NATIONAL INNOVATION AND THE ACADEMIC RESEARCH ENTERPRISE

Public Policy in Global Perspective

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CHAPTER TEN

The United States

DAVID D. DILL

The growing belief among policymakers worldwide that economic growth and international competitiveness are related to national innovation has refocused global attention on US policy and particularly on the role that universities play in the American National Innovation System (NIS). Empirical research on the performance of national innovation systems consistently places the United States among the leading nations (Balzat 2006). International scorecards, such as the European Innovation Scorecard developed by the European Commission, use the US NIS as a primary benchmark (UNU-MERIT 2008).

The national research system of the United States, which as in all countries is a core component of its National Innovation System, would be noteworthy if only for its massive scale, contributing over 44% ($343,747 billion) of the total gross domestic expenditures for R&D (research and development) ($773,998 billion) among the OECD (Organisation for Economic Co-operation and Development) countries in 2006 (OECD 2007a). The US investment in R&D is 2.6 times that of Japan ($130,745 billion), the OECD country with the next highest expenditures, and more than 2.4 times that of China ($144,037 billion), the non-OECD country with the highest (and fastest-growing) expenditures. For the United States, as for most other OECD countries, the Academic Research Enterprise (ARE) represents a relatively small portion of the national research system. In 2006, industry performed 70.3% of the research, universities 14.3%, and government laboratories 11.1% (OECD 2007a). The proportion of national R&D performed by the US ARE was in fact significantly below the OECD average of 17.6%, while US industry's proportion was somewhat larger than the OECD average of 68.0%.

The growing importance of national innovation to economic growth has inspired

US policymakers as well, leading to increased national investments in knowledge. The OECD suggests that national expenditures on R&D, software, and higher education can serve as proxies for knowledge investment (OECD 2007b). Within the OECD countries, this investment averaged 4.9% of GDP in 2004. The United States expended the highest percentage (6.6%), followed by Sweden (6.4%), Finland (5.9%), and Japan (5.3%); the EU average was 3.6%. The OECD suggests the United States and Japan appear to be moving more rapidly to a knowledge-based economy than the European Union, as their respective expenditures in knowledge as a percentage of GDP have grown more rapidly than the average for the EU countries since 1994. In 2005 the United States invested 2.62% of its GDP on R&D expenditures, in comparison to the OECD average of 2.25% (OECD 2007a). With regard to the ARE, the apparent US advantage is somewhat less obvious. For example, US expenditures on higher education R&D (HERD) as a percentage of GDP were 3.7% in 2005, below the OECD average of 4.0% (OECD 2007a).

The growth in the American economy during the 1990s and the comparative advantage of the United States in a number of high-tech fields have been attributed in part to the strength of the US ARE. A comparative econometric analysis has also suggested that the US ARE represents the “efficiency frontier” in terms of numbers of publications and citations relative to national HERD investments (Crespi and Geuna 2004). Therefore, international policymakers seeking models for reforming their national innovation systems have been particularly attentive to the framework conditions for the ARE in the United States.

Many OECD countries are now closing the efficiency gap with the US ARE due to positive productivity gains in their academic science systems, but also due to observed negative productivity growth in the US system (Crespi and Geuna 2004; King 2004). Several nations in the European Union as well as Australia and Canada now produce more scientific articles per million population than the United States, although the United States trails only Switzerland in the relative prominence of cited scientific literature (OECD 2007b). The OECD suggests three additional proxy indicators of the output and impact of national investments in science and technology (OECD 2007b): patents, the technology balance of payments in highly R&D-intensive industries, and the technology balance of trade in the same industries. The United States leads on many of the OECD R&D performance measures, but not all, and when controlled for gross domestic expenditures on R&D, the US advantage over EU countries and Japan is much less obvious.

Within the United States these recent trends have led to growing concerns about possible inefficiencies in the American ARE policy framework (Adams and Clem-

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mons 2006; Foltz et al. 2005) and to calls for policy changes in order to maintain the effectiveness of national capabilities for innovation and productivity growth across the economy (COSEPUP 2006; Galama and Hosek 2008). In his 2006 State of the Union Address, President George W. Bush responded to these concerns by announcing the "American Competitiveness Initiative," which featured substantially increased funding for innovation-enabling research in the physical sciences and engineering, tax credits to encourage additional private-sector investment in innovation, and related policy measures to foster increased innovation and productivity growth in the service sector.

In international comparisons the US ARE stands out not only because of the acknowledged reputation and performance of its research universities, but also because of its distinctive framework conditions: In contrast to the governments of other OECD countries, the US national government has never exercised direct control over higher education and has also played a very limited role in regulating the academic, research, and administrative policies of its universities. This laissez-faire framework encouraged the development of an extensive and diverse set of public and private universities, which for their funding were initially dependent upon local sources of political and financial support. As a consequence, many universities were motivated to perform research of local benefit and to forge links with local industry. The earliest federal intervention into this emerging system was in fact an attempt to foster innovation in the leading industry of the day. The Morrill Land-Grant Act of 1862 was intended to promote scientific advances in agriculture. Since World War II, US federal policy has played an increasingly influential role in the development of the ARE, utilizing a number of distinctive policies. These have included allocating the vast majority of national support for academic research competitively (Trow 2000), providing this support to both private and public universities, and more recently altering the laws governing intellectual property rights in higher education. Reviewing the long antipathy in the United States to developing a national industrial or technology policy, and noting the increasingly influential role American universities play in technical innovation, Crow and Tucker (2001) concluded that the framework conditions of the US ARE now serve as the nation's de facto technology policy.

The sections that follow examine the instruments of federal policy and their influence on the US ARE. After a brief description of the composition of the US ARE, I discuss the evolution over time of federal policy on academic research. Succeeding sections explore the primary policy instruments currently employed by the federal government to influence academic R&D, research-doctoral education, and the relationship between academic research and economic development. In the concluding section I assess the overall strengths and weaknesses of the framework conditions for the ARE in the United States.

The Academic Research Enterprise in the United States

Given the large number of institutions in the American higher education system, defining the US ARE is not a simple task. The use of the term *university* is not regulated in the United States. As a result there are many institutions with "university" in their title that do not provide doctoral education, including primarily undergraduate academic institutions that offer master's and/or professional degrees, as well as the McDonald's corporate training facility, which is named Hamburger University. In contrast, the provision of doctoral education is regulated by six regional accrediting organizations, which assure that institutions offering the doctoral degree meet threshold academic standards. In order for students at these accredited institutions to be eligible for federal financial aid, the six accrediting agencies must in turn meet standards set by the US Department of Education. Consequently, the number of doctoral-degree-granting universities in the United States is indirectly and modestly influenced by federal policy. Therefore, if we define universities as those engaged in both research and doctoral education, the US ARE consisted of 283 institutions as of 2004 (Carnegie Foundation for the Advancement of Teaching 2007).[1]

Within this overall group of institutions the academic research effort is quite concentrated. The National Science Foundation (NSF) reports that the top 100 US research institutions accounted for 80% of all R&D dollars expended in 2006 (NSF 2007). This NSF analysis, however, includes a number of specialized medical and health centers, as well as the Woods Hole Research Facility, that do not offer doctoral degrees. If we further confine the analysis to traditional research universities offering both undergraduate and doctoral education of respected quality (Geiger 2004), we can identify the core of the US ARE as 66 public and 33 private universities (table 10.1) that in 2006 collectively performed 74% of federally funded academic R&D and granted 71% of US doctoral degrees (Hoffer et al. 2007; NSF 2007).[2]

The performance of the overall US research system is influenced by both federal and state policies, including direct financial support for R&D activity, tax incentives, and related regulatory instruments. The performance of the "public" research universities is also influenced by the policies of the fifty states, which vary substantially both in funding for academic R&D and in their regulatory frameworks for higher education (McDaniel 1996). The influence of US state policy on the ARE is therefore separately analyzed in parallel chapters in this book by Roger Geiger (chapter 11) and William Zumeta (chapter 12) on Pennsylvania and California, respectively. However, all of the institutions in the US ARE, both public and private, are substantially affected by federal research funding and regulatory policies. While only 29.3% of the overall US R&D system is financed by the federal government (OECD 2007a), the ARE is much more dependent upon federal support than that percentage implies. Of the $47 billion expended on academic R&D in 2006, over $30 billion, or 62.9%, was provided by the federal government, a proportion of subsidy that has remained relatively constant over the past decade (fig. 10.1). In contrast, as also depicted in figure 10.1, state and local government provided 6.3% of the R&D expenditures in colleges and universities (which was obviously concentrated in public universities), industry provided 5.1%, and the institutions provided 19.0% (consisting primarily of fees, gifts, and endowment funds). The remaining 6.7% expended on academic R&D came from other sources; among these sources were nonprofit foundations, which historically have been highly influential on the US ARE (Geiger 1993).[3]

Historical Evolution of Federal Policy on the ARE

The US Constitution does not explicitly mention education, thereby delegating primary responsibility for education to the states. Nonetheless, soon after the new republic's founding, proposals were advanced for a national university that would include advanced scientific training and be supported by the federal government (Dupree 1957). The first US president, George Washington, discussed the idea of a national university with the Congress. In addition, during his presidency Washington proposed federal support for a national military academy, which was opposed by his secretary of state, Thomas Jefferson, on constitutional grounds. Nonetheless, when Jefferson subsequently became president, he signed into being the first federal initiative in higher education, the founding of the US Military Academy at West Point in 1802. Presidents Jefferson and John Quincy Adams also became advocates for a national university, but because of continuing constitutional questions in Congress, the idea never came to fruition. However, four more federally operated service academies were subsequently created, all oriented, as was West Point, to bachelor's, or first-level-degree, education.[4]

The more traditional starting point of federal higher education policy is usually accorded to the Morrill Land-Grant Act of 1862, signed into law by Abraham Lincoln. As the US Military Academy's focus was on engineering, so the federal initiative on land-grant colleges was intended to stimulate education in the "agri-

TABLE 10.1.
Ninety-nine selected US public and private research universities

Public	Public	Private
Arizona State University	University of Colorado, Boulder	Boston University
Auburn University	University of Connecticut	Brandeis University
Clemson University	University of Delaware	Brown University
Colorado State University	University of Florida	California Institute of Technology
Florida State University	University of Georgia	Carnegie Mellon University
Georgia Institute of Technology	University of Hawaii, Manoa	Case Western Reserve University
Indiana University, Bloomington	University of Illinois, Chicago	Columbia University
Iowa State University	University of Illinois, Urbana-Champaign	Cornell University
Kansas State University	University of Iowa	Dartmouth College
Louisiana State University, Baton Rouge	University of Kansas	Duke University
Michigan State University	University of Kentucky	Emory University
New Mexico State University	University of Maryland, College Park	George Washington University
North Carolina State University	University of Massachusetts, Amherst	Harvard University
Ohio State University	University of Michigan, Ann Arbor	Johns Hopkins University
Oregon State University	University of Minnesota, Twin Cities	Massachusetts Institute of Technology

Pennsylvania State University
Purdue University, West Lafayette, IN
Rutgers, the State University of NJ, New Brunswick
SUNY, Albany
SUNY, Buffalo
SUNY, Stony Brook
Texas A&M University
University of Alabama, Birmingham
University of Arizona
University of California, Berkeley
University of California, Davis
University of California, Irvine
University of California, Los Angeles
University of California, Riverside
University of California, San Diego
University of California, Santa Barbara
University of California, Santa Cruz
University of Cincinnati
University of Missouri, Columbia
University of Nebraska, Lincoln
University of New Mexico
University of North Carolina, Chapel Hill
University of Oklahoma, Norman
University of Pittsburgh
University of South Carolina, Columbia
University of South Florida
University of Tennessee, Knoxville
University of Texas, Austin
University of Utah
University of Virginia
University of Washington, Seattle
University of Wisconsin
Utah State University
Virginia Polytechnic Institute and State University
Washington State University, Pullman
Wayne State University
New York University
Northwestern University
Princeton University
Rensselaer Polytechnic University
Rice University
Stanford University
Syracuse University
Tufts University
Tulane University
University of Chicago
University of Miami
University of Pennsylvania
University of Rochester
University of Southern California
Vanderbilt University
Wake Forest University
Washington University in St. Louis
Yale University

Source: Geiger 2004.

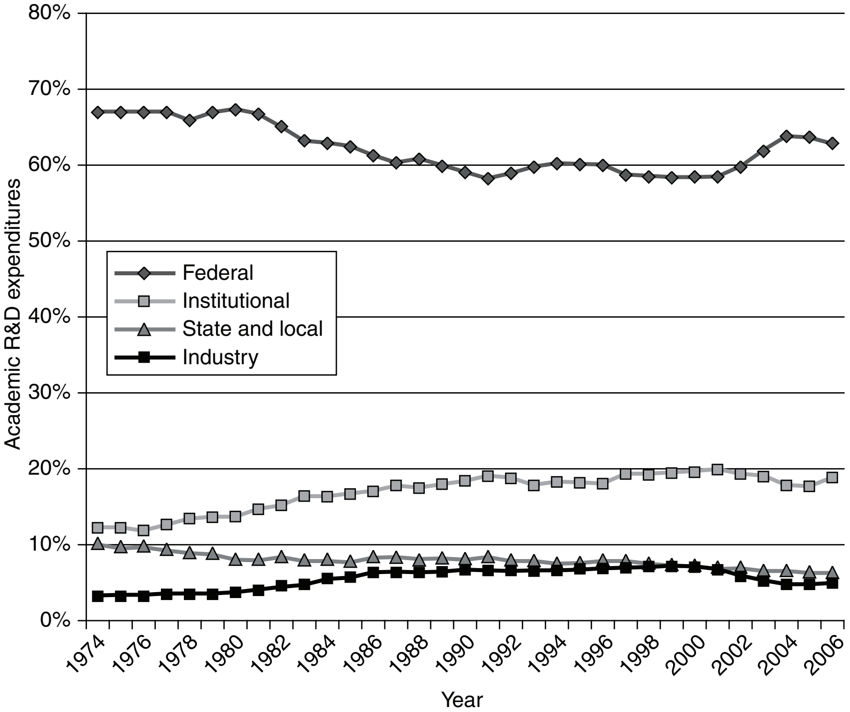

Fig. 10.1. Academic R&D expenditures by funding source, 1974–2006. *Source:* National Science Foundation, Division of Science Resources Statistics, Survey of Research and Development Expenditures at Universities and Colleges, WebCASPAR database, http://webcaspar.nsf.gov. *Notes:* WebCASPAR tables that include the "Highest Degree" classification variable may differ slightly from published tables because of institution branch aggregation that is done in WebCASPAR for ranking purposes.

cultural and mechanical arts" (Geiger 1986). These early federal initiatives in higher education thus reflected the public interest in practical and immediately useful education, in direct contrast to the focus on classical education then prevailing in both the private and emerging public colleges of the early nineteenth century. The first federal initiative explicitly addressing academic research was the Hatch Act of 1887, which established Agricultural Experiment Stations within the existing federally supported land-grant universities. These stations were intended "to aid in acquiring and diffusing among the people of the United States useful and practical information on subjects connected with agriculture, and to promote scientific investigation and experiment respecting the principles and applications of agricultural science."[5] This first federal effort to support academic science continued to reflect the public interest in utility but took a form that subsequently became unusual in federal policy—block grants to universities for research.[6]

Because of the US Constitution, the federal government took no active role in constraining the rapid proliferation of colleges and universities during the nineteenth century. The development of higher education in the United States was therefore shaped by four main factors: the Supreme Court decision in the Dartmouth College case of 1819, which established private colleges and universities as legal entities independent of the state; the generally permissive higher education licensing practices of the states; the provision of higher education by the states themselves; and the resulting competition among the many private and public institutions for students and resources. In this unique context, it was primarily those institutions with the size and resources to support graduate education that developed into research universities (Geiger 1986). Before the twentieth century, therefore, research prospered most at established private institutions, such as Yale and Harvard, or newly founded private universities, such as Johns Hopkins and Chicago, that had access to independent wealth.

The development of US federal policies supporting academic research in fields other than agriculture was significantly influenced by military requirements (Dupree 1957). In response to government's need for scientific advice during the Civil War, a small group of academic scientists quietly steered a bill through Congress in 1863 founding the National Academy of Sciences (NAS). The National Academy was a self-selected group of researchers who had "earned distinction by actual discoveries enlarging the field of human knowledge" (Dupree 1957, 147). The Academy was to be an advisory body to the federal government, providing research-based knowledge to requesting government departments. Members of the National Academy would receive no government compensation, but government agencies would pay the necessary expenses of commissioned research. However, with the end of the war the government's need for such advice declined, and the National Academy became largely an honorific body dependent for its survival on private support.

At the beginning of the twentieth century, federal funding for research had reached more than $11 million, which was larger than the total budgets of the top fifteen research universities of the day (Geiger 1986). Except for agricultural research, though, these federal funds supported applied research on government-defined problems carried out by a rapidly growing number of government bureaus and laboratories. During World War I the scientific challenges posed by submarine detection, poison gas, and explosives reinvigorated the US government's interest in harnessing academic science for war-related research (Geiger 1986). In response the NAS created the National Research Council (NRC) as an independent administrative entity supported by private foundations to coordinate research activities in the national defense. At that time no mechanism existed for directing federal funds for military research into civilian hands, so the NRC identified academic scientists who could be commissioned into the military to conduct relevant research in military labs. At the conclusion of the war in 1918, President Woodrow Wilson permanently recognized the NRC by executive order as the part of the NAS empowered to advise the government on military and related industrial problems.

During the early part of the twentieth century, large and influential private foundations, particularly those established by the fortunes of the Carnegie and Rockefeller families, altered their funding strategies for higher education to concentrate on graduate education and research. Given the large number of institutions of higher education, they adopted a competitive process of awarding grants in which proposals would be peer-reviewed by leading researchers from the established research universities.[7] During the interwar years, the foundations also supported the further development of the NRC by providing graduate fellowship funds for the NRC to allocate competitively for graduate education. As a consequence, the US ARE, as it rose to prominence prior to World War II, was essentially a privately funded system.[8]

This distinctive history influenced the fundamental norms of the US ARE and helped to shape the federal academic research policy that emerged during and after the war. In particular, the following characteristics were all visible before World War II: the US federal emphasis on supporting "best science" through competitive research grants; the tradition of federal (as well as private foundation) research priorities being defined primarily by civilian scientists; the reliance on peer review of proposals for federal research support by an elite of accomplished researchers; the resulting highly stratified nature of the US ARE; and the opposition of many academic scientists to proposals for better coordination of federal science policy, because of their belief that greater federal involvement would constrain scientific choice.

With the advent of World War II, the leaders of the NRC believed that scientific advances had rendered obsolete the tradition of academic researchers responding to research needs defined by the military and that a new system was needed in which the foremost civilian scientists would advise the military on potential scientific applications. Vannever Bush of the NRC's Committee on Policies outlined this idea to President Franklin D. Roosevelt in 1940. Soon thereafter the president appointed the National Defense Research Committee (NDRC), chaired by Bush and composed of academic researchers drawn from the NRC's Committee on Policies as well as liaison officers from relevant federal and military agencies. The research supported by the NDRC was thus coordinated by a group of civilian scientists who worked part-time, retaining their academic positions throughout the war. Because of the need to coordinate war-related medical research as well as research development and procurement activities, the NDRC was subsumed under the wartime Office of Scientific Research and Development (OSRD), also under the direction of Vannever Bush.[9]

The activities of the NDRC and the OSRD during World War II set the institutional framework for future federal science policy. These agencies established the tradition in which federal allocations in research were decided by an elite group of self-selected academic scientists. They also set the precedent of awarding the majority of federal research funds through contracts to the nation's best universities.[10] In contrast to the practice during World War I, a conscious effort was made by the civilian scientists governing these agencies to permit researchers to conduct war-related research at their home universities. Consequently the NDRC established new federal laboratories, such as the Radiation Lab at MIT, to be managed under contract by research universities. In the decentralized structure Bush and his colleagues designed for the NDRC and the OSRD, the influence, scientific choice, and autonomy of academic researchers was maximized.

The widely acknowledged contribution that academic scientists made to the US war effort, symbolized by the Manhattan Project, altered public as well as academic perspectives regarding federal involvement in academic research. But the participation of academic scientists in military research during World War I and the much more extensive effort in applied research during World War II had been purchased at some cost to the system of basic research in the universities. In the postwar world there was clearly a need to provide stable, long-term federal funding for basic research. In 1944, as the war effort wound down and the OSRD was to be closed, Vannever Bush arranged for President Roosevelt to request a report from OSRD outlining postwar science policy. Bush's response, *Science, the Endless Frontier* (1945), argued that continued federal support for basic research was essential for a strong economy and called for the creation of a national research foundation modeled on OSRD. The insulation of academic science from the pressures of national politics was to be ensured through a presidentially appointed board of civilian scientists, which would choose the foundation director. The foundation would be the primary means of supporting basic research in the sciences, including medical- and defense-related research.

This proposal to centralize funding for all federally supported basic research proved controversial, and over the next five years, while the Congress debated Bush's proposed foundation, it authorized the continuation of existing federal contracts for research and the development and initiation of new contracts under the Public Health Service (the National Institutes for Health); the army, the navy, and the air force; and the newly created Atomic Energy Commission. As a consequence, when a much diminished national research foundation, the National Science Foundation (NSF), was finally formed in 1950, it filled the remaining small space in an already established federal research matrix, one that provided support for basic scientific research and graduate education in the university sector. American postwar federal research policy therefore adopted a pluralistic, uncoordinated framework, in which mission-oriented agencies were the primary supporters of university research.

The birth of the NSF did not herald the expected new age of federal support for disinterested basic research. In 1953 over 87% of federal funds for academic R&D, which included the federal contract research centers operated by universities, were related to the military needs of the Atomic Energy Commission and the Pentagon (Geiger 1993). During this same period, presidential budget requests for the fledgling NSF were continually underfunded by the Congress. The Russian launch of Sputnik in 1957, however, presented a challenge to the United States that resulted in a radical alteration of federal science policy. A first response was the creation of the National Aeronautics and Space Administration (NASA) in 1958, which added another large mission-oriented agency supporting academic research in the basic sciences to the existing pluralistic federal funding system. More significantly, the Russian space exploits fostered a national insecurity about US educational achievement that led to the adoption of the unprecedented National Defense Education Act (1958). This legislation provided substantial new federal monies for graduate fellowships as well as for research in specialized academic fields, such as area studies and languages, that were deemed essential to the national defense (Geiger 1993). The NDEA legislation, which also subsequently provided support for higher education facilities, was therefore particularly helpful to the research universities.

Over the next decade, the cold war–inspired federal expenditures for the NDEA legislation and related increases in support of basic research by the NSF and the mission-oriented agencies transformed federal policy on academic research.[11] In 1953, prior to Sputnik, academic R&D represented .07% of US GDP; universities conducted 25% of national basic research; and 43% of higher education research was supported by the federal government. By 1968 academic R&D had more than tripled to .25% of US GDP; universities conducted 50% of national basic research; and 77% of higher education research was supported by the federal government, a proportion of government funding for academic research not since matched (Geiger 1993). The 1960s thereby represented the "golden age of academic science" (Geiger 1993) for the US ARE and shifted federal academic research policy from its postwar overwhelming emphasis on applied research to a predominant focus on basic research.

Paralleling this growing emphasis on federal funding for research and graduate education were attempts to provide greater coordination to federal science policy. In 1957 President Dwight D. Eisenhower appointed the first Presidential Science Advisor, a position that has been continued in succeeding administrations. This advisory domain within the executive branch was expanded in 1959 to include the Federal Council for Science and Technology (currently titled the President's Council of Advisors on Science and Technology) and in 1962 the Office of Science and Technology (currently titled the Office of Science and Technology Policy). Both branches of Congress created matching committees on science, and the Library of Congress, which serves as the research arm of the Congress, later added the Science Policy Research Division (currently titled the Resources, Science, and Industry Division).

Despite, or perhaps because of, these and preceding efforts to reorganize federal research policymaking, US science policy—and consequently the US ARE—is generally regarded as poorly coordinated, "composed of a fragmented matrix of science policy institutions, each with limited roles" (Kleinman 1995, 22). In cross-national comparative studies of science and technology policy, the US R&D system and organization is usually placed at the pluralistic, less centralized, market-oriented end of the spectrum (Lederman, Lehming, and Bond 1986). While most OECD countries have more than one government agency responsible for science and technology policy, the US framework is much more fragmented than that of the other leading industrial countries, and this is particularly true with regard to policies affecting the US ARE. The NSF has been assigned some responsibility for coordinating US national science policy, beyond its data-gathering activities, but it has had limited influence on overall federal science policy and has much less capacity for coordination and planning than comparable agencies in, for example, France and Japan (Lederman, Lehming, and Bond 1986). Some have suggested (Kleinman 1995) that this lack of coordination in federal science policy was an outcome of the political battle over Vannever Bush's proposal for a national research foundation and that if this policy proposal had been better managed, US federal science policy would have taken a different, more coordinated form. Appealing as this argument may be, there is ample evidence in comparative studies of US industrial, labor market, income, and social policies that poorly coordinated federal policies are more the norm than the exception (Wilensky and Turner 1987). The unique division of powers between the executive branch and the Congress, the complexities of federal-state relations, and the nonprogrammatic and non-discipline-enforcing character of US political parties create an institutional framework in which coherent national policies have been rare. From this perspective it may be debatable what can be learned from an analysis of US federal policy on the ARE. However, because of the high visibility of its research universities, the United States inevitably serves as an influential model for other national policymakers, and this is currently reflected in the implementation of competitive research funding as well as doctoral education reforms in many other countries. For this reason a systematic overview of current US federal policies on the ARE and their perceived strengths and weaknesses is likely to be of value.

The US Federal Policy Framework

Given its constitutional constraints and national cultural traditions, federal policymaking on the ARE in the United States has followed what Van Vught (1994) has characterized as the "state supervisory model" rather than the "state control model" typical of Europe and much of the rest of the world. Consistent with this general approach, US federal policy has relied primarily on the instruments of financial "incentives" (i.e., contracts and grants) and "market mechanisms," such as the redefinition of intellectual property rights and the provision of information on research doctoral education, with very limited recourse to the instrument of "rules" (i.e., regulation) and almost total avoidance of the instrument of "non-market supply" (i.e., direct government provision) (Weimer and Vining 2005).

The primary policy instrument affecting research has been federal funding of research contracts and grants as reflected in the overall investment in this activity, the divisions between basic and applied research, and the relative emphasis on different subject fields. A distinctive characteristic of US policy design on academic research has been the almost total federal reliance on allocating its support on a competitive basis and reimbursing indirect costs rather than allocating support directly in the form of institutional grants. Similarly, federal influence over doctoral education has been primarily through financial incentives in the form of competitively awarded scholarships and grants, although changes in the flow of foreign-born students after the terrorist attacks on the United States have revealed the potential influence of visa-governing regulations on PhD programs. The federal government has also subsidized the provision of information on the quality of research-doctoral education by the National Academy of Sciences. To better connect academic research to economic development, the federal government provides competitively awarded subsidies and grants for universities and industry. The related innovative change in framework laws governing intellectual property rights in universities in the early 1980s has also received a great deal of international attention.

The following sections outline the nature of these policy instruments and review related research on their impacts and limitations.

RESEARCH POLICY

In the US higher education system, federal policies on academic research support are extremely influential on the conduct and performance of the ARE. As discussed above, the pluralistic structure of federal science or R&D policy means that US national policy on research support for the ARE is not formally stated but must be interpreted from the collective actions of various government funding entities. US federal policy can be inferred to a certain extent from the overall level of funding for academic research, the distribution of support between basic and applied research, the distribution of support among both social priorities and research fields, and the degree of concentration in academic research funding within the overall ARE. However, an important aspect of US federal policy on academic research, and one that does reflect a conscious national policy choice, is the nature of the academic research allocation process. From a comparative perspective, US academic research policy is distinctive in its emphasis on the competitive allocation of federal research funds, in its reliance on peer review, and in its emphasis on indirect cost recovery. These important aspects of US federal policy will also be discussed.

In March 2000, the European Council set out a ten-year strategy to make the European Union the most competitive and dynamic knowledge-based economy in the world. A key element of this "Lisbon Strategy" was a target for investments in R&D equal to 3% of EU GDP. This target was set to close the gap in R&D investment between the European Union and the United States. While US expenditures on R&D as a percentage of GDP have averaged 2.63% over the past decade, the federal share of R&D had been in continuing decline since reaching a high of 1.92% of GDP in 1964. Federal support for R&D as a percentage of GDP rose slightly after 2000, but to a level still below that of 1994 (fig. 10.2).

Federal support for university R&D as a percentage of GDP averaged 0.20% over the same period, similarly declining during the 1990s before rising to 0.24% in 2006. However, federal monies have a much more critical influence on academic R&D, and therefore on basic research, than on overall R&D. Between the early 1970s and early 1980s, the academic sector's share of basic research declined from slightly more to slightly less than one-half of the national total. In the early 1990s, however, its share of the national total began to increase once again and was an estimated 56.5% in FY2006 (figure 10.3). Federal funds supported 63% of overall academic R&D and 64% of academic basic research in FY2006 (NSB 2008).[12]

Of the $30 billion in federal academic research support in FY2006, 74%, or $22.3

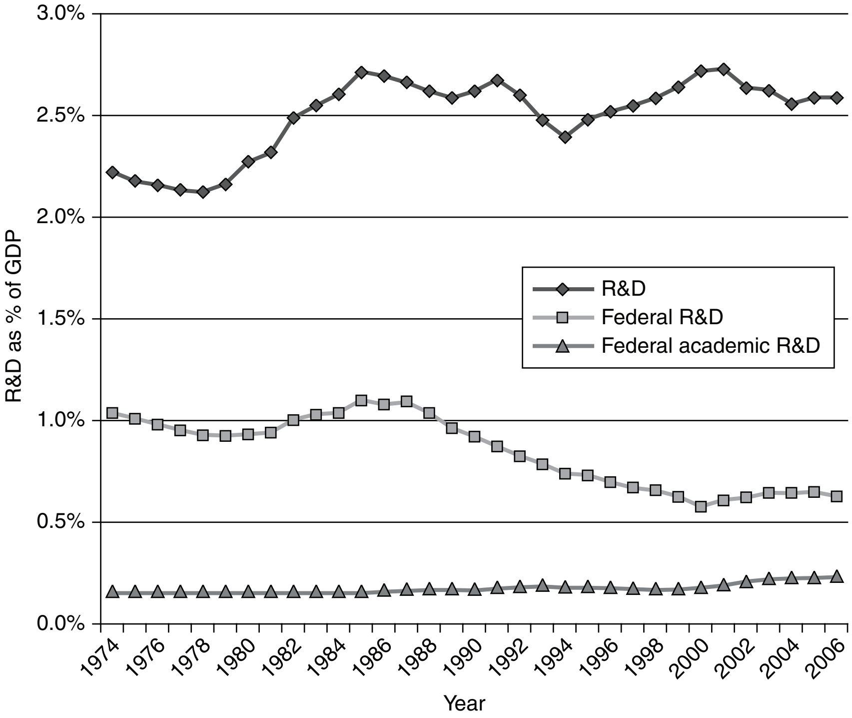

Fig. 10.2. R&D expenditures as percentage of GDP, 1974–2006. *Source:* National Science Foundation, Division of Science Resources Statistics, Survey of Federal Science and Engineering Support to Universities, Colleges, and Nonprofit Institutions, WebCASPAR database, http://webcaspar.nsf.gov.

billion, was defined as basic research (NSB 2008). However, this federal contribution is the combined result of discrete funding decisions by a number of R&D-supporting agencies with specific applied missions. Most of the federal government's R&D is mission-oriented; that is, it is intended to serve the goals and objectives of the agency that provides the funds (e.g., agricultural research for the US Department of Agriculture). As Harvard president James Conant once observed (Geiger 1993), the vast majority of federal academic research funding does not support "disinterested" basic research, but instead supports "programmatic" research that the funding agencies believe would eventually have utility for the sponsor. In contrast, as indicated in table 10. 2, many other national governments have traditionally included as part of their support for R&D large block grants (i.e., General University Funds [GUF]) that are used at the discretion of individual higher education institu-

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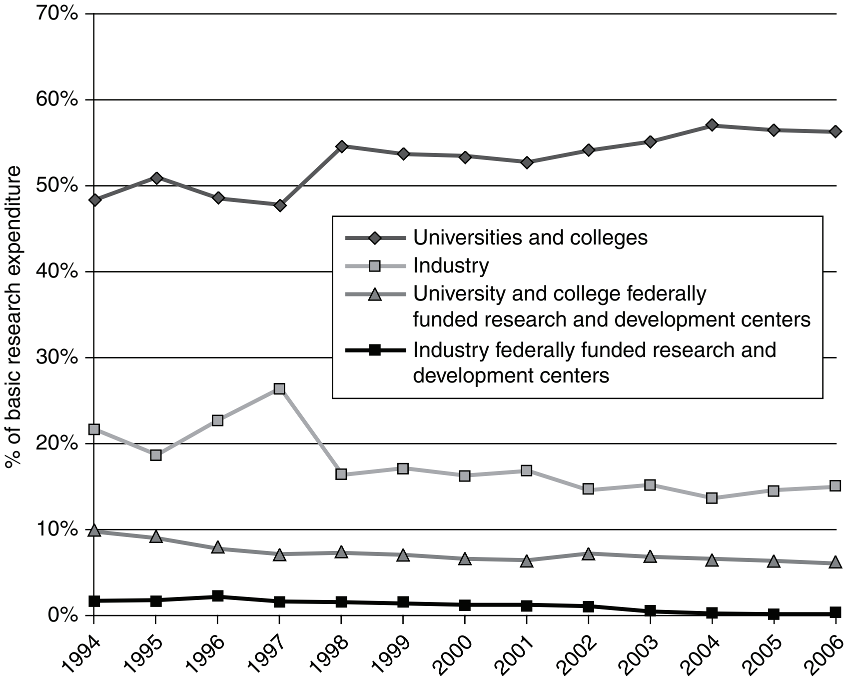

Fig. 10.3. Percent of total basic research expenditures, by selected performing sectors, 1994–2006. *Source:* National Patterns of R&D Resources: 2006 Data Update, National Science Foundation, Arlington, VA, www.nsf.gov/statistics/natlpatterns/.

tions to cover administrative, teaching, and research costs. In each of the European G-7 countries, these GUF account for 50% or more of total government academic R&D to universities and in Canada for roughly 45% of total government academic R&D support (NSB 2008). Consequently, by design US federal academic research policy involves the national government much more directly in defining the social purposes of academic research than do the national policies of governments in other countries.

As table 10.3 shows, the goal of improving human health (National Institutes of Health) motivated an estimated 63.2% of total US federal financing of academic R&D in FY2007. An additional 7.9% was funded for defense (Department of Defense), 4.8% for space (National Aeronautics and Space Administration), 3.2% for energy (Department of Energy), and 2.3% for agriculture (US Department of Agriculture). The National Science Foundation, whose mission is clearly basic research, provided 13.3% of academic R&D funding, although, as is noted below, these funds are concentrated in the fields of science and engineering and arguably are heavily influenced by the socioeconomic goal of industrial production. In comparative perspective, federal allocations reflect the significant and long-term national emphasis given to both human health and defense in academic research funded by the US government in comparison to the social goals of other countries (as suggestive evidence, see table 10.2).

These national policy differences are also reflected in the relative emphasis given to research in particular academic subjects by the US federal government. Table 10.4 provides the most recent analysis of federally financed R&D expenditures by academic field.[13] Corresponding to the agency expenditures on academic R&D discussed above, federal academic R&D support in 2006 was overwhelmingly concentrated in the life sciences, which represented 69.7% of federally supported expenditures in the sciences and 59.3% of total academic R&D (table 10.4). The more detailed analysis of life sciences expenditures available from the National Science Board (2008) indicates that 20.3% of total federal support for academic R&D was invested in the biological sciences and 33.9% was invested in the medical sciences. Engineering received 13.0% of total academic R&D funds, followed by the physical sciences at 10.3%. In contrast, the social sciences received 2.1% of total funding (psychology, which is separately categorized in NSF reporting, received 1.9%.), while the humanities, including the visual and performing arts, received .2% of total federal funding for academic R&D. Overall academic R&D expenditures in selected OECD countries (table 10.5) suggest that US federal policy places a higher priority on the biomedical sciences and a much lower priority on engineering, the social sciences, and the humanities than do other developed countries.

As previously noted, a widely acknowledged weakness of US federal academic R&D policy is its decentralized character. Because different federal agencies make budgetary decisions on federal academic R&D, and because these decisions are driven by the missions of each agency rather than some overall conception of the needs for academic basic research (or doctoral education), the results may not be socially optimal. A 2001 National Academy of Sciences (NAS) study (Board on Science, Technology, and Economic Policy 2001) reviewed national trends in federal support of graduate education and research and concluded that the existing policy apparatus was creating serious underfunding in the physical sciences, engineering, and mathematics. While there were real, significant increases in federal academic R&D in the first five years of the twenty-first century, the vast majority of those funds were designated for a doubling of the NIH budget. This growth of biomedical research reflected federal priorities, but the decreases in many S&E (science and

TABLE 10.2.

Government R&D support for selected OECD countries, by socioeconomic objectives, 2005 or 2006, in percentages

	Defense	Human health	General university funds	Nonoriented research	Space	Industrial production	Energy	Agriculture	Other
United States (2006)	57.9	21.8	0.0	5.5	7.6	0.3	0.9	2.0	4.0
Japan (2005)	4.0	3.9	33.9	16.3	6.7	7.3	16.8	3.3	7.8
Germany (2005)	5.8	4.3	40.6	16.3	4.9	12.6	2.8	1.8	11.6
United Kingdom (2005)	31.0	14.7	21.7	16.0	2.0	1.7	0.4	3.3	9.1
Canada (2006)	3.6	15.0	32.6	8.0	4.2	11.4	4.8	6.7	13.6

Source: NSB 2008, fig. 4-28, www.nsf.gov/statistics/seind08/start.htm.

Notes: Countries listed in descending order by amount of total government R&D. Data are for years in parentheses. R&D is classified according to its primary government objective, although it may support several complementary goals, e.g., defense R&D with commercial spin-offs is classified as supporting defense, not industrial development.

TABLE 10.3.

US federal obligations for academic R&D, by agency, 1997–2007, in percentages

	Department of Agriculture	Department of Defense	Department of Energy	National Aeronautics and Space Administration	National Institutes of Health	National Science Foundation	All other agencies
1997	3.5	10.7	4.6	5.7	56.2	14.5	4.7
1998	3.1	10.6	4.7	5.9	56.5	14.0	5.2
1999	3.3	9.9	4.2	5.3	58.6	13.9	4.9
2000	3.3	9.5	4.0	5.0	60.0	13.5	4.7
2001	3.3	11.7	3.8	4.8	58.9	12.8	4.8
2002	2.8	10.4	3.6	5.0	61.4	12.7	4.2
2003	2.8	8.5	3.5	4.8	63.3	13.1	4.0
2004	2.7	8.4	3.5	4.8	62.8	12.9	4.8
2005	2.9	8.8	3.3	4.4	63.0	12.4	5.2
2006 (est.)	3.2	9.5	2.9	4.6	62.0	12.3	5.7
2007 (est.)	2.3	7.9	3.2	4.8	63.2	13.3	5.2

Source: NSB 2008, appendix table 5-6, www.nsf.gov/statistics/seind08/start.htm.

TABLE 10.4.
Federally financed R&D expenditures at universities and colleges, by field, FY2006 (current $M)

Field	Expenditure	%
Science	26,221	80.5
Computer sciences	1,015	3.9
Environmental sciences	1,763	6.7
Life sciences[a]	18,268	69.7
Mathematical sciences	373	1.4
Physical sciences	2,705	10.3
Other sciences	2,097	8.0
Psychology	629	1.9
Social sciences[b]	711	2.1
Engineering	4,236	13.0
All non-S&E fields[c]	773	2.3

Source: NSB 2008, table 5-1 and appendix table 5-3, www.nsf.gov/statistics/seind08/start.htm.

Note: Detail may not add to total due to rounding.

[a] Includes biological sciences, $6,240 million, and medical sciences, $10,434 million.

[b] Includes economics, political sciences, sociology.

[c] Includes humanities and visual and performing arts (which received a combined $60 million), as well as professional fields such as business and management, communications, education, journalism, library science, law, and social work. Education received the most federal support at $435 million.

TABLE 10.5.
Share of academic R&D expenditures, by country and S&E field, 2002 or 2003, in percentages

Field	United States (2003)	Japan (2003)	Germany (2002)	Australia (2002)	Netherlands (2002)
Natural sciences and engineering	91.0	67.8	77.0	73.2	72.8
Natural sciences	39.5	12.1	28.5	29.7	17.9
Engineering	14.5	24.7	19.8	11.5	21.0
Medical sciences	30.9	26.7	24.6	25.2	28.3
Agricultural sciences	6.2	4.3	4.0	6.9	5.5
Social sciences and humanities	7.3	32.2	20.2	26.8	24.8
Social sciences	6.2	NA	8.2	20.6	NA
Humanities	0.4	NA	12.1	6.2	NA
Academic R&D	100.0	100.0	100.0	100.0	100.0

Source: NSB 2008, table 4-15, www.nsf.gov/statistics/seind08/start.htm.

Notes: Detail may not add to total because of rounding or because some R&D could not be allocated to specific fields. For United States, $0.7 billion could not be allocated between NS&E and social sciences.

NA = detail not available but included in totals.

engineering) fields observed by the NAS were the result of independent decisions by federal agencies confronting a constrained budget environment, rather than any serious consideration of national S&E priorities. Because such a large proportion of doctoral students are supported by assistantships on federally funded research grants, these agency decisions also affect the future supply of S&E doctorates in critical fields. The NAS called for the president to develop a means for evaluating the overall federal research portfolio in light of national needs and to adjust budget allocations accordingly.

Several actions by the Bush administration appeared to be responsive to these concerns (Intersociety Working Group 2008). The president's Office of Management and Budget introduced the Federal Science and Technology budget. This budget, a collection of selected R&D and non-R&D programs that emphasize basic and applied research, was designed to provide an alternative measure of the federal investment in science and technology and to help track federal S&T investments in the budget process. The president's National Science and Technology Council also implemented a number of interagency R&D initiatives in global change research, information technology, and nanotechnology. Finally, President Bush announced in his 2006 State of the Union address the new American Competitiveness Initiative (ACI) to boost federal investments in physical sciences research. Federal budgets since that announcement have reflected these priorities, with increases for key physical science funding agencies, including the NSF.

However, as an American Association for the Advancement of Science (Intersociety Working Group 2008) analysis of the FY 2009 budget notes, increased funding for physical sciences and engineering research in the three federal agencies participating in the ACI has been offset by cuts in related research funding by other federal agencies. Consequently, the federal R&D portfolio remained unbalanced. In addition, while other countries are making significant investments in research as a means of enhancing their economic competitiveness, total US federal support of basic research in real terms decreased for the fifth year in a row, down 9.1% from 2004.

THE FEDERAL ACADEMIC RESEARCH ALLOCATION PROCESS

US federal academic R&D policy is also distinguished by its reliance on peer review of grant proposals, on competitive allocation of research funds, and on indirect cost recovery. While peer review[14] by researchers to help judge the merit of proposals for research funding plays an important part in US academic research funding, there is more variance in this policy than is often acknowledged (Foltz 2000). For example, the NIH uses exclusively panel reviews in which peers meet in one location to collectively review research proposals. NSF relies to a greater extent on the judgments of program managers using the advice of peers who review proposals by mail, either alone or in conjunction with a panel format. In contrast, many Department of Defense research allocation decisions are made exclusively by program managers. Criticisms have been raised as to the integrity of the peer-review process, particularly following the "big crunch" of the 1990s, when federal R&D funding ceased to match the growth in the academic research system (Foltz 2000).[15] In this more competitive context, it has been alleged that the peer-review system has become particularly vulnerable to politicization, favoritism, and strategic maneuvering, but there is limited empirical evidence to support these allegations (Chubin and Hackett 1990; Foltz 2000). However, it has been suggested that the US peer-review system for assessing grant proposals could be strengthened by focusing more on research output measures (Chubin and Hackett 1990). A more critical question may be the economic efficiency of an allocation system based largely on the review of individual grant proposals in a time of declining probability of obtaining federal research funds. Critics suggest that this new environment entails substantial opportunity costs in researcher time spent preparing and writings proposals rather than conducting research (Foltz 2000).

As already noted, the US federal academic R&D process is unusual in the high proportion of funds allocated competitively. This federal policy appears to provide the opportunity for a more efficient allocation of research funds than national policies that restrict government research funding to certain institutions or sectors of higher education. Historically R&D (and doctoral education) has been highly concentrated within the overall US higher education system. However, within the US ARE the concentration of academic R&D funds has been declining since the mid-1980s (Geiger and Feller 1995). The share of federal academic R&D received by the 99 universities (66 public and 33 private) previously described and listed in table 10.1 was 80% in 1979–80, 79% in 1989–90, 74% in 2000, and 74% of the $30 billion allocated in 2006 (Geiger 2004; NSF 2007). A recent analysis (NSB 2008) similarly notes that the top ten university recipients obtained about 20% of the nation's total academic R&D expenditures in 1986, compared with 17% in 2006. There was less change in the shares of the universities ranked 11–20 and 21–100 during this period. The decline in the top universities' share was offset by an increase in the share of those universities outside the top one hundred. This latter group's share increased from 17% to 20% of total academic R&D funds, signifying a broadening of the base of university performers.[16] The composition of the universities in any particular group is not necessarily the same over time, as mobility occurs within groups. Three of the top ten universities in 1986 were not in the top ten in 2006.

This dispersion of research funds could be an indicator of the effectiveness of a competitive research allocation policy. However, this argument must be interpreted with some caution. The state share of federal R&D funds has been a divisive issue of long standing in US national politics. The distribution of agricultural research funds on a formula basis to the states was the first federal academic R&D policy, and a similar approach was a favored congressional alternative to Vannever Bush's postwar proposal for a national research foundation. In response to increasing congressional concern about the "undue concentration" of R&D funds among the states, the NSF in 1978 initiated the Experimental Program to Stimulate Competitive Research (EPSCoR). The program's goal was to improve the competitive ability of the five states traditionally receiving low percentages of federal R&D support (Feller 2007). The EPSCoR program did not simply set aside funds for the selected states. Each eligible state submitted a proposal designed to develop and use the science and technology resources resident in the state's major research universities to improve the state's capacity to compete for subsequent R&D funding. Proposals were required to include state and industry matching funds and were subject to peer review. Although "experimental," the program continues and has now been extended to five other federal agencies granting R&D funds as well as to twenty-two additional states. Over the past decade the program has experienced a fourfold increase from $79.1 million in 1996 to $353.4 million in 2006 (NSB 2008). Studies of the impact of the NSF EPSCoR program discovered a modest increase in the share of competitively awarded federal R&D for states targeted by the program (Yin and Feller 1999) and a decrease in numbers of publications as well as an increase in citation impact (Payne 2006). Payne (2006) interpreted this latter divergent result as evidence that the design of the EPSCOR program, which included peer review of EPSCoR grants, motivated participating scientists to improve the quality of their research.

In contrast, another important influence on the dispersion of federal academic R&D—"earmarking"—provides less evidence of benefiting the public good and may be contributing to the detected inefficiency of the US ARE. Academic earmarking is the congressional practice of allocating federal R&D funds for research facilities or projects directly to colleges and universities through appropriations bills, thereby bypassing merit-based peer review. The practice began in the 1980s when federal funds for academic research facilities began to decline and has grown rapidly over the past decade. Between 1980 and 2003 the cumulative annual growth rate (CAGR) for academic earmarks was 19.4%, accelerating to 31% since 1996, while the CAGR for federal funding of academic research between 1980 and 2003 was less than 4% (de Figueiredo and Silverman 2007). Academic earmarks set a record of over $2.4 billion in FY2006, leading to a congressional moratorium on most

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domestic earmarks for that year (Intersociety Working Group 2008). But Congress resumed its earmarking prerogative in FY2008.

Academic earmarks are estimated to represent between 5% and 6% of federal academic R&D allocations (NSB 2004) and, as such, further diminish the actual amount of federal R&D competitively awarded to the ARE. Since these earmarks are allocated to a wide range of colleges and universities, including institutions that are not part of the ARE, they likely account for a measurable amount of the reduction in the academic R&D share of top-ranked universities observed over the past decades (de Figueiredo and Silverman 2007). Some Congress members have defended academic earmarks, arguing that these allocations, somewhat similar to the EPSCoR programs, represent "public values" that correct for biases in the federal R&D peer-review process (Savage 1999).

An analysis of the academic earmarking process, however, reveals that the allocations are influenced less by public values than by the location and influence of particular Congress members on congressional appropriations committees (de Figueiredo and Silverman 2007). Academic earmarks are not, consequently, allocated to the best research universities or the neediest states and therefore do not lessen research concentration so much as intensify it, based upon different variables. For example, the top state recipient of academic earmarks from 1988 to 1996 was Pennsylvania, which was also ranked in the top five recipients of federal R&D grants.[17] Academic earmarks also do not appear to enhance the research capability of universities. Receiving academic earmarks does not guarantee an improvement in an institution's share of competitively awarded grants (Savage 1999), and the citation rates of publications resulting from earmarked funds are statistically and substantially lower than those resulting from peer-reviewed projects (Payne 2006). Academic earmarks have appeared primarily within the budgets of federal agencies, such as the departments of defense and agriculture. To date the budgets of the National Institutes of Health and the National Science Foundation, which are the primary sources of federal academic R&D, have been relatively free of earmarked funds. But as de Figueiredo and Silverman (2007) note, lobbying for earmarks is increasing even among the leading US research universities. Left unchecked, this rent-seeking behavior can spiral upward to a "tipping point," at which the peer-review system will unravel.

A final distinguishing trait of the US academic R&D allocation process is its reliance on indirect cost reimbursement rather than on direct grants to universities for research infrastructure and facilities.[18] The reliance on indirect costs means that federal subsidies for research facilities and infrastructure are to a great extent allocated on a competitive basis and therefore are arguably more effectively concentrated in those universities that have proven their capability to perform high-quality research. Federal academic R&D grants include both the direct costs of research (such as materials and labor) and a percentage of indirect costs (such as facilities maintenance and renewal, heating and cooling, and research administrative staff). Reflecting this breakdown, indirect costs are now termed facilities and administrative (F&A) costs in the United States. Indirect cost rates are negotiated by each university with a lead federal agency and therefore vary by institution. Following a scandal at Stanford University in the early 1990s, the president's Office of Management and Budget placed a cap on the percentage of allowable administrative costs. Overall, F&A costs are estimated to be about 25% of federal academic R&D expenditures (Goldman et al. 2000).

Indirect cost recovery supplements, to some extent, the limited federal allocations for research facilities (table 10.6). The federal government's share of construction funding for research space experienced a decline and reached its smallest proportion (4.7%) since 1986–87 in FY2002–3, before rising to 7.4% in 2004–5 (NSB 2008).[19] Not coincidentally, the growth of academic earmarks, most of which are for facilities, corresponded with the decline in direct federal research facilities grants as well as with the rise in capital costs of conducting scientific research (Ehrenberg, Jakubson, and Rizzo 2003; Feller 2007; Savage 1999).

While indirect cost reimbursement potentially offers a more efficient allocation process for supporting research infrastructure and facilities than direct grants, the US policy has a number of weaknesses (Noll and Rogerson 1998). Negotiated indirect cost rates provide few incentives for universities to become more efficient in their use of research facilities and research infrastructure, as increases in these activities raise overhead reimbursements. Further, the accounting and auditing requirements necessary to justify negotiated rates are quite costly. By contrast, prospective reimbursement of research overhead based upon a benchmark of peer research universities would eliminate most of these costs and provide incentives for research universities to economize on their F&A expenses. Studies of research university overhead costs suggest that general variables, such as university region, research mix, control, and research quality could be used to identify peer groups for setting such benchmark F&A rates (Noll and Rogerson 1998).

DOCTORAL EDUCATION POLICY

Federal policy on doctoral education is exercised primarily through the provision of doctoral and postdoctoral fellowships, traineeships, and research assistantships,

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TABLE 10.6.

Federal academic S&E obligations, by activity, 1971–2005 (constant 2000 $M)

	Federal obligations for S&E	R&D (%)	R&D plant (%)	S&E facilities and equipment (%)	Fellowships, traineeships, and training grants (%)	Federal obligations for general support of S&E (%)	Other federal obligations for S&E (%)
1971	8,256.27	5,466.49	105.50	101.23	1,483.54	351.20	748.31
		(66.21)	(1.28)	(1.23)	(17.97)	(4.25)	(9.06)
1975	7,639.20	6,115.39	121.94	13.68	547.98	126.20	714.01
		(80.05)	(1.60)	(0.18)	(7.17)	(1.65)	(9.35)
1980	9,022.55	7,835.30	71.15	7.11	395.71	172.39	540.89
		(86.84)	(0.79)	(0.08)	(4.39)	(1.91)	(5.99)
1985	10,423.47	8,970.53	163.63	7.11	363.47	171.15	747.59
		(86.06)	(1.57)	(0.07)	(3.49)	(1.64)	(7.17)
1990	12,887.10	11,097.39	174.34	23.68	484.70	177.13	929.87
		(86.11)	(1.35)	(0.18)	(3.76)	(1.37)	(7.22)
1995	15,687.64	13,214.01	370.30	55.96	731.68	286.39	1,029.30
		(84.23)	(2.36)	(0.36)	(4.66)	(1.83)	(6.56)
2000	19,857.23	17,269.81	239.62	59.70	782.84	314.18	1,191.08
		(86.98)	(1.21)	(0.30)	(3.94)	(1.58)	(5.99)
2005	25,173.10	22,192.32	374.24	35.46	924.84	353.01	1,293.21
		(88.16)	(1.49)	(0.14)	(3.67)	(1.40)	(5.14)

Source: NSF Survey of Federal S&E Support to Universities, Colleges, and Nonprofit Institutions, WebCASPAR Integrated Science and Engineering Resource System, http://webcaspar.nsf.gov.

Note: Detail may not add to total because of rounding.

the latter supported by the previously discussed academic R&D grants. US federal policy, in contrast to that of some other countries, exerts little or no direct influence over the conduct of doctoral education, but there are several federal policies that have an indirect effect. As already noted, federal policy supports institutional accreditation, but this process has a negligible impact on doctoral-level education in the United States. In contrast, changes in visa and immigration policies following the September 11, 2001, attacks on the United States have revealed both the relevance and the important influence that these framework laws have on doctoral education. Finally, the National Research Council (NRC) has been conducting publicly available evaluations of US research doctoral education programs for over twenty years, and there is some evidence that these assessments are affecting research university behavior (Dill 2006). Although the NRC is a private, nonprofit institution, it was originally formed to provide science, technology, and health policy advice to the federal government under a congressional charter. In addition, the NRC research doctoral assessments have been regularly subsidized by grants from the NSF and the NIH.

As in other countries, the most significant federal policy on doctoral education is financial support for students. In 2005 federal agencies provided over $1 billion in support of 82,448 full-time graduate students in doctorate-granting universities, almost double the 42,175 students supported twenty years earlier (NSF 1994, 2008). While federal S&E support for fellowships, traineeships, and training grants has almost tripled since 1985, federal graduate student support controlled for inflation still has not regained the levels of the early 1970s, although the US population increased from 200 million to 300 million over the same period (table 10.6). Research assistantships associated with federal academic R&D provided the largest proportion of federal graduate support (80%), with much smaller numbers of students receiving federal fellowships (10.9%), and traineeships (8.8%), proportions that have remained relatively constant over the past twenty years (NSF 1994, 2008).[20] Overall, federal agencies supported 21% of full-time S&E graduate students in doctorate-granting universities, with over 58% of those receiving their support from the NSF and the NIH (NSF 2008).

While the percentage of graduate students supported by federal funds is a relatively small share of total graduate enrollment, the percentage of students receiving federal support is particularly significant in the biological sciences (38.7%), the physical sciences (34.6%), and chemical engineering (34.0%) (NSF 2008). In addition, an NRC analysis of federal funding and doctoral enrollment trends in the 1990s discovered a high correlation between declining federal support in a field and declining graduate enrollment and PhD production (Board on Science, Technology, and Economic Policy 2001). National policy is even more significant in S&E postdoctoral training, where 70% of the 48,653 postdocs in 2005 received federal support (NSB 2008). Postdocs who are federally supported, like federally supported graduate students, receive the largest proportion of their government support from research grants. Over 56% of postdocs are supported by research grants. The influence of the national emphasis on health R&D is very evident in postdoctoral training, where over two-thirds of postdocs are working in the biological, medical, and life sciences.

The substantial increases in federal R&D and support for S&E doctoral education in the last decades of the twentieth century stimulated US PhD production in the natural sciences and engineering, peaking in 1996 with over 20,000 doctorates. But following the leveling-off of real federal S&E support in the 1990s, US natural sciences and engineering PhDs declined to 19,000 in 2002 before increasing between 2003 and 2006 to over 24,000 PhDs, primarily due to growth in the life sciences and engineering (Hoffer et al. 2007; NSB 2008). The proportion of PhDs produced in science and engineering has also increased, from 37.5% in 1976 to 53.4% in 2006, but this growth is also explained by substantial increases in the shares of the life sciences and engineering. While the 45,596 PhDs produced in 2006 represents a new and positive-appearing high for US universities, the overall figure is somewhat misleading. As discussed below, this growth is due almost entirely to foreign residents. The number of US citizens receiving PhDs actually declined from 1996 to 2006, despite the substantial growth in PhD production, and while the number of US citizens receiving PhDs in the life sciences increased over the period, the numbers in both the physical sciences and engineering declined.

As in the case of academic R&D funds, research doctoral education has historically been quite concentrated in the US ARE. The ninety-nine universities previously described (see table 10.1) produced 71% of the 45,596 research doctorates granted in 2006 (Hoffer et al. 2007). However, also parallel to R&D funding, the growth in the number of PhDs over the past thirty years has been accompanied by an increased dispersion of doctoral production. Because the most highly ranked universities tend to limit the growth of their doctoral programs, the vast majority of the increase in PhD production has occurred in smaller universities that receive less federal R&D money and have fewer highly ranked research doctoral programs (Freeman, Jin, and Shen 2004).

As noted, foreign students on temporary visas have accounted for virtually all of the overall growth in the number of US S&E doctoral graduates since 1976 (Hoffer et al. 2007). Temporary residents received 11% of newly awarded S&E doctorates in 1976 and 31% in 2006. Foreign citizens now account for an even larger percentage of individuals in postdoctoral training, with the proportion of temporary residents increasing from 40% in 1985 to 55% in 2005 (NSB 2008). Temporary residents earn a significant proportion of their doctoral degrees in particular fields. In 2006 foreign students on temporary visas earned more than half of doctoral degrees awarded in mathematics and physics and almost two-thirds of the PhDs awarded in computer science, engineering, and economics (Hoffer et al. 2007). Until the 1990s, about 50% of temporary residents receiving an S&E doctoral degree planned to stay in the United States, but this percentage increased during the 1990s, and by 2006, 76% of foreign-born recipients of S&E doctoral degrees reported plans to stay in the United States. As the Committee on Science, Engineering, and Public Policy noted in 2005, US R&D as well as the US ARE have accordingly become highly dependent upon foreign nationals who received their doctoral degrees in the United States. For example, S&E occupations data from the 2000 census indicated that about 38% of doctorate-level employees were foreign-born and nearly half of the doctoral-level staff and 58% of the postdocs and fellows at the NIH were foreign nationals. Furthermore, by 2003, 33% of full-time S&E doctoral faculty in research universities were foreign born, and in the physical sciences and engineering the proportion was 47% (NSB 2008).

As a consequence, the more restrictive visa regulations designed to safeguard the United States following the attacks of September 11, 2001, quickly revealed the significance of national immigration policies for the ARE. An NRC study of the impact of these new regulations (COSEPUP 2005) discovered that following 9/11 there was a measurable increase in the visa refusal rate and consequently a decline in the number of student visas issued. The number of GRE exams taken by foreign nationals also substantially declined. In 2003–4 there were significant drops in international graduate student applications (down 28%), admissions (down 18%), and enrollments (down 6%) at US universities.

If US leadership in S&E was to be maintained, the study's authors argued, changes in US immigration policy were required. The committee recommended extending the duration of visa clearances for students and scholars from all countries and ensuring that foreign students and scholars could attend scientific meetings outside the United States without serious delays in reentering. The committee also called for the creation of new nonimmigrant-visa categories for doctoral-level graduate students and postdoctoral scholars, whether they are coming to the United States for formal educational or training programs or for short-term research collaborations or scientific meetings.

The second significant policy instrument influencing US doctoral education is the Assessment of Research Doctoral Programs carried out by the National Research

Council. The NRC conducted its first assessment in 1982, repeated the assessment in 1993, and is has now completed its third assessment.[21] The organization of the NRC rankings is quite different from that of other league tables (Dill and Soo 2005). The rankings are subsidized by federal agencies, including the National Institutes of Health and the National Science Foundation, and the assessments are designed and carried out by some of the leading social scientists in the United States. While the NRC rankings include reputational peer judgments, they also include objective data on measures that research and experience have indicated are important determinants of academic quality in research-doctoral programs. These include inputs, such as the number of faculty members and doctoral students in each program, and crucial process measures, such as student time to degree. Also included are objective output measures like the number of doctoral graduates each year and the number of faculty publications, as well as significant outcomes, such as the number of times faculty publications were cited and the number of distinguished awards received by the faculty.

Following the assessment conducted in 1993, the NRC commissioned a study by leading social scientists of the methodology used in that assessment. The committee's report (Ostriker and Kuh 2003) concluded that valid academic rankings can assist funders and university administrators in program evaluations and are useful to students for graduate program selection. However, rankings would be harmful if they gave a distorted view of the graduate enterprise that encouraged behavior inimical to improving its quality. To guard against this, the committee recommended the following improvements:

- presenting ratings as ranges rather than rankings to diminish the focus of some administrators on hiring decisions designed purely to "move up in the rankings";
- expanding the quantitative measures used in the rankings to include institutional characteristics, doctoral program characteristics, and faculty characteristics that research has shown contribute to a reputation for quality;
- surveying a sample of advanced graduate students in selected fields regarding their assessment of their educational experience, their research productivity, program practices, and their institutional and program environment in order to encourage a greater focus by programs on education in addition to research; and
- determining whether programs collect and publish employment outcomes of graduates for the benefit of prospective students, in order to encourage programs to pay more attention to improving those outcomes.

Of particular interest was the committee's analysis of the reputational indicators used in the NRC rankings. The reputational measures had traditionally included two questions, one on the scholarly quality of the program faculty and a second on the effectiveness of the doctoral program in training scholars. The reputational survey had been limited to members of the discipline being rated. Nonetheless, the committee concluded that the strong correlation between the two reputational measures in past NRC assessments "suggests that raters have little knowledge of educational programs independent from faculty lists" (Ostriker and Kuh 2003, 36). Therefore, although the reputational measure will be continued, it will be limited to scholarly reputation of the program faculty alone. Furthermore, the NRC committee determined that because more highly ranked programs were the most visible, some measure of the rater's familiarity with the program should be included. Finally, the NRC assessment, unlike most available league tables, presents all its data in an unweighted form. Thus, users of the assessment can apply their own preferences to the data and make their own comparative judgments—impossible with weighted measures.

There is some evidence that the impact of the NRC rankings has been positive for US doctoral education. In a series of well-known articles in the higher education literature, Martin Trow (1983, 1999) described the extensive changes made in the departmental structures of the biological sciences at the University of California, Berkeley, over a period of twenty years. Berkeley radically changed the means of appointing and promoting faculty members in the university's biological community and redesigned the nature of facilities for the biological sciences. Trow argued that the impetus for these dramatic changes, which markedly strengthened biological research and education at Berkeley, came in part from the decline in the rankings of several of the biological sciences departments revealed in the NRC assessment of 1982. Similarly, Ron Ehrenberg (2002; Ehrenberg and Hurst 1996) has described how administrators at Cornell were able to use the objective measures of the NRC rankings of 1995 to develop a causal model of quality in research doctoral programs that helped to guide the university's strategic research decisions. In sociology the analysis revealed that the department's low ranking was due to its small size, not to its faculty's productivity; therefore the university decided to continue the department and increase its number of faculty. In biology the assessment led Cornell to devote resources to particular areas in which the university had special strengths and which would likely be important in the coming years.

KNOWLEDGE TRANSFER POLICY

Policymakers are now directing increasing attention to the role of research universities in innovation policy, national strategies designed to enhance economic development and international competitiveness. A recent international assessment (Polt et al. 2001) placed the United States among the countries with high performance on industry-science relationships. Several indicators suggest the recent growth of these relationships in the United States. The share of university research funding provided by private industry tripled between 1970 and 2000, although it has been noted that this support, in fact, restored the strong links that had existed earlier in the twentieth century (Hall 2004). The number of joint research ventures with at least one university partner registered with the federal government doubled in the 1990s, and papers jointly authored by university and industry scientists increased from 6,000 in 1980 to almost 9,000 in 1990 (Polt et al. 2001).

Industry-science interactions have long been a characteristic of the US system. The framework conditions of US higher education, featuring limited federal control and a nationally competitive market composed of private and state-supported universities, served to encourage entrepreneurial behavior by research universities that included organized efforts to transfer basic research to local business and industry. The initial US federal policy on R&D was motivated by a desire to connect academic research to agricultural development. Since World War II the programmatic nature of federal R&D funding—for example, in defense, space, and biomedical sciences—likely further facilitated the linkages between many university researchers and private industry.

In the 1980s, US federal policy on technical innovation became more formalized with the passage of the Patent and Trademark Laws Amendment Act (Bayh-Dole Act of 1980) and the National Co-operative Research Act of 1984, which encouraged the formation of university-industry joint research ventures. A large number of federal programs have been initiated to promote industry-science links, such as the Advanced Technology Program (ATP) of the Department of Commerce and the collaborative research infrastructure programs of the National Science Foundation, which include the Industry/University Cooperative Research Centers, Science and Technology Centers, and Engineering Research Centers.

The Bayh-Dole Act of 1980 provided blanket permission to recipients of federal R&D funds, including universities, to file for patents on the results of federally sponsored research and to exclusively license these patents to others. Under the act, universities are required to share any resulting income with the relevant academic researchers and to use the remaining portion of revenues for scientific research or education. Prior to the act, the US government held the rights to inventions based on federally funded research and granted them on a nonexclusive basis to anyone. Various federal agencies had in the past negotiated Institutional Patenting Agreements (IPAs) with individual universities, but no uniform policy existed.

The passage of Bayh-Dole has often been hailed as a landmark policy that helped initiate university patenting and licensing activity with subsequent significant benefits for the US economy. An empirical analysis of the impacts of the policy, however, suggests a more complex picture (Mowery et al. 2004). The Bayh-Dole Act did encourage universities to be more directly involved in and expand their licensing activities. Prior to 1980 a number of universities, particularly public universities with incentives to be connected to the local economy, were engaged in patenting faculty research. But many of these universities sought to insulate themselves from the commercial activity by relying upon third parties or legally separate foundations to manage their patents.

The federal endorsement of university licensing reflected in the Bayh-Dole Act persuaded both public and private universities to establish their own technology transfer and licensing offices (TTOs) and to more systematically pursue the commercialization of university inventions (Dill 1995). Following the act, the number of research universities with technology transfer offices that manage and protect intellectual property increased eightfold to over two hundred, and the number of university patents registered increased fourfold (Phan and Siegel 2006). A 2000 survey of TTOs indicated that university income from licensing and patenting actives represented 4.7% of their research expenditures (Thursby and Thursby 2003). The average income per active license was $66,465, but only 43% of licenses earned royalties.[22] The average income per university was $8 million, but 79% of the universities earned less than $5 million, and half reported income less than $824,000. These data support the view that at many research universities the cost of running a TTO likely exceeds the revenue from licensing. In addition, a recent analysis of TTOs and research outputs reveals that universities with established offices prior to Bayh-Dole (all of which are high federal R&D performers) are much more efficient producers of articles and patents than the many universities that created offices following the act (Foltz et al. 2005). However, the purpose of the Bayh-Dole Act was not to add to the revenue of universities but to increase commercial innovation, and the evidence that the growth in university patenting and licensing has accomplished this is still unclear.

Indeed, the supposed impact of the Bayh-Dole Act on universities has been brought into question (Mowery et al. 2004). Universities have increased their share of US patenting after the act, but the rate of growth in this activity accelerated in the early 1970s, prior to Bayh-Dole, and remained fairly constant through the 1980s and 1990s.[23] Factors other than the Bayh-Dole Act have created incentives for the growth in university patenting and licensing activity, including the drop in federal funding per full-time researcher in the 1980s and 1990s and the rise of new science-based industries in biotechnology and microelectronics.

A central assumption of the Bayh-Dole legislation was that patenting and exclusionary licensing were necessary conditions for the transfer and commercial development of university inventions. Exclusive patents can provide incentives for commercial firms to invest in costly development of an embryonic invention. There is some evidence that at the time of patenting, most university inventions seem to fit this profile, the majority being filed as "proof of concept" or "prototypes" rather than "ready for practical use." But whether this means the inventions require exclusive licenses to facilitate commercialization is still unclear (Colyvas et al. 2002; Thursby and Thursby 2003). Field research on commercial innovations suggests that the primary channels by which university research influences commercial innovation are publications, conferences, and consulting, with patents and exclusive licensing less significant, and only then in certain fields such as biotechnology (Cohen, Nelson, and Walsh 2002).

One frequently voiced concern is that the increased incentives for patenting and exclusive licensing have diverted universities from basic to applied research. The available research, while limited, provides little evidence to date of a shift toward more applied work. NSF annual surveys of academic R&D expenditures reveal no decline in the basic research share since the late 1980s (NSB 2006). Case studies of major research universities and surveys of faculty members provide little evidence of shifts in research direction or changes in the proportion of basic research (Hall 2004; NSB 2006; Thursby and Thursby 2003).

A more significant concern is that the increasing incentives for patenting and licensing may affect researchers commitments to "open science" by encouraging publication delays, the withholding of data, and increased secrecy in research. There is some evidence, for example, that patenting and restrictive licensing are being applied to theoretical research results and research tools, such as software and databases that are critical inputs to future research (Hall 2004). While Bayh-Dole permits exclusive licenses, it does not require them, and nonexclusive licenses for research tools may better serve the public interest. The possible negative impact of university patenting and licensing on open science has led to calls for revisions in the Bayh-Dole Act and further suggests that a policy focus on property rights may be too narrow a conception for facilitating effective knowledge transfer (Nelson 2004).

In addition to redefining property rights, US policymakers have utilized other instruments to stimulate closer linkages between universities and industry. These have included legislation designed to encourage collaborative research among industry, universities, and federal laboratories (the National Cooperative Research Act of 1984); subsidies for joint research between industries and universities (the US Commerce Department's Advanced Technology Program); and grants for shared use of expertise and laboratory facilities (NSF Engineering Research Centers, Science and Technology Centers, and Industry-University Cooperative Research Centers). In the complex quilt of the US ARE, where the fifty states as well as private industry are also supporting similar initiatives, including research parks, the specific influence and impacts of these federal policies are difficult to identify. Research on university technology transfer activities, however, provides some insight into the validity of the assumptions underlying the design of these policies.

The early literature on university-industry cooperation often focused on a clash of cultures between academic researchers and industry researchers (Cohen et al. 1998). While there had been a long tradition of university-industry links in agriculture and engineering research, the increase in industry-funded research and the development of many new cooperative research centers in the 1980s and 1990s generated debate within universities. Surveys of those involved in cooperative university-industry research centers often noted the shift from the norms of open science to those of industrial innovation—research was more applied, the communication of research findings was more restricted, information was more likely to be omitted from published papers, and publication itself was more likely to be delayed (Cohen et al. 1998).

Nonetheless, universities actively sought to be involved in cooperative research centers, in part because of federal government support and the incentive they provided for industrial funds for academic research. The cooperative centers also evolved into a significant part of the US ARE. By 1990 these centers were receiving 25% of federal academic R&D, and the NSF centers were producing 20% of university patents (Cohen, Nelson, and Walsh 2002; Polt et al. 2001). Research on the cooperative research centers' impact on industry also suggested that they resulted in increases in the number of patents and R&D budgets of the participating industrial laboratories (Adams, Chiang, and Starkey 2001). The positive impacts on industry were observed to be greater for NSF centers and for centers at universities that received larger amounts of federal R&D, both indicators of high research quality. Studies of successful university incubators associated with the ATP program stressed the value of substantial knowledge flows from the university to the firm, noting that start-ups that had university licenses and university faculty on their senior management teams were less likely to fail (Phan and Siegel 2006).[24] Again, an important predictor of successful university-related start-ups was the amount of federal R&D received by the university.

However, studies of the benefits of the cooperative research centers to industry continually downplay the importance of identifying new technologies compared to the enhancement of scientific knowledge and the improvement of human capital (Bozeman 2000; Kim, Lee, and Marschke 2005; Phan and Siegel 2006). Industrial participants in NSF Engineering Centers reported that the single greatest benefit was the ability to recruit students and graduates (Bozeman 2000). Surveys of industrial participants in the cooperative research centers rarely cited direct or tangible outcomes, such as patents or licenses, as an important benefit of cooperative activity (Bozeman 2000; Phan and Siegel 2006). Instead, frequent mention was made of the benefits of knowledge transfer through the channels of open science: publications, consulting, personnel exchanges, and the informal exchanges among bench scientists.[25]

This research suggesting the important role of the channels of open science to university-industry cooperative research centers is consistent with the results of the major US empirical study of the influence of public research on industrial R&D (Cohen, Nelson, and Walsh 2002). University R&D was discovered to be an important influence on industrial R&D, but more influential in the development of projects than in their initiation.[26] Only in certain industries, notably pharmaceuticals, cars and trucks, and aerospace, was university R&D important to new projects. The contribution of university research to industrial R&D was discovered to arise primarily through research findings rather than through prototypes, a finding that is consistent with the previously noted emphasis on the positive benefits of scientific information in cooperative research centers. Research in engineering was revealed to be the most valuable contributor to industrial R&D, followed by materials and computer science research. Medical and health science research were, of course, influential on R&D in the pharmaceuticals industry. With the exception of chemistry, the basic sciences were perceived to be less influential on industrial R&D, a result consistent with the strong focus on engineering and applied sciences in the NSF cooperative research centers. The most important source of information on university research for industrial R&D by far was reported to be publications and reports, followed by meetings and conferences, informal interaction, and consulting. Recent hires were observed to be a less important source of information but of equivalent weight with patents and joint or cooperative centers. Licenses were given a low weight, equivalent to personnel exchanges. Cohen, Nelson, and Walsh (2002) observed variations in these weightings across industries. For example, patents and licenses were a key source of university research in pharmaceuticals, partly because patents are more effective in protecting inventions in drugs than in any other industry, but even in pharmaceuticals the channels of open science were rated higher. Overall, the study suggests that it is the public expressions of university research through publications, meetings, conferences, and informal interactions that convey the content of university research to industry, rather than the private channels of patents and licenses. Start-up firms were more likely to use university research in their R&D, although again this pattern was reported to be strongest in the pharmaceuticals industry.

In sum, an important contribution of the various federal programs designed to stimulate linkages between industry and universities was that the interactions they provided over time helped to change the norms and behavior within both universities and industrial R&D labs in ways that facilitated technology transfer. These programs also developed networks between university researchers and industrial scientists that facilitated informal and formal communication on university research and reduced the transaction costs of university-industry relations (Polt et al. 2001). Studies have found these types of networks to be important to successful industrial innovation in numerous industries.

US Federal Policy: An Assessment of Strengths and Weaknesses

Many OECD indicators suggest the strength of the US ARE. The numbers of publications, citations, patents, and Nobel prizes; the attractiveness of its doctoral and postdoctoral programs to the best students around the globe; and the various rankings of its universities in international league tables provide additional evidence of the quality of American research universities. There is a tendency to associate this strength with national policy, to assume that the quality of the ARE reflects steps taken by the federal government. To some extent this is certainly true. The United States is among the world leaders in the amount and proportion of support by the federal government for R&D, and the allocation of these funds to the ARE primarily through competitive processes is a distinctive and clearly influential national policy that has permitted a significant number of public and private universities to develop a world-class critical mass in research.

In comparative perspective, however, other significant framework conditions of the US ARE include its limited federal control and the nationally competitive market composed of private and state-supported universities, which encourages entrepreneurial research behavior on the part of the research universities (Polt et al.

2001; Trow 2000). As a consequence, US research universities have a high degree of autonomy in how they organize their research activities, doctoral education, and university-industry relationships. Furthermore, faculty members are not civil servants but have individually negotiated employment contracts, which permit them a great deal of mobility and flexibility. The competitive allocation of academic R&D, the competitive admission of doctoral students, and the multiple sources of university funding all create incentives for the autonomous universities to innovate new forms of research management (e.g., centers and institutes), new structures for doctoral education (e.g., graduate schools), and new approaches to university-industry relationships (e.g., technology transfer offices) that have proven effective. Federal policies over the past twenty years have also been influential in encouraging further productive linkages between universities and industry. While the decentralized nature of federal R&D funding has a number of obvious weaknesses, several international observers have suggested that the reliance on overlapping research funding agencies with different missions creates incentives for innovative interdisciplinary research and may have contributed to US leadership in new fields, such as biotechnology (Polt et al. 2001).

Whether the existing US framework conditions will be as effective in the new internationally competitive world of research universities is less clear. In a widely discussed report (COSEPUP 2006) titled *Rising above the Gathering Storm,* the National Academy of Sciences argued that US strengths in sciences and engineering are eroding and thereby threatening the nation's economic development. With regard to national policy on the ARE, the report called for new initiatives that reflect weaknesses already documented above. The National Academy recommended growth in federal support for basic research in the physical sciences, engineering, math, and computer sciences and substantial federal five-year research grants for the best early-career researchers. The report also recommended a major new centralized, competitive fund for facilities and equipment to improve research infrastructure; changes in federal visa policies affecting international students, particularly doctoral students in S&E fields; and adjustments in patent laws designed to ease researchers' use of patented inventions. The report focused heavily on human capital development in the sciences and engineering, including support for K-12 teachers and programs to encourage more undergraduate majors and doctoral students in these fields.

Despite the continued real growth in federal support for academic R&D in the United States, the productivity of American research universities, as measured by research publications and citations, has not been keeping pace (NSB 2008). The US share of world S&E articles dropped from 38.1% in 1988 to 30.3% in 2003, and the American share of world academic literature cited in S&E articles dropped from 51.7% in 1992 to 42.4% in 2003 (NSB 2006). While one would expect the US share to decline as other nations expand their pool of S&E researchers, there is also evidence that the number of US S&E articles plateaued during this period and in several science and engineering fields actually declined (Freeman 2005; NSB 2008). The costs of producing these academic publications also suggest waning productivity. In 1995 the United States produced 6.75 academic articles per $1 million of academic R&D; by 2000 this ratio had declined to 4.87, and by 2005 to 3.73 (NSB 2008).

Recent econometric studies confirm this growing inefficiency in the US ARE and suggest several reasons for it (Adams and Clemmons 2006; Foltz et al. 2005). Despite the significant increases in earmarking previously noted, the researchers suggest that federal academic R&D allocations are still associated with greater research productivity. However, the research share of total R&D expenditures of the less productive research universities is growing because of their ability to attract nonfederal support for their research and doctoral activities. These nonfederal sources include state and local funds, industrial support, and the institutions' own support of R&D, which has grown rapidly over the past thirty years (fig. 10.1). An econometric study of research universities that included both research publications and patents as outputs also discovered falling productivity (Foltz et al. 2005). While increases in federal R&D funding again positively affected research output, increases in industrial support for research positively influenced output only when federal R&D support remained dominant.

A recent qualitative national study of US universities (Brewer, Gates, and Goldman 2002) provides further insights into the possible sources of this inefficiency. The researchers detected evidence of an increasingly costly "arms race" for prestige among US universities. In the United States, research is a revenue market because of the competitive allocation of federal research funds and the growing funding of university research by business and industry. But the amount of external research funding received by a university and the number of publications by its faculty have also become important indicators of prestige in various university rankings. Many lower-ranked universities, therefore, seek to increase their prestige by investing in PhD programs, in laboratories, libraries, computer facilities, and research management as well as by attracting more research-oriented faculty. There is also increasing evidence that some universities subsidize their federal research activity through increased investment in grant matching funds and/or by attempting to lower their indirect cost rate (Feller 2000). Since the funds to support these research investments are derived from revenue markets (e.g., public financing, student tuition, private giving, and industrial support) that are not effectively tied to research quality, the inputs to the US ARE continue to rise but are not matched by equivalent outputs. One implication of this analysis is that the public interest might be served better by an even more rigorous link between federal R&D funding and university research quality than now exists. This could include larger amounts of competitively allocated federal funds for research facilities and equipment, as suggested by the NAS (COSEPUP 2006) and/or an increase in indirect costs as a means of better supporting the most productive research universities.

The most serious problem for US federal ARE policy, however, appears to be the human capital problem stressed in the recent NAS report (COSEPUP 2006). The United States, more than any other developed country, has historically been heavily reliant on immigration as a source of its strength in S&E research, and its reliance has become greater as the number of foreign-born doctoral recipients in key S&E fields has rapidly expanded over the past thirty years. As one observer noted, the US national strategy for the development of human capital in critical S&E fields has been to rely on the "idiocy" of other countries. However, as developing countries become more open, invest more in their ARE, and provide challenging economic opportunities for their most able citizens, the US strategy of relying on immigrants for its strength in S&E fields will become less feasible (Freeman 2005).

The NSF is specifically charged with developing basic research and human capital in S&E fields, but the overall federal approach to this task has a number of serious flaws. First, S&E doctoral production is close to a pure public good that must be heavily subsidized by federal policy. While the fifty states should have an obvious economic interest in S&E doctoral education, the most able doctoral students are highly mobile and less likely than other levels of students to stay in the state in which they are trained (Ehrenberg 2005). Therefore, support for doctoral education is often a low state priority compared to support for first-level degrees. US state-supported universities are consequently highly dependent upon tuition, private gifts, industry support, and most particularly federal R&D to maintain the quality of their S&E doctoral programs. Second, federal support for doctoral education and postdoctoral training is provided overwhelmingly through R&D grant funding, with several important consequences. As noted previously, the reliance on research grant support for doctoral education distorts the supply of graduates because the fields supported by federal grants reflect the research needs of mission-oriented agencies rather than the national needs in S&E education. Doctoral production in biomedical fields in the United States is therefore extremely large, while doctoral production in other critical S&E fields may not reflect national priorities.

In addition, while eligibility for federal graduate fellowships and traineeships is limited to US citizens, foreign-born students are eligible for assistantships on federal R&D grants. The emphasis on R&D grants to support US doctoral education therefore has the effect of attracting a very large number of foreign doctoral students to the United States. These foreign students are very able, and the majority currently stay and make significant contributions to US society and to the ARE. But the dependence on foreign immigration suppresses the enrollments of able, native-born students in S&E doctoral programs. An analysis of the US doctoral market confirms the general economic theory that increases in the supply of a particular skill group depress the earnings and employment opportunities of that skill group (Borjas 2006). A 10% increase of foreign-born doctoral students in a particular field or at a particular time reduces the earnings of that cohort of doctoral students by 3% to 4%. Further, US postdocs, who are most prevalent in the basic sciences, earn about 50% less than the wages doctoral recipients would receive in a regular job—the wage equivalent to a comparably aged baccalaureate recipient. This low wage is significantly influenced by the willingness of foreign-born doctorates to accept postdoctoral positions in the United States. The heavy reliance on foreign-born students in US doctoral and postdoctoral training thereby creates a "vicious cycle" in which the low wages for US S&E research assistants and postdocs do little to discourage foreign-born students who have limited economic opportunities in their home countries. However, these low wages have a substantial impact on the career decisions of native-born students, who have many attractive alternatives to S&E doctoral programs.

With the predictable exception of the biological sciences, this impact is clearly visible in the actual career choices of US permanent residents who received S&E baccalaureates. The number of undergraduate S&E graduates planning advanced study in any field declined steadily from 48% in 1984 to 28% in 1998 (Zumeta and Raveling 2002). Among the most able students, as measured by GRE scores, those planning graduate study in S&E fields declined by 8% between 1992 and 2000.[27] The largest decreases occurred in engineering and mathematics. Reflecting the career alternative available to able students in a developed country, students forsaking S&E graduate study chose professional schools in business and non-MD health professions, careers with good income prospects and less need for extended graduate education. Finally, even those citizens continuing on for S&E doctoral education are disadvantaged by current federal policy. The previously noted dispersion of PhD degrees among the US ARE particularly affected the quality of doctoral education obtained by US citizens (Freeman, Jin, and Shen 2004). As discussed, because top-ranked research universities resist expanding the size of their doctoral programs, the majority of the increase in doctoral education between 1973 and 2000 occurred at smaller universities of lower academic quality as measured by NRC research-doctoral rankings and federal R&D grants. During this period foreign students, whose numbers also dramatically expanded over these years, disproportionately enrolled in the high-quality doctoral programs, while native-born students, particularly women, disproportionately enrolled in lower-quality programs.

Federal policy indirectly influenced these results because of its very heavy emphasis on graduate research assistantships as a means of supporting doctoral education rather than doctoral fellowships and traineeships. As previously noted, federal support for scholarships and traineeships in real terms still has not regained the levels of the 1970s, even though the significance of S&E doctoral education to the economy and society has increased substantially over that period and the US population has increased by 50%. In a recent analysis of the NSF Graduate Fellowship Program, the authors discovered that the pool of applicants for the fellowships varies with the relative value of the stipend, the number of S&E baccalaureate graduates, and the number of awards granted (Freeman, Chang, and Chiang 2005). For every 10% increase in the size of the stipend, the number of applicants goes up 8%–10%, and their measured skills increase. Between 1999 and 2005 the NSF increased the value of its graduate fellowship stipends from $15,000 to $30,000. However, the number of awards has not changed over the years. The number of S&E fellowships granted per S&E baccalaureate in 2000 was one-third of those granted in the 1950s and 1970s. Freeman, Chang, and Chiang (2005) concluded that the supply of native-born doctorates in S&E could be substantially increased by providing more lucrative and larger numbers of federally funded doctoral fellowships.

Conclusion

An evaluation of the framework conditions for the US ARE suggests a number of important general points for public policy. First, institutional autonomy, which permits universities to respond to changing social demands, has been an important strength of the US ARE, providing opportunities for universities to develop innovative organizational forms that better meet the needs of the larger society. Second, the competitive allocation of academic R&D support, using overlapping agencies or research councils, encourages greater productivity and possibly generates greater originality in academic research. If anything, the recent US experience provides additional support for the importance of allocating national academic R&D on the basis of research merit. Third, the contribution of university research and knowledge to economic development can be enhanced by national policies encouraging stronger links between universities and industry. The redefinition of property rights to university research may play some role in encouraging technology transfer, but the US experience suggests that as important, if not more important, are policies designed to strengthen traditional channels of scientific communication between university and industry, including publications, conferences, academic consulting, and regional networks. Finally, high-quality S&E doctoral education plays an increasingly important role in developing the ARE. Since research doctoral education can truly be described as an internationally competitive market, government provision of valid and reliable information on the quality of doctoral programs can be a particularly influential instrument for academic improvement. In addition, the US experience suggests that national policies, while offering opportunities for the best international graduate students, also need to emphasize strong incentives for native-born students to pursue doctoral education in critical S&E fields.

NOTES

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1. The Carnegie Classification includes institutions as doctoral-granting universities if they awarded at least twenty doctorates in 2003–4; therefore this figure does not include doctoral-granting institutions below this level of activity. Doctoral-level degrees that qualify recipients to enter professional practice (e.g., JD, MD, PharmD, DPT) are also not included in this definition. By Carnegie Classification convention, this count also does not include Special Focus Institutions, such as free-standing medical schools and centers.

2. There are other comparable rankings of the leading US research universities. See, