evident, and accordingly, significant differences in their acceptance of the different gestation periods required before support of various forms of R&D can reasonably be expected to produce tangible improvements in economic activity. Overall, these differences may be summarized in terms of the relative emphasis given by states to strategies directed at "general R&D capacity strengthening versus applied R&D problem solving" [SRI, 1988, p. E-10].

Feller [1988] described three basic thrusts to state technology development programs: (a) research infrastructure/human capital; (b) generic/precompetitive research; and (c) spin-off/product development. A fourth strategy, (d) technical assistance/manufacturing modernization, is increasingly evident. The following vignettes transform program rationales for a selected number of state programs into an R&D framework and set the stage for subsequent discussion of the match between state experiences and federal decisions.[1]

Research Infrastructure/Human Capital

The infrastructure approach is most clearly evident in Texas's two major programs. The Advanced Research Program targets basic research projects in several scientific fields, including astronomy, atmospheric science, chemistry, mathematics, oceanography, and physics, as well as (singularly, for a state program) the social sciences. The Advanced Technology Programs support research in areas in which Texas universities have demonstrated strengths (e.g., biomedicine), but also in scientific and technological fields such as material science, biotechnology, and marine technology, in which universities in the state are considered to have embryonic capabilities. As described by state officials, these programs are predicated on two beliefs: that academic research contributes to the knowledge base from which technological innovations emerge, and that the state's long-term economic growth depends on the quality of its human capital, including the attraction of world-class university researchers and the recruitment, training, and retention of graduate students [Texas Higher Education Coordinating Board, 1988]. Consequently, each of the two programs focuses on individual researchers rather than on centers, is oriented more toward education than technology transfer or job creation, and encourages but does not require the contribution of matching funds by industry.

Development of the research and graduate infrastructure of regional universities is also a major goal of some of the state programs typically viewed as applied research grant programs. The Massachusetts Centers for Excellence program and Florida's Applied Research Grant programs emphasize applied R&D projects with near-term commercial application and require matching contributions from industry. However, in each case, these projects are tied to the larger objective of orienting the state's universities toward increased emphasis on faculty research and graduate education [Ferguson and Ladd, 1988; Florida, 1990].

Generic/Precompetitive Research

Two of the larger state programs, New Jersey's Advanced Technology Centers and Ohio's Thomas Edison Centers, may be viewed as comprehensive R&D programs. Each is conducted in a decentralized manner through separate centers, but with major commitments to generic research.

New Jersey's program bridges several strategic thrusts. The New Jersey Commission on Science and Technology [1988] has described its early efforts in science and technology as having

[1] Distilling the R&D strategies embedded in state technology programs is difficult because these programs are economic development programs, not science or technology programs per se. Thus analyses directed at the theoretical and empirical associations between science and technology inputs and economic growth may be unduly restrictive in that they fail to consider indirect associations between specific R&D strategies and economic growth, and the possible stimulative effects of state activism. In addition, state programs are experiencing shifts in strategy, allocation criteria, and administrative practices within the framework of largely unchanged mission statements and organizational forms. Snapshot accounts are readily dated.

largely been focused on the development of a science and technology research infrastructure in New Jersey. Our investments have been primarily directed towards support of research in academic settings; unlike some other state development agencies (i.e., the Economic Development Authority), the bulk of funding has not been directed to specific firms.

Further, the Commission notes:

Our strategic emphasis in these early years calls for the development of science and technology resources which will improve the business climate for all science and technology firms, whether or not they are active participants in Commission programs. In the long run, this approach should lead to greater business formation, and better company survival rates, than would otherwise be the case. [p. 5]

Organized around biotechnology, advanced materials, telematics, and environmental protection research, the aggregate activities of the eleven New Jersey Advanced Technology Centers span basic research, generic research, applied research, technology transfer, education, and clinical research. The state's strategy also explicitly views the centers as a training ground for a technically trained, scientific work force. Among the state programs, New Jersey's most emphasizes the importance of world-class basic research programs as essential components of an overall state R&D strategy. The Center for Advanced Food Technology, for example, is described as "unique in the world for its industry-university cooperative mechanisms for conducting precompetitive interdisciplinary research" [New Jersey, 1990, p. 6]. The Center for Ceramic Research at Rutgers University is similarly described as "fulfilling its mission to provide world-class resources for the development of new technologies in both advanced and traditional ceramics," while the Center for Photonics and Optoelectronic Materials is presented as strengthening the lead of New Jersey–based companies in emerging technologies related to light-based telecommunications systems and high-speed optical computers [p. 13].

Ohio's Thomas Edison Centers program is comprised of nine autonomous centers. Although diverse in technology, mission, regional coverage, and clientele, the activities of these centers cluster about three broad categories of mission and client relationships: providing information or adaptations of existing technologies for smaller, technologically less-sophisticated companies; generating state-of-the-art knowledge for larger companies; and generating cutting-edge technologies for the creation of new companies and products [National Research Council (NRC), 1990]. Collectively, these centers span the gamut of R&D activities. The Edison Polymer Innovation Corporation, for example, links "two internationally known polymer research institutions, Case Western Reserve University and the University of Akron" [p. 17] and about 80 corporate members, including most of the polymer companies in Ohio and many worldwide polymer companies, in a program directed at generic research, company-directed research, and problem solving. The Edison Materials Technology Center has a quite different orientation: It serves firms in the Dayton area, primarily through short-term problem solving and applied R&D projects.

The implicit research/innovation/technology transfer/commercialization theories reflected in the support by New Jersey and Ohio of leading-edge technologies and generic/precompetitive research are that (a) the competitive position of firms in markets characterized by rapidly changing technologies is significantly affected by the speed with which these firms can introduce new products into the market; and (b) this positioning can be improved by closer linkages to "upstream" suppliers of knowledge [Nelson, 1986]. The fields and types of research supported in the New Jersey and Ohio (and New York) programs accord with the increased participation of R&D-intensive firms in strategic alliances that have generally been presented as supplementary to the firm's principal reliance on its corporate R&D staffs for product development [Fusfeld and Haklisch, 1987; Link and Tassey, 1987].

By emphasizing generic research and the involvement of research universities rather than all institutions of higher education, the New Jersey and New York programs and selected Ohio centers have tended to attract the participation of Fortune 500, R&D-intensive firms. Implicit in this combination of partners and projects is a technology transfer process between academic research and commercial production that is based on a firm's in-house R&D capabilities to receive and transform the basic/generic research performed by universities into commercial products. This capability has been identified as a critical determinant of a firm's willingness to contract out for research and development [Mowery, 1980; Mowery and Rosenberg, 1989], and as a key to the success of new strategic alliances.

Spin-off/Product Development

Pennsylvania's Ben Franklin Partnership Program (BFP) is the primary example of a state strategy that emphasizes the targeting of selected technologies for commercialization. The BFP is a comprehensive program that includes four advanced technology centers (ATCs), seed research grants, small business incubator loans, and seed venture-capital funds. Each of the four ATCs is affiliated with a university or consortium of universities. These ATCs are in effect administrative units that organize and oversee discrete projects in R&D, entrepreneurial development, education, and training, with specific projects conducted by a network of academic researchers, not-for-profit organizations, and firms.

Pennsylvania's original strategy combined two distinctive features—an emphasis on the "more rapid commercial application of R&D into the marketplace" [Plosilla, 1986, p. 268], and acceptance of the premise, associated with the work of David Birch [1987], that small firms are the principal sources of technological innovation and new job creation. Accordingly, the program's award criteria emphasize the participation of young, entrepreneurial companies in the university–industry projects supported through the advanced technology centers, and focus relatively more so than other states on product development rather than on generic research projects. In allocating funds among its four centers, the Ben Franklin Partnership Program also accords considerable weight to matching contributions by firms (on the grounds that the ratio of the match to the dollars requested from the state is a meaningful indicator of the prospective commercializability of the project's output).

The BFP R&D strategy posits close linkages between (very) applied research and commercial introduction of technological innovations. In effect, the program seeks to use commercially oriented academic R&D as the springboard for the formation of new firms. It thus implicitly treats scientific and technical knowledge (and state investment in higher education) as a stock that may be readily drawn upon, and that with minor investments may be configured into commercial innovations. Indeed, although organized around four ATCs tied to sponsoring universities, the Ben Franklin Partnership Program is permeated by a concern that funds not be used for academic research but for projects having commercial potential.

Although couched in the long-term character of the linkages between technological innovation and economic growth, the BFP also was characterized relative to other state programs by its far greater emphasis on near-term outcomes and on job creation as the primary desideratum of project performance. This emphasis in turn has led to short-term demands on grantees for demonstrable outcomes, although there are indications of a shift in the program's priorities toward longer-term projects, which presumably also would allow for less developmentally focused applied research projects [Christman, 1988].

Technical Assistance/Manufacturing Modernization

The overlapping activities of problem-solving R&D, technical assistance, technology transfer, and manufacturing modernization are becoming an increasingly visible facet of many state technology programs. In states with ATCs, these programs complement endeavors at technological innovation[2]; in other states, expanded or new technology modernization programs targeted at existing firms are becoming a central component of state strategies. According to a 1989 National Governors Association survey, 167 state- and federally-supported organizations offer a broad band of services, including technology assistance, to small and medium-sized firms. Nine states currently support 13 state-supported technology extension services that provide direct consultation for technology deployment. These programs are conducted through a heterogeneous array of organizational forms, and include long-standing programs, university-based programs such as Georgia Tech's Industrial Extension Service and the Pennsylvania Technical Assistance Program (PennTAP), and community college-based programs such as Ohio's Technology Transfer Organization (OTTO), as well as newer organizations with expanded modernization missions. Examples of these are the Michigan Modernization Service, which offers a range of services that includes assessments of a firm's manufacturing, training, and market needs, and Pennsylvania's Industrial Resource Centers, which are organized about specific technological clusters [Shapira 1990a, 1990b; OTA, 1990]. In general, state-supported technology extension services serve small and medium-sized businesses by facilitating access to existing off-the-shelf technology. Only one third of the firms using these services report requiring access to new technologies.

For small firms, the context for problem-solving R&D has been described by the National Research Council [1990, p. 6] in its account of Ohio's Thomas Edison Centers: "Many smaller enterprises, in particular, lack the expertise to make critical decisions about changes in technology, operating procedures,

[2] New Jersey, for example, in addition to its advanced technology centers, has developed a set of Technology Extension Centers organized about specific technologies, such as polymer processing, fisheries and aquaculture, and cancer treatments, to reach a wider array of small and medium-sized firms, public and not-for-profit users of technological innovations.

and staff training." The general operating characteristics of centers organized to provide this service are laid out as follows:

> These activities are unlikely to reach companies located beyond the effective day-to-day operating radius of the center (about 30 miles). Although these activities might not have unique intellectual content and might not achieve recognition beyond the region, they can meet fundamental industrial needs directly and effectively. Even if neither the local companies nor the local academic institutions have unique resources, the marriage of industry and academe for a common purpose can be a powerful technological and economic tool. [pp. 6–7]

Technical assistance programs reflect the state official's view that existing firms need assistance to close the gap from "average" to "best" practice. Firms also often require specific solutions to bottleneck problems, with solutions to these problems requiring either short-term problem-focused R&D or technical assistance. Implicit too in these efforts is the view that market failures require governmental assistance to underwrite a socially optimal supply of this knowledge.

In addition, a new source of demand for technical assistance has arisen from small high-tech firms seeking to capitalize on the generic research findings emanating from state-funded centers of excellence. Lacking the in-house capabilities of the large firms that participated in the centers and who were satisfied with the generic character of research findings, small high-tech firms at times required detailed, in-plant instruction if they were to benefit from the research findings emerging from centers of excellence [Williams, 1986].

The increased attention to technology transfer and technical assistance draws from a number of sources. Within states with advanced technology centers, it represents recognition by state officials and center directors that demonstration of the impacts of research activities is needed if the centers are to continue to receive state support. It also represents protection against political charges that only the large firms benefit from the state's programs. In New Jersey, for example, each of the four Advanced Technology Centers has a modicum of technology transfer and educational activities; indeed, reflecting the increased importance of technology transfer to state officials, each center was required as of 1990 to direct at least 10% of the funds it received from the commission for technology activities toward either major research sponsors or small New Jersey businesses that "would not otherwise participate in a research program" [New Jersey, 1990, p. 3]. For other states with only a few resident firms directly involved in the production of high-tech products or with universities with world-class research capabilities, the new emphasis on technological modernization represents an effort to maintain the technical competitiveness of firms that supply components in the face of more stringent demands for input reliability and global outsourcing.

EVALUATION

Methodological, empirical, political, and policy questions pervade the evaluation of state technology development programs and the validity of the claims made by and for state programs [Feller, 1988; Evans and Triplett, 1989;

Jaschik, 1987]; even more, they affect recourse to state experiences in the formulation of national science and technology policies.

Evaluation issues raise a number of immediately identifiable and specific methodological and descriptive points. These include at least the following three questions: What techniques are states employing to evaluate their programs? What findings have emerged from these evaluations? What is the validity of existing statements about the effectiveness of state programs? These issues are noted here, albeit primarily as steps necessary to examine the role that perceptions of program effectiveness play in conditioning agreement among members of a policy community about alternative approaches.

The difficulties of evaluating state technology development programs have been widely recognized from their inception. As described by Watkins and Wells [1986],

> . . . there are numerous technical difficulties associated with the newness of most programs, the absence of standardized effectiveness measures, the lack of data collection on program impact and the difficulty of attributing causality in such data where it exists. [p. 83]

Similarly, most of the state program managers who participated in a 1987 workshop on program assessment noted the difficulties of judging the extent and accuracy with which new economic development could be attributed to specific research and development programs and of providing quantitative data on the short-term and long-term impacts of their programs [Government–University–Industry Roundtable, 1987].

The need to justify program budgets to state legislatures as well as self-motivated efforts to determine the effectiveness of program strategies has propelled programs into periodic assessments despite these difficulties. As total expenditures for technology development programs mount—they are now in excess of $100 million in several states—legislatures have increased the pressure for demonstrable economic benefits. Moreover, the close identification of state advanced-technology programs with the governors who initiated them, as in Pennsylvania, Ohio, Michigan, and New Jersey, has led to efforts to convert gubernatorial projects into the broadly accepted ongoing operations of state government as these individuals prepare to leave office. Evaluation thus becomes an element in providing a documented basis for routinization. Telephone interviews conducted in early 1990 point to a number of major evaluation projects underway that extend beyond annual budget justifications.

In the context of multiple program objectives, multiple activities within programs, and the methodological and data difficulties cited above, evaluations of state advanced-technology programs have tended in general to be structured about three broad criteria: management and administration, performance and results, and relationships. A number of proximate indicators involving an assemblage of quantitative and qualitative sources have been used to gauge performance within each criterion, including patent disclosures, commercial application of research findings, technical excellence of research activities, participation of start-up firms or small businesses, number and characteristics of participants in entrepreneurial and outreach programs, and quality of administrative leadership [Dimanescu and Botkin, 1986; Feller, 1988; Osborne, 1990].

For the most part, assessments of state programs have taken one of two forms. They are either internal state documents prepared by program officials in preparation for annual budget reviews or by legislative oversight bureaus as part of sunset audits, or they are qualitative assessments by outside observers. Allowing on the one hand for potential partisan biases and on the other for data and resource constraints, legislative audits represent a potentially important source of information on program impacts. In the main, though, legislative oversight reports tend to be confined to the corridors of state capitals, with the outcome assessments, criticism, and recommended changes in programs absent from or muted in more widely disseminated accounts.

External reviewers have been used in several states to conduct specific forms of evaluation. In New York, they were used to make recommendations during the original competition to establish centers; in Texas they are used to make peer review judgments on the scientific merit of individual research proposals. Most recently they have been used in Ohio in a series of reviews of the state's Thomas Edison Centers. Among these latter reviews was one conducted by the NRC's Commission on Engineering and Technical Systems. Because of the national standing of the review body and the highly complimentary and supportive tenor of its findings, the NRC document serves as a useful guide to current assessment techniques.

The NRC report [1990] notes that a common purpose to contribute to economic development in Ohio has led the nine Thomas Edison Centers to diverse missions, organizations, and clients. "One result of this diversity," according to the NRC, "is that no set of evaluation criteria can be applied uniformly to all centers." Furthermore, the report continues, "the multiple purposes of the programs, the long periods necessary before some of the activities will significantly augment the state's economic base, and the impossibility of controlled experiments make quantitative evaluation difficult" [p. 1]. Given these difficulties as well as the absence of hard data, "the only realistic evaluations are qualitative," a situation, in the NRC's view, that is not likely to change over the next few years. Centers are thus to be judged "according to evidence of networking, a broad base of industrial and academic support, the willingness of larger companies to invest money and of smaller companies to invest time, and clearly defined missions and programs aimed at regional economic development" [p. 25]. The NRC report concludes by finding the Edison Centers program to be "a vigorous, well-managed program that is valued by Ohio's industrial community"; to be "making a significant and growing contribution to industrial competitiveness in Ohio"; and to be "a well-conceived approach to government–university–industry partnerships that reflect Ohio's situation" [p. 25]. The report also notes that "despite the unavailability of quantitative measures of contributions to economic development, the Edison Centers program has undeniably resulted in significant increases in much-needed technical assistance to small industries." It is also credited with "real progress" in the transfer of technology from research universities to industries of all sizes and in the fostering of the commercial exploitation of several emerging technologies.

Several issues beyond the difficulties noted above shape the extent to which existing assessments of state experiences are reliable and valid guides to federal R&D policies. First, most assessments relate to the overall objective of these programs—economic development. In general, but especially so in the case of comprehensive programs that encompass a number of policy instruments, the association between positive outcomes related to economic development and specific program elements related to research and development is seldom directly evident. The loose analytical or empirical coupling between these two creates the possibility of strategy–instrument–outcome linkages that can be irrelevant when not outright misleading. For example, Osborne's encomiums to the Ben Franklin Partnership Program for its role in stimulating the growth of Pittsburgh's high-technology sector identifies matching grants to seed capital funds, conferences, publications and mentoring programs, and annual fairs for venture capitalists; what is absent is any reference to the program's distinctive R&D strategy, which accounts for approximately 60% of its expenditures [Osborne, 1990]. More to the point, although noting that the evaluations of the Ben Franklin Partnership Program suggest "a basically sound program which has made important contributions to the state's economy," the Ben Franklin Partnership Fund Board has expressed its concern about the diminishing importance of research and development activities relative to third-party entrepreneurial assistance projects as a factor in new job creation start-up of new companies, and has called attention to the imputed costs of job creation [BFP Board, 1988, pp. 7–8]. Thus, given the comprehensiveness of the BFP, it is logically consistent for the overall program to contribute to economic development, even though large components of its efforts are ineffective or inefficient.

The issue of the absence of data is a recurrent one, but in a different context and for different reasons than are suggested in the NRC report. The supply of data available to assess state programs (and the reliability of the data used) has been a function of program structures, the selective posing of questions, and the absence of auditing procedures to verify claims. The decentralized character and diverse activities of centers of excellence programs means that state officials tend to request or receive data that would permit them to monitor administrative performance and to assess proximate outcomes on the basis of the activities of centers and program elements. This emphasis is appropriate given that the primary audience for these evaluations is executive budget offices or legislative appropriations committees. It means, however, that the evaluations are strikingly uninformative as to how and why programs are having the impacts reported. In particular, these evaluations provide little information about how the other parties—firms or universities—behave in response to state incentives. Hendry's [1989] characterization of the policy literature on industrial innovation is appropriate here:

> The general presumption appears to be that the passage from a policy's formulation by government to its implementation in industry is not in itself problematic. The firm's response is taken for granted and taken, moreover, at face value. It takes very little reflection to realize, however, that the apparent response of a firm may be very different from its real response, and that the latter may well differ significantly from what was envisaged by the policy makers. [p. 4]

In the absence of systematic evaluation protocols, specific assessments of state evaluation policies are highly vulnerable to undue reliance on statements from business firms and single case studies concerning new firm formation, job creation or retention, or product development. Endorsement by participants of state programs—a frequent mode of evaluation—is of uncertain value, however. Hendry calls attention to differences between a firm's public or rhetorical response to government measures and its private or actual response.

> This difference takes on a particular significance when public policy rests on some form of coordination or cooperation things that can be readily created in form without having any reality in substance. Most policy measures do in fact incorporate some form of collaborations—between firms in precompetitive research, between firms and government establishments or universities, between different government agencies—but neither the theoretical form of this collaboration nor the rhetoric of those involved in it is necessarily any guide to what is taking place at a substantive level. The rhetoric will be guided by a desire to maximize both friends and funding. The practice is more likely to be dictated by the internally established aims and priorities of the organization in question. [p. 5]

The quality of evaluation relates of course both to the internal and external validity of the statements made about these programs, both for state and national purposes. The laboratory analogy is used at times to highlight the special advantage of the "limited" nature of state experimentation.[3] According to Osborne [1988, p. 2], "Those experiments that worked could be applied nationally; those that failed could be discarded." But this proposition does not necessarily hold. Passing political muster in terms of renewed appropriations is not synonymous with achieving program outcomes, particularly if the side conditions of effectiveness or efficiency are introduced. The factors that expert panels have looked at, as in the National Research Council's review of Ohio's Thomas Edison Centers program, cover (and similarly blur) multiple paths of causation. In addition, although specific project activities may have been terminated, it is not readily apparent that programs themselves, which by some absolute or relative standard either have failed or are failing, have been terminated. Strong grass-roots ties are already evident between the local academic, business, and government constituencies that have built up about centers and elected state officials. Major cutbacks would likely run into political opposition even in the face of critical evaluations.

For the most part, existing evaluations and studies lack any modicum of experimental design, including as minimum conditions the collection of baseline data, efforts to adjust for cyclical or secular trends, or use of rudimentary comparisons. Absent, too, are efforts to collect or assemble data that would permit analyses of intervening (or confounding) relationships, such as industrial structure or technological field, that other studies have found to be important in analyzing the impacts of government support of the commercialization of technology.

Case histories of successful projects can be cited [Weinberg, 1988], and numerous examples of successes appear in program documents and the relevant literature. These accounts seldom detail causes for success. They jump from program design to bruited outcome; failure is seldom described. More importantly, given the scale of these programs and the number of grantees

[3] Bryce's [1888] aphorism on the American political system has been (and is) aptly quoted here:

> Federalism enables a people to try an experiment in legislation and administration which could not be safely tried in a large centralized country. A comparatively small commonwealth like an American State easily makes and unmakes its laws; mistakes are not serious, for they are soon corrected; other States profit by the experience of a law or a method which has worked well or ill in the state that has tried it. [p. 84]

and projects they involve, a number of successes is a probable outcome; unless very large in economic impact, they do not attest to the overall efficiency of a program or the validity of the underlying theoretical basis of the program's strategy.

Biases toward Type I errors are endemic both in state program accounts and the literature[4]; they are the product of the political character of these programs at both the state and national levels [Feller, 1984], the largely unaudited character of program claims, the predilection of commentators to focus on political and organizational relationships, the disregard or erroneous treatment of propositions derived from economic or evaluation frameworks, and a "pro-innovation bias" [Rogers, 1983] that follows from the desire both to see innovative state programs succeed and to use them as a lever to move a refractory national administration.

Overall, accepting the difficulties inherent in the undertaking, existing evaluations of state technology development and technology transfer programs are less well done than they could be, and the validity of the "lessons" contained in existing accounts of state programs is itself open to review.

But more is at issue than the extent to which existing assessments and accounts meet standards of reliability and validity. Policy formulation in some settings may be seen as a match between analysis and analogy, between examination of alternatives and coalescence about (and commitment to) reportedly successful undertakings. Evaluation, so to speak, occupies the midfielder's position. Analogies are frequently used and indeed potentially efficient techniques of policy formulation. Rather than undertake a systematic analysis of alternatives, policy makers formulate policies or react to situations by reasoning that approaches which purportedly fit similar situations are appropriate to their situation. In addition, as Ruse has suggested, analogies can serve as heuristics. They break apart the properties of new situations that appear to resemble other situations, thereby leading to discovery followed by an improved understanding of a problem and new insights into attainable solutions [Ruse, 1986].

Analogy, however, may segue into and displace evaluation. Using analogy to justify a program can mislead policymakers about a problem or lead to incorrect assessments of the effectiveness of policies offered for emulation and adoption. By positing but not demonstrating that N has some properties of M and therefore must have other factors of M relevant to the issue at hand, analogy can displace logical and empirical tests.[5]

The effect is carried over into policymaking by a process well described by Carol Weiss [1988, p. 9]: Evaluation results affect policies not by influencing

[4] Type II errors are also likely. Pressures for short-term, quantifiable outcomes and the use of lists of indicators taken from other state economic development programs, such as industrial development loans, push state officials toward performance measures such as patents, leverage ratios, dollar awards from federal agencies, job retention and creation, and away from consideration of impacts that do not fit within mandated reporting requirements or that are given little weight in legislative budget hearings. Similar self-censoring can occur in those states in which center directors submit budgets to state boards that allocate funds on a competitive, "performance" basis.

[5] "The truth of that from which you are arguing is vitally important. If M does not exist, or does not have properties a_i through a_n, or does not have b, or if N does not have properties a_i through a_n, your analogy-as-justification (in its present form) collapses. Your general statement is unsupported, or N is not an instance of M" [Ruse, 1986, p. 34].

single decisionmakers who are selecting among options at a single, fixed point in time, but rather by generating a set of generalizations that come "into currency among the many groups and interests involved in a policy domain." When assimilating and sifting the multiple bits of information they receive about new programs and claims of success, policy actors perform their own intuitive metaanalysis as they figure out what the current state of program knowledge is. According to Weiss,

> . . . as evaluation moves into currency and becomes accepted by informed publics, it can change premises that are taken for granted in the issues that are seen as problematical. . . . It can show which kinds of actions work well and thus recast the types of alternatives that are considered as potential solutions. In these ways evaluation serves to enlighten policy discourse. [p. 11]

Similarly, John Kingdon [1983] has observed that something akin to a bandwagon effect often occurs as policy specialists reach some understanding of a fairly narrow set of alternatives from which choices might be made. In this context the language of experiments and laboratories, coupled with evaluation reports and claims, exerts influence within an intergovernmental system. Claims that state science and technology programs are effective and have relevance to national policies are widely disseminated at the same time that reservations about the state of knowledge of state technology development programs are emerging.

CONCLUSION

Describing the initial acceptance of the somatic mutation thesis, molecular biologist Harry Rubin [1980] wrote:

> Yet there is no force that can resist an idea whose time has come, whether the idea be right, wrong, or simply inadequate. Timeliness, rather than determination to take the whole evidence into account, may be responsible for the current popularity of the somatic mutation hypothesis.

Timeliness also influences the status accorded state technology development programs in the dialogue over the formulation of national science and technology policies. A cascade of studies and calls for economic reindustrialization encountered first the Reagan administration's antipathy and now the Bush administration's resistance to any semblance of an industrial policy. States in the meantime acted, as Anton [1989] has written, in response "to political pressures to 'do something' at a moment in history when no one knew what could or should have been done" [p. 343].

To return to the first of this article's opening three questions, what states have done is establish programs that encompass a variety of R&D strategies. As suggested above, it is conceptually possible to aggregate those approaches to arrive at a spectrum from support of basic research (and research infrastructure) to applied research projects. However, this diversity of state projects, a feature applauded in the context of the "laboratories of democracy" analogy, requires an assessment of their relative effectiveness if they are to be used to shape federal programs. State strategies such as in Texas and Pennsylvania, for example, represent fundamentally contrasting theories of the linkages among academic research, technological innovation, economic growth, and administrative practices.

This contrast suggests that the widespread proposition in accounts of state programs—that each state is a unique actor that selects, develops, and adopts a program that best suits its needs and resources—is not acceptable when the level of action shifts to the national government. For example, Pennsylvania's Ben Franklin Partnership Program's standing as "a model program—and it is recognized as such throughout the nation" [Osborne, 1987, p. 59], must be carefully examined at least from the perspective of its import for national R&D policies. The BFP's emphasis on small high-tech firms as progenitors of economic growth rests heavily on a thesis whose analytical and empirical bases are increasingly questionable [Brown, Hamilton, and Medoff, 1990; Dunne, Roberts, and Samuelson, 1989; Passell, 1990].[6] In addition, key features of the Ohio, New Jersey, and New York programs, with their emphasis on university–industry alliances targeted at generic research, closely resemble strategies found in existing federal initiatives, most notably NSF's Engineering Research Centers. The relevant issue at the national level may relate less to the use of any or all state programs as models than to the garnering of political support for increased budgetary outlays for programs directed at fostering technological innovation.

As for the second question, state programs are for the most part unproven undertakings.[7] Evaluation of state technology programs has essentially remained stuck on dead center. Citation of the difficulties of conducting controlled experiments to justify uses of the qualitative measures as the only feasible method of evaluation, as in the NRC report on Ohio's Thomas Edison Centers program, uses the difficulties of performing "perfect" evaluations to legitimize a state of practice currently below feasible standards. Recitation of difficulties in evaluation and caveats concerning interpretation of findings have become ritualistic: dissemination of claims [e.g., Thornburgh, 1989], findings, and lessons to policy networks continue unchecked by unanswered questions about reliability, internal validity, and external validity. Well-established quasi-experimental approaches to the evaluation of social interventions, the numerous techniques available to evaluate field experiments [e.g., Cook and Campbell, 1979; Judd and Kenny, 1981; Mohr, 1988], and the use of these techniques to examine comparable programs [Luger and Goldstein, 1990] have been essentially disregarded.

Finally, the relevance both of state programs and of existing accounts of these programs to national science and technology policy is open to question. Although insightful about the characteristics of the American political system and state economic development programs, contemporary accounts are not

[6] Referring to the empirical basis of Birch's thesis, Tornatzky and Fleischer [1988] write:

> Although most of this qualifying research tended to confirm the disproportionate role that new high-technology firms played in job creation, they pointed out that the numerical estimates of this contribution were quite unstable and highly contingent upon databases used, unit of analysis, and other statistical assumptions [p. 258].

[7] After surveying state-level university-based efforts to increase manufacturing productivity through the transfer of technologies, Wyckoff and Tornatzky [1988] write that although these programs are "laudable" and "represent an interesting economic development strategy that seeks to build on indigenous strengths," as yet, "the concept of state-level manufacturing programs remains unproven" [p. 480].

couched in an analytical framework conducive to assessments of national policies. Seldom addressed in any of these accounts is the proposition that market failure exists in any or all of the specific elements contained within state programs—R&D, technical assistance, entrepreneurial development. Examination of the form and magnitude of market failure, and of countervailing potentials for government failure [Krueger, 1990]—issues likely to be raised in policy debates at the national level—are largely absent. Existing accounts are also studded with questionable propositions about the processes of technological innovation, particularly the processes by which academic research is transformed into commercial products.

There are missed opportunities in all of this. States could indeed serve as laboratories to address important theoretical and policy issues. Notable among these is the search for an analytically defensible and operationally viable national technology policy. Analytically, debates over U.S. technology policies are dominated by the property rights/appropriability paradigm derived from a neoclassical perspective of the economics of research and development. Increasingly, this paradigm is seen as deficient because it provides little (or incorrect) guidance on the effects of public-sector support on the commercialization of research and development [Dasgupta and Stoneman, 1987; Mowery and Rosenberg, 1989], or on the conditions under which selective use of policy instruments can promote technological change without being subverted by rent-seeking behavior [Pack and Westphal, 1986]. This recent theoretical work, however, has been faulted for "say[ing] relatively little about the practical aspects of policy implementation" [Schankerman, 1990, p. 1759]. A related emphasis on the need to customize generic policy approaches to specific organizational and industrial settings is provided by Nelson and Langlois [1983], who observe "that the kinds of government programs that have shown themselves feasible and effective vary greatly among industrial sectors, depending upon the nature of governmental involvement and the nature of competition in the industry" [p. 814].

State science and technology programs would appear to offer a "natural" test bed for comparative analysis, for they offer a distinctive array of the organizational forms, mechanisms of support, technologies, and industrial sectors needed to transform emerging theoretical perspectives into effective and efficient operational programs. But they have not been analyzed in this way. At most the current set of generalizations about state experiences is properly seen as a set of working hypotheses that now require scrutiny, not as tested experiments that provide lessons to guide national policies.

None of this is to gainsay the public-sector entrepreneurship exhibited by state officials; the possible salutary demonstration effects of this stance on federal policy makers; the scientific, technological, or economic advances that are likely to be generated by these programs; and their continuing potential to yield new insights into processes of technological change and government–university–industry partnerships. It is rather that the use, diffusion, and acceptance of Justice Brandeis's observation, "It is one of the happy incidents of the federal system that a single courageous State may, if its citizens choose, serve as a laboratory; and try novel social and economic experiments without risk to the rest of the country," has been overdone. Using analogy to justify the basing of national policies on state experiments has entered the realm of negative analytical returns.

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