Universities and State Policy Formation: Rationalizing a Nanotechnology Strategy in Pennsylvania

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Abstract

Technology-based economic development programs have become a salient feature of the state policy landscape since the 1980s. While much research exists on the topic, little attention has been given to the processes of policy formation. State programs have moved towards high technology areas emphasized at the federal level over the past decades, and nanotechnology became one of the latest targets. This paper examines the eight-year process through which Pennsylvania adopted a "state-wide strategy," culminating in the Pennsylvania Initiative for Nanotechnology. In this process, programs that responded to the interests of multiple agents came first, and a state policy was formulated after the fact. This pattern of "rationalized policy formation," as opposed to rational policy formation, may be more common than suspected. Its strengths and weaknesses in this Pennsylvania case are discussed.

KEY WORDS: state policy, science and technology, technology-based economic development, university, policy formation, nanotechnology

Introduction

Technology-based economic development (TBED) programs have become a salient feature of the state policy landscape since the 1980s. Such programs are part of the evolution of state economic development policy from the industrial recruitment approach to the entrepreneurial approach (Berglund & Coburn, 1995; Eisinger, 1988, 1995; Plosila, 2004).[2] Their design and objectives have been examined in light of a growing body of knowledge on technology transfer, the economics of public R&D, and the role of innovation in economic growth (Feller, 1997; Feller, 2004). States have experimented with a wide range of approaches over the years, as expressed in the 'Laboratories of Democracy' (Osborne, 1990) metaphor. The metaphor denotes the optimism of TBED proponents on the role of states in fostering innovation. As state high-technology initiatives have gained renewed momentum over the decade (Douglass, 2006; Geiger & Sá, 2005), advocates have propagated 'best practices' and proposed a range of policy instruments (National Governors Association, 2007; State Science and Technology Institute [SSTI], 2006). Underlying these prescriptions is the belief that states will (and do) in fact employ rational models of policy making, based on the systematic analysis of state capabilities and strategic choice of technological areas and programs.

Nonetheless, there has long been criticism of state technology policies. Against the optimism of enthusiasts of state policy experimentation, some analysts wonder if the collective learning that might result from decentralized innovation is reliable given the weakness of assessments and evaluations (Feller, 1992a). Also, the characteristics of state policy making in this sector are sometimes viewed as antithetical to the development of effective programs. Previous studies have noted the tendency for geographical dispersion of resources, pork barrel allocations, and short-term objectives that match the electoral cycle to influence the formation of state high technology initiatives (Douglass, 2006; Etzkowitz, 1997; Feller, 1984, 1992b). These features are detrimental to good policy, as both theorists and practitioners believe that maintaining a long-term perspective is crucial for TBED, and that merit-based criteria should guide resource allocation (Feller, 2004; Plosila, 2004; SSTI, 2006; Zumeta, 2006). Merit, whether by academic standards or market principles, is preferable to favoritism as a criterion for allocating scarce resources to both upstream investments in scientific quality and infrastructure and downstream subsidies to applied research and development (R&D) and commercialization efforts.

Hence, one fundamental issue to the success of state TBED concerns the ability of states to design and implement high technology programs effectively. Exploiting such areas successfully through strategic planning is a major theme in this policy realm (Feller, 2004). Reports on the implications of state policies have appeared frequently, but studies of how states form high-technology programs have been less common. Nonetheless, a few previous studies on the formation of state TBED programs suggest that modes of policy making affect policy effectiveness (e.g., Atkinson, 1991; Portz & Eisinger, 1991).

This paper contributes to the sparse literature on the formation of state technology programs by examining the process through which a 'statewide strategy for nanotechnology' came about in Pennsylvania. The selection of this case is propitious for exploring how states adopt TBED programs in an emerging technological area. The Pennsylvania Initiative for Nanotechnology (PIN) was announced in 2005 after six years of state investments surpassing $42 million. As one of the first states to make investments in the field, Pennsylvania allows for the investigation of the role of analysis and planning in the formation of state technology programs, as opposed to simple imitation of existing policies. As presented by the state, PIN seems to be a textbook case of a TBED initiative: it targets an inchoate science-based technology for which no industrial agglomeration has yet achieved a dominant position; it involves industry and the state's higher education institutions, both in R&D and educational efforts; and, finally, it purportedly rests on a strategic assessment of state capabilities and technological opportunities.

The research was exploratory and sought to identify relevant themes and analytical categories, rather than test a preestablished set of propositions. The following questions were addressed: How and why did Pennsylvania choose to invest in nanotechnology? Who were the actors shaping that decision? How did the current initiative get formed and why? What was the role of the preexisting science and technology (S&T) policy infrastructure in the elaboration of a strategy for nanotechnology? How does PIN relate to the state capabilities in the field? The evolution of the state nanotechnology policy was reconstructed based on elite interviews, following the "chain" sampling technique. In-depth, semistructured interviews were conducted with current and former state officials, university administrators, scientists, and industry representatives. Interviews were conducted between spring 2005 and spring 2006.

The paper proceeds as follows. The next section synthesizes studies on the formation of state high technology policies. The following section presents the case study. Next, Pennsylvania's efforts are contextualized nationally. The final section discusses findings and conclusions.

Literature—TBED Policy Formation

The premise of TBED is that if states are to prosper in a global knowledge economy, they need to build innovative capabilities and carve out niches in which they can excel (Plosila, 2004; SSTI, 2006). Despite the trend among states of pursuing the latest technological waves, we know little about how states develop TBED programs in emerging areas of technology. This problem is interesting as the inchoate state of such technologies entail substantive risks and uncertainties for policy makers.

Hard-pressed to produce tangible outcomes, 'economic development policy makers in the American states face strong political incentives to do the wrong thing' (Hart, 2007, p. 4). The 'wrong thing' is industrial recruitment policy, which generates political dividends despite the cumulative evidence of ineffectiveness in generating economic development. These dividends accrue from the visibility of beneficiary constituents of successful industrial recruitment efforts, the large facilities erected that help attract publicity, and the tangible economic activity generated (and the invisibility of foregone revenues and opportunity costs). TBED programs, on the other hand, aim at influencing a range of largely unspecified actors, and their benefits are more diffuse. Inherently long term, investments on building innovative capabilities and creating entrepreneurial cultures coexist with the short-term political pressures for hard, short-term measures of employment generation and business development. TBED policies may have unclear tangible benefits to substantiate their claims for state resources.

Notwithstanding the uncertainty, most states are presently committed to TBED strategies in one way or another. Previous studies suggest that governors are key to the adoption by states of high technology agendas (Douglass, 2006; Etzkowitz, 1997; Feller, 1984). This is consistent with recent findings on entrepreneurial economic development policy (including but not limited to TBED) that policy making follows a technocratic pattern (Hart, 2007). Governors and their appointees to senior positions shape policy, and entrepreneurs—the target constituency—do not appear to influence policy making. On the other hand, Plosila (2004) claims that S&T became institutionalized in state governments in the 1990s, making the continuity of high-tech programs less dependent on gubernatorial and legislative cycles.

In one of the few efforts to investigate the choice of states for investments in high technology in the 1980s, Portz and Eisinger (1991) observed three models of state policy making in the field of biotechnology. The interest-based model is characterized by the state response to public and private interests in the policy community. The second model consists of states' employing a strategic planning process to verify and exploit existing resources in the field. In the third model states perform an initial strategic assessment followed by allocations that respond to the interests of actors.

Atkinson (1991, pp. 37–38) argued for the importance of the mode in which interests interact with the state to shape TBED policy. He identified pluralist and corporatist modes of interaction in his investigation of state high-technology programs. The former consists of multiple interests competing with each other to influence state policy through lobbying efforts. In the latter, interests cooperate with each other and are involved in policy making by the state. Atkinson asserts that the corporatist mode leads to more effective policy for two main reasons: (1) organized interests brought into the policy process are more likely to influence the state to form and maintain high-technology programs, and (2) corporatist bodies often conduct analysis and communicate their needs to state policy makers, facilitating the design of effective programs. Pluralist lobbying, on the other hand, is characterized as leading to policies designed to serve particular and scattered interests.

The actors involved in TBED policy making have disparate interests that relate to different policy alternatives. Relevant actors in TBED policy making include business, higher education, economic development organizations, venture capitalists, and entrepreneurs (Atkinson, 1991; Douglass, 2006; Feller, 1992b; Plosila, 2004). Among these, universities have assumed particular prominence as central partners in TBED efforts (NGA, 2007; Plosila, 2004; Portz & Eisinger, 1991; SSTI, 2006). Atkinson (1991) argued that pressure from higher education institutions is likely to drive state policy toward upstream investments in scientific infrastructure and basic research. Feller (1992b) hypothesized that heavy involvement from industry in the policy-formulation process also leads states to adopt upstream programs. However, influence from state economic development agencies and small firms shifts the emphasis to downstream programs, which are more likely to generate employment in the short term. More recently, Douglass (2006) suggested that industry seems to have greater influence over state officials than universities in the formation of upstream programs.

A Policy for Nanotechnology: The Case of Pennsylvania

TBED Policy in Pennsylvania

Pennsylvania typifies the efforts of many states to adapt to long-term restructuring of the American economy. Pennsylvania has the sixth largest population and the sixth largest economy among the American states. Since 1960, the steady erosion of high-wage manufacturing jobs has contributed to a lackluster economy, an aging population, and an exodus of young workers. Moreover, the commonwealth has been the site of TBED initiatives for quite some time. It established a technology assistance program for industry as early as 1956, but more ambitious initiatives date from the 1980s, especially the four regional Ben Franklin Partnerships. Pennsylvania thus illustrates the struggle of once prosperous manufacturing regions to adapt to the so-called knowledge-based economy. It also represents an active state in terms of TBED policy making, with a history of experimentation with high-technology programs and an institutionalized S&T infrastructure. In general, Pennsylvania has since the 1980s been regarded as a leader in TBED (Etzkowitz, 1997; Osborne, 1990).

The development of nanotechnology policy in Pennsylvania occurred on top of an established, albeit evolving, TBED infrastructure. The key state actor for S&T

Table 1. Pennsylvania Programs for Technology-Based Economic Development

Program	Year	Aim
Ben Franklin Partnership (BFP)	1982	Use university science and technology to strengthen industry competitiveness and job creation
Industrial Resources Centers	1986	Assist small manufacturing firms to adopt advanced process technologies [precursor to the federal Manufacturing Extension Partnership]
Pennsylvania Technology Investment Authority (PTIA)	1999	Support university research and business development in technology areas
Life Sciences Greenhouses	2001	Uses tobacco settlement funds to support commercialization of discoveries arising from university biotechnology research
Pittsburgh Digital Greenhouse		To commercialize robotic and digital technologies
Ben Franklin Technology Development Authority [merger of BFP and PTIA]	2002	Use university science and technology to strengthen industry competitiveness and job creation
Keystone Innovation Zone	2004	Build alliances between regional economic development organizations and universities

policy in Pennsylvania is the Department of Community and Economic Development (DCED). The Secretary of this department reports directly to the governor, and the DCED is the chief source of discretionary funds for the policies in question.

Pennsylvania TBED programs are regionally decentralized. This assures that initiatives are consistent with local conditions, but also provides the opportunity for regional interest groups to set their own goals and vie for state resources. Pennsylvania's most renowned TBED policy, the Ben Franklin program, illustrates the pattern. Currently, four highly autonomous regional authorities administer the program. Besides the original mission of linking university S&T with industry, these authorities serve as conduits for other state programs of TBED funding. Since it was established in 1982, the Ben Franklin programs have provided some support for universities, community colleges, and local economic development organizations, but the majority of its funds has supported small and start-up companies (Nexus Associates, 2003; Rahm & Luce, 1992, pp. 41–51). The general pattern of centralized funding and regional implementation is visible in other major state initiatives. (For a list of other Pennsylvania TBED programs, see Table 1.)

An 'Accidental' Policy for Nanotechnology

The origins of the PIN—and its financial commitments to nanotechnology—lie in the first state allocations to nanotechnology in the late 1990s, before such investments became fashionable. In 1997, the DCED agreed to provide $2 million to support a Penn State proposal to the Semiconductor Industry Association for a research center. At the time, Penn State was establishing a new nanofabrication facility as part of the National Science Foundation (NSF)-sponsored National Nanofabrication Users Network. Companies using the nanofabrication facility were reporting a need for skilled clean-room technicians. When the SIA proposal collapsed, Penn State requested and received authorization from the state to use the $2 million allocation to create a clean-room technician education program called the Pennsylvania Nanofabrication Manufacturing Technology (NMT) Partnership. The program seemed to fulfill a useful role and faced no opposition. Starting in 1998, the NMT Partnership received annual state funding of $2–$3 million. The program resulted in the nation's first associate degree program in nanofabrication for Pennsylvania community colleges, in addition to other training and outreach programs (Hallacher, Fonash, & Fenwick, 2002). The NMT Partnership attracted federal funding as well. In 2001, it was designated an NSF Advanced Technological Education Center for Nanofabrication Manufacturing Education, receiving a four-year, $2.8 million award. Other federal grants followed.[3]

As the NMT partnership was being developed in 1998, the Ben Franklin Technology Partners of Southeastern Pennsylvania detected interest in nanotechnology among local companies. It organized several industry forums in 1999 and 2000, recruiting the participation of local and national organizations. In this same time period the Ben Franklin center was assisting the NSF to develop its new Partnerships for Innovation program, and the DCED was reorganizing its approach to supporting university research. These efforts culminated in a one-day strategy session in the spring of 2000 involving representatives from Ben Franklin, NSF, the Council for Urban Economic Development, the Progressive Policy Institute, the Eastern Technology Council, the DCED, the University of Pennsylvania, Drexel University, a private consulting firm (ANGLE Technologies Group), and others. The outcome of this session was a successful $600,000 Partnerships for Innovation proposal to the NSF with matching funds provided by the state and Ben Franklin to establish a nanotechnology center. This center linked universities, economic development organizations, and firms in the region.

Led by the University of Pennsylvania, Drexel University, and the regional Ben Franklin center, this group submitted a proposal to the state DCED in 2001 requesting $10 million and over three years to establish a Nanotechnology Institute (NTI), focusing on research and commercialization. The NTI proposal was particularly aimed at exploiting opportunities in the emerging field of nanobiotechnology, reflecting the heavy concentration of biotechnology and pharmaceutical companies in the Philadelphia area, and the biomedical research strengths of the University of Pennsylvania. The NTI proposal was approved in 2001 and received $3.5 million of annual state funding. NTI offers grants and services to firms wishing to commercialize nanotechnology, awards seed grants to university researchers, and hopes to promote workforce development. Beyond these activities, it serves a promotional and networking function to stimulate activity linked with nanotechnology.

Penn State observed the success of the Philadelphia group and nurtured its own plans. The university is a significant performer of materials research and it perceives itself as a leader in the area (The Pennsylvania State University, 2005). In 2002, Penn State submitted a proposal to the state modeled on the NTI proposal requesting $3.5 million to support nanotechnology research and commercialization, separate from the annual request of $1.7 million for the ongoing NMT Partnership. The university sought to continue its workforce development program, but also to receive support for research and commercialization at a comparable level to its state neighbors UPenn and Drexel. In response, a single award of $3.5 million was approved through the Ben Franklin program in 2002 to support nanotechnology education, research, and commercialization activity at Penn State. In the following two years, Penn State succeeded in obtaining separate allocations for each of the programs. Located in rural central Pennsylvania, Penn State operates in a rather different context from the Philadelphia group, despite the similarity of their resource claims. As a significant performer of industry-sponsored research, Penn State forges relationships with major corporations in diverse fields.[4]

A New Administration and the Pursuit of a Strategy

When Governor Ed Rendell took office in January 2003, the new Secretary of DCED expressed some skepticism about the economic development potential of nanotechnology, especially in the near term. He stressed the need for a strategy to help guide the Commonwealth's ongoing investments in nanotechnology. In 2003 the Secretary commissioned a study of nanotechnology in Pennsylvania by the ANGLE Technology Group, a consulting firm that had previously been associated with the creation of the NTI. The stated purpose of this effort was to examine the state's situation in nanotechnology and develop recommendations for further action. In particular, DCED sought to situate ongoing and proposed investments in the context of a state strategy for TBED.

The ANGLE Report asserted that Pennsylvania has the capability to be the national leader in nanotechnology commercialization. The report proposed a strategy, an action plan, and performance metrics, organized around six elements: building and sustaining the academic research base, leveraging existing industry to drive commercialization, promoting statewide collaboration, developing industry clusters, supporting workforce development, and establishing national leadership (ANGLE Technology Group, 2004). The report recommended undertaking more research for industry, the establishment of 'Regional Collaboration and Focus Centers,' the creation of statewide bodies, including an advisory council, a Nano-Forum, a database, and a governor's advisory group, as well as various promotional activities (pp. 51–55). However, the report did not evaluate the impact of the existing state initiatives described earlier, nor did it make any funding recommendations. In 2003 and 2004, Pennsylvania provided slightly under $10 million of annual funding to support the three major elements of its nanotechnology "policy": the NMT Partnership, the NTI, and the Penn State nanotechnology research and commercialization program.

While UPenn, Drexel, and Penn State developed their homegrown initiatives based on their local interests, the Commonwealth supported other programs relevant to nanotechnology. For example, since 2001 the DCED has supported the Center for Optical Technologies at Lehigh University, located in the northeast region of the state. The Lehigh center performs nanotechnology research and commercialization in optics and photonics, but is not entirely dedicated to "nano" as such. State funding for this center has risen from an initial $1 million grant in 2001 to subsequent allocations of $3 million through 2005. Roughly one-third of this funding is devoted to research at the nanoscale. Lehigh University has asserted an active role in nanotechnology despite its relatively small size. The DCED has also supported the Pittsburgh Digital Greenhouse, with annual funding of $3–$5 million per year since 2001. The Greenhouse involves Carnegie Mellon University, the University of Pittsburgh, private industry, and others in efforts to develop and commercialize robotic and digital technologies. Like the Center for Optical Technologies, these state-funded efforts impinge on nanotechnology even though they are not dedicated to nanotechnology per se. Finally, DCED has provided annual funding of approximately $3 million to support participation by Lehigh University in the NSF Materials Science and Engineering Center (MRSEC) at Carnegie Mellon University, an effort that can be viewed (liberally) to support nanotechnology R&D.

In 2005, Alcoa, PPG, U.S. Steel, and Bayer MaterialScience combined with the Pittsburgh Technology Council to support the Pennsylvania NanoMaterials Commercialization Center (PNCC). These firms—heavyweights in the materials industry—are committed to present and future applications of nanotechnology. They have a large economic footprint in professional, if not manufacturing, employment. For example, the Alcoa R&D Center employs 650. The commonwealth awarded the council $200,000 to establish this center, matched by the four corporate partners. The center is essentially an intermediary, aiming to encourage much larger investments of "other people's money," principally from the federal National Nanotechnology Initiative (NNI). It specifically intends to stimulate and commercialize research in nanotechnology. The center is thus intended to complement corporate R&D laboratories by bolstering the ties with university research and entrepreneurial firms.

During 2004 and 2005, the commonwealth undertook a series of conferences and workshops involving industry and universities, which were intended to develop a collective response the ANGLE Report. This effort included a statewide conference in spring 2005 entitled *The Business of Nano*, following up on similar events in 2004 and 2002. Following these deliberations, the DCED subsequently released the white paper *Pennsylvania Initiative for Nanotechnology* (Pennsylvania Department of Community & Economic Development, 2005a). Despite the workshops, conferences, and discussions that had taken place, the white paper largely echoed the ANGLE Report. The commonwealth then suspended funding for the NTI and the Penn State research and commercialization program, and reduced the allocation to the NMT Partnership to $1.4 million. DCED officials explained that this step was taken to establish a basis for launching the new Pennsylvania Initiative for Nanotechnology in 2006, based on the ANGLE Report and subsequent deliberations.

In 2006, the state allocated $11.1 million to PIN. The programs funded in the previous years were supported: $3.5 million for the NTI, $2.5 million for Penn State research and commercialization, $2.6 million for the NMT Partnership, $1.4 million for Lehigh to support its participation in the Carnegie Mellon MRSEC and a nanophotonics research infrastructure, and $1 million to the Pennsylvania NanoMaterials Commercialization Center in Pittsburgh.[5] In this latest chapter in the evolution of Pennsylvania's nanotechnology "strategy," the state sustained ongoing programs that evolved from the bottom up, on a decentralized (and sometimes internally competitive) fashion. But now state funding for nanotechnology is, at least nominally, part of a statewide initiative. According to the state governor, PIN 'is positioning the Commonwealth to be a national force in this building wave of development' (Pennsylvania Department of Community & Economic Development, 2005b, p. PA02).

Pennsylvania's Efforts in Context

Considering that nanotechnology resembles biotechnology in the salience of academic science for industrial innovation (Zucker & Darby, 2005), an argument might

Table 2. State Totals for University Nano NSF Funds, Publications, and Patents, 2002–2004

State	NSF Nano Funds (in millions)	Nano Publications	Nano Patents Issued
California	119	2,077	530
New York	100	937	97
Pennsylvania	62	935	100
Illinois	59	874	98
Massachusetts	59	984	172
Texas	40	782	127

be made that economic gains from nanotechnology will accrue to a few regions where there is a significant concentration of academic and industrial R&D and a supportive innovative infrastructure. This is true within the United States and beyond, as several countries have built research capacity in this area (National Science & Technology Council, 1999). The sense that the United States must take concerted action in a race for leadership in this area was aptly exploited by policy entrepreneurs at the federal level to advance a national nanotechnology agenda the late 1990s (McCray, 2005). The NNI was formalized in 2001, and the federal commitment to supporting nanotechnology was signed into law in 2003, with the 21st Century Nanotechnology Research and Development Act (Public Law 108–153). Industrial groups with a stake in nanoscale research and engineering have largely backed these efforts (e.g., Chemical Industry Vision, 2020 Partnership, 2003; Semiconductor Research Corporation, 2003). Annual funding for the NNI quickly surpassed a billion during the decade (circa $1.4 in 2007), disbursed through 13 federal agencies (NRC, 2006).

These large investments in nanotechnology prompt states to use their own resources to leverage federal R&D dollars. This leveraging role has been a feature of state TBED policy across fields of technology (Feller, 2004; Plosila, 2004). As one might suspect, Pennsylvania's move and aspirations are not unique. Indeed, by 2003 no fewer than nine states had already made nanotechnology-related investments, particularly in R&D infrastructure (Murdock et al., 2003). Enthusiasm over this science-based technology is evident, and its economic relevance is already taken for granted by many (Roco, 2005; Zucker & Darby, 2005). Hence, a proximate driver of state nanotechnology programs is interjurisdictional competition for federal research dollars; the ability to grow, attract, and retain nanotechnology-related businesses lies in the long-term horizon.

Rather than an open field, the subnational competition for leadership in nanotechnology seems to be circumscribed to a few states that possess established scientific and innovative infrastructures. The data in Table 2 illustrate the relative standing of major states in the production of nanoscience and nanotechnology-related innovation. Far from capturing all nanotechnology-related activity, these data are rough proxies of states' scientific strengths in the field (NSF funding and publications) and innovative activity (patents).[6]

These data suggest that Pennsylvania is well positioned nationally in terms of scientific activity and innovation in nanotechnology. In every category, California was the clear leader, followed by the same five states in different orders. More apposite are the five states that trail California. This is Pennsylvania's peer group for nanotechnology—and its rivals for obtaining key resources for TBED. In addition, Zucker and Darby's (2005) longitudinal data on research and business activity in nanotechnology (1980–2003) suggests that Pennsylvania is linked with some of the most active regions in the field. Philadelphia is among the top ten metropolitan regions (Philadelphia-Wilmington-Atlantic City) in terms of research and business creation in nanotechnology.

California and New York have made the largest and most conspicuous investments in nanotechnology. Among the other states listed earlier, only Pennsylvania has an explicit strategy to promote nanotechnology through state investments. Illinois has made opportunistic and leveraged investments to expand facilities for nanotechnology. Texas and other states have policies to stimulate TBED that encompass nanotechnology along with biotech, informatics, or any other research-based field (Geiger & Sá, 2005; Murdock et al., 2003).

California obviously possesses a strong research base as well as an abundance of entrepreneurial spirit. These comparative advantages received a further boost for nanotechnology earlier in the decade, when the state committed support for university–industry collaborations in key areas. The California NanoSystems Institute (CNSI) has received $100 million in state funding over four years to assert scientific leadership in several specialties, as well as working closely with industrial partners to assure the transfer and commercialization of innovations (Douglass, 2006, pp. 10–12; Geiger & Sá, 2005, p. 9). Opened in 2003, CNSI is based at University of California-Los Angeles but also draws on faculty from University of California-Santa Barbara. The initiative for this and the other three California Institutes for Innovation arose in late 1999 from the efforts of a policy entrepreneur, who successfully sold the project to the president of the University of California and former Democratic Governor Gray Davis.[7] About a year later, the four institutes were selected and the state committed a total of $400 million to those units. More recently, California established the Blue Ribbon Task Force on Nanotechnology to craft a strategy to 'ensure the state's leadership in the field' (Blue Ribbon Task Force on Nanotechnology, 2005, p. 4).

Nonetheless, Zumeta (2006) contends that the state lacks capacity for strategic policy making in S&T, and that the potential to develop such capacity is undermined by the state's ballot initiative process. Through the initiative process, policy entrepreneurs can succeed in earning citizen approval to commit state funding for their proposed programs, trumping strategic priorities from the executive branch. That was indeed the story of California's most consequential commitments to nanotechnology, which came about as a function of savvy policy entrepreneurialism.

New York has undoubtedly made the largest financial and political commitments to nanotechnology since the 1990s. These have been centered at the University of Albany, which has aptly exploited state support to build an impressive R&D infrastructure. The governor and senior politicians in the legislature backed New York's substantial investments in S&T programs. State appropriations to university research infrastructure were packaged into multiple "center of excellence" programs administered by the New York State Foundation for Science, Technology, and Innovation. The state invested circa $500 million in the Albany Nanotech complex, complemented by $2.5 billion in corporate investments. The University at Albany created in 2004 the country's first college of nanoscience and engineering, capitalizing on the clout of the R&D venture, and support from the state's key politicians. In general, New York State has combined entrepreneurial and industrial recruitment approaches to build a nanotechnology agglomeration around Albany: in addition to stimulating local entrepreneurialism, over $1 billion has been devoted to retaining IBM and recruiting AMD manufacturing plants in the Capital Region (Geiger and Sá, in press).

Pennsylvania's investments fall short by a large margin compared to those of New York and California. Spread out across a number of institutions and programmatic priorities, the $53 million allocated under the guise of investments in nanotechnology in Pennsylvania (2000–2006) pales in comparison to the more focused efforts at building CNSI and Albany Nanotech. However, California and New York are clearly outliers. Very few states have the economic muscle to commit resources for emerging science-based technologies at such a scale. It is symptomatic that both in New York and California, various institutions and regions have received state support in other S&T areas, while investments in nanotechnology remained mostly focused on a few institutions. In the politics of TBED in these states, it was possible to prioritize big projects in a few universities because state funds for nanotechnology were a slice of a larger pie. The geographically redistributive logics of state technology programs were still present, perhaps making the total commitments politically palatable.

A different argument might also be made on the feasibility of state policies for nanotechnology. Clearly, the unbridled optimism of nanotechnology advocates needs to be viewed critically (McCray, 2005). It might take many years before significant economic benefits from nanotechnology are realized, and the ability of states to sequester such benefits within their borders is arguable. For the federal NNI, this is not as pressing a concern, because the goal is to create national-level capabilities in nanoscience and engineering. States, however, frame TBED in terms of the creation of local high-wage jobs. Policies for nanotechnology might appear too risky an investment of state funds if measured against that yardstick, particularly given the lack of clear evaluation mechanisms and an accountability framework.

Conclusion—Nanotechnology in Pennsylvania: Rationalized Policy Formation

The nanotechnology policy created in Pennsylvania can be regarded as the result of an interest-based model of policy making (Portz & Eisinger, 1991). The formation of a Pennsylvania policy for nanotechnology emerged from the interests of local actors—mostly universities, sometimes in partnership with local economic development organizations and industry. The choice of nanotechnology as an area for state investments had less to do with calculated efforts to get ahead in a nascent technological wave, than with the state response to the proposals of universities and their partners. In the case presented here, state programs essentially provided supplemental support for the basic nanoscience and engineering activities of selected universities based on their own initiatives, and linked these activities with other organizations. Interest-driven programs predated any strategic assessments. The state's move to formulate a "strategy" served the purpose of rationalizing, justifying, or legitimizing past and future state commitments, but certainly not crafting or informing policy. The PIN is thus an example of "rationalized policy formation."

In this instance of rationalized policy formation, the state responded essentially to university interests. Considering the nature of emerging science-based technologies—inchoate research fields with highly relevant prospects for industrial innovation—it is not surprising that universities become key actors in the nanotechnology policy process in Pennsylvania. Universities have the research capacity to steer scientific advancements in the field, and have become increasingly involved in economic development generally (Feldman et al., 2002; Feller, 1990; Florida & Cohen, 1999; Tornatzky, Waugaman, & Gray, 2002). In addition, universities are naturally inclined to seek greater resources for their basic research and education activities, all of which are resource intensive. They are immersed in a competitive environment that creates incentives for the diversification of revenue sources and the pursuit of discretionary funding for improvements in infrastructure (Geiger 2004).

According to Atkinson's (1991) frame for discussing the role of interests in state technology policy formation, Pennsylvania represents a mixed mode, whereby a corporatist intermediation of interests occurred in some places (e.g., NTI, PNCC), but a pluralist mode prevailed at the state level. The local corporatism can be institutionally ascribed to the regional decentralization of the TBED policy structure in Pennsylvania, which allows and indeed fosters the coalescence of substate interests. Despite the later efforts by the DCED to liaise actors with a stake in nanotechnology through conferences and consultations, no statewide intermediary body emerged to link or coordinate the various competing interests throughout the state. While some regional initiatives involved a range of actors, they remained essentially linked to their localities. Besides, rationalized policy formation did not lead to changes in the "rules of the game" among state officials, the participants in the funded programs, and the stakeholders in the nanotechnology industry in Pennsylvania. Providing direct pledges for discrete projects remained the mode of support for nanotechnology.

Having characterized the formation of the PIN, we now consider the implications of Pennsylvania's approach. To its credit, Pennsylvania was one of the first states to invest in nanotechnology knowledge assets lodged within the universities, and it remains one of the few with an explicit framework to fund research and commercialization in various regions. A consequence of Pennsylvania's approach is that the state does not have "a" nanotechnology policy, but rather four regional policies, each generated by different considerations and each having a unique structure. It might be argued that this is an appropriate approach, given the different characters of these regions. This was the rationale for decentralizing the Ben Franklin Partnership into four regional units (Rahm & Luce, 1992, pp. 43–44). By doing so, the state allows for local actors to have a greater influence over TBED policy decisions, which might therefore better reflect their economic and political conditions.

Besides, by working with the regional initiatives and allowing for field-originated ideas to shape PIN, the state avoided controversy and managed to nurture nanotechnology programs for almost a decade. Considering the inchoate state of nanotechnology, developing research capabilities is a fundamental step to exploit the innovative potential of this science-based technology (Zucker & Darby, 2005). In this perspective, Pennsylvania's initiative could be viewed as a test bed that ignites interest in nanotechnology among the relevant agents without overcommitting state resources to this inchoate field. Larger and more conspicuous investments may invite greater public scrutiny, which has been virtually absent in this case.

However, from the perspective of interstate competition for "national and international leadership" in science-based industries, the drawbacks of the Pennsylvania approach are evident. States would more likely benefit from targeted rather than scattered investments, considering how costly it is to build scientific leadership. California's investments seem to go in this direction, and New York's commitments to Albany Nanotech have been clearly focused on establishing a nanotechnology cluster. (It is worth noting that the paths pursued by California and New York did not involve careful strategic analysis either.) In Pennsylvania, however, PIN is a relatively small pie that feeds many. Investment in nanotechnology, as in other discrete areas, evolved independently, although anchored bureaucratically in the same state departments and agencies. By responding to local interests in an *ad hoc* fashion, state officials created a playing field where unique claims of universities for supplemental funding could be articulated. Given these dynamics, it is not surprising that no strategic vision seemed to exist on whether or not the state could attain a leading position in nanotechnology and how it would achieve such a feat, despite the rhetoric of policy documents. The evidence presented in the previous section suggests that Pennsylvania possesses greater potential than that reflected to date in the aspirations of the current nanotechnology policy.

Moreover, Pennsylvania's approach does not lend itself to policy evaluation and learning. Reflecting findings of previous studies on economic development policies (Dewar, 1998; Eisinger, 1995), program survival overtook the technical criteria of efficiency and effectiveness as the driver of policy continuation. Even if one considers that the economic development outcomes of Pennsylvania's nanotechnology programs are not appreciable in the short run, the state is poorly equipped to assess the quality of its investments.

We conclude by considering whether Pennsylvania's rationalized policy formation is simply an idiosyncratic example, or illustrative of broader trends in state technology policy. We have a few reasons to suspect that such rationalizations are not unusual. First, reports on state TBED policies are often silent on the antecedents of programs (e.g., SSTI, 2006) and thus do not reveal the real starting points of state initiatives. The early policy formation process tends to be obscured in later accounts.

Second, interests associated with state technology programs obfuscate rigorous assessments, and unwarranted 'success stories' get disseminated by those with a stake in them (Feller, 1992b). This is consistent with Dewar's (1998) argument that 'public stories' are maintained to assure the political support to and continuity of state of economic developed programs but that those stories may not reflect the underlying reality. Part of these stories refers to the motivators and drivers of policy formation. Strategic assessments and substantive analysis presents a more palatable narrative than the interests of particular actors involved in the policy process.

Third, the increasing 'professionalization' of the field of economic development policy contributes to the dissemination of tools and recipes for policy making (Hart, 2007). Driving state investments strategically through planning is a central element of TBED (Atkinson, 1991; Feller, 2004; Portz & Eisinger, 1991), and it also appears in prescriptions of how states should design nanotechnology initiatives (Murdock et al., 2003).[8] Such prescriptions stem from the belief in a technocratic policy process, and may influence the views that state officials hold on how best to influence policy making. Nonetheless, as cautioned by Feller (2004, p. 144):

> Concerning the exaggerated emphasis on strategic planning, 'strategic' as used in state technology-based economic development planning is as much the required rhetorical adjective needed in contemporary policy environments to justify or explain the programs and decisions of public sector and not-for-profit organizations as it is a substantively meaningful predictor of future outcomes. State technology-based economic development programs are strategic primarily in the sense of concentrating resources on selected technological areas, not in the sense of taking into account the actions of rivals.

We can add that the political need to stamp one's own mark on ongoing state allocations to S&T, as well as to draw a line between past and present policy initiatives, may also drive strategy-setting for symbolic purposes.

Finally, states stand to benefit from creating incentives and structures for policy making that exploit the valuable contributions of research universities to regional development and consider the overall needs of the state as well. Universities are uniquely positioned to help states foster technological innovation in emerging fields. Nonetheless, they are not regional development agencies. They will thrive on what they do best—advancing and disseminating knowledge through research, teaching, and outreach—and each university seeks to outperform its peers. Individually and collectively, universities would actually benefit from a policy process that elicits their participation rather than one that simply responds to interests, as their claims for resources could be more fully related to the wider contexts of state policy needs and industrial R&D. States, if they wish to lead in innovation rather than simply follow federal priorities and emulate peers, need to create channels for universities, industry, and other agents in the economic development community to interact in productive ways.

Notes

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2 In the former, states' efforts to spur economic development are based upon incentives for individual firms to attract or retain their operations. In the latter, states attempt to promote endogenous growth by supporting entrepreneurial activity through various mechanisms such as incubator facilities, technical assistance programs, venture capital provisions, and funding for research and development (R&D).

3 In July 2001, a $600,000 NSF Partnership for Innovation award was received to explore the workforce and technology development needs of biotechnology and pharmaceutical industries congregated in the southeastern region of Pennsylvania. A NSF Nanotechnology Undergraduate Education (NUE) award was received in June 2003 to support development of baccalaureate programs in nanotechnology. In June 2003, a NSF ATE planning grant was received to explore the feasibility of a national center for nanofabrication manufacturing education.

4 Through 2003, Penn State researchers copublished 63 papers in nanoscience and engineering with scientists at 41 different firms. A few of these were Pennsylvania small firms, but several were large regional corporations (Air Products, Allied Signal, Corning, Dupont, Merck). Nonetheless, university

facilities and research infrastructure serve as a magnet for smaller companies in the state as well. Through 2003, an estimated 57 Pennsylvania-based companies had participated in nanoresearch at Penn State. At least a dozen participants were major corporations or subsidiaries; the rest ranged from small- to medium-size firms down to university start-ups.

5 The Pennsylvania State System of Higher Education also received $113 thousand to develop nanotechnology curricula.

6 A database with 112 universities was constructed of variables that could be identified with nano: scholarly publications (with nano*), funding from NSF classified as nano (the only agency for which this was possible), and patents (issued with nano*). Because of year-to-year variability, three years were used (2002–2004).

7 The policy entrepreneur was Richard Lerner, a supporter and collaborator of Davis, who had been president of Scripps Institute in San Diego and a professor of immunochemistry (Douglass, 2006).

8 Indeed, Murdock and others (2003) have proposed that states stand to benefit from adopting strategic approaches to invest in the field: establishing leadership teams, coalescing key stakeholders, and identifying and exploiting comparative advantages are part of the recipe.

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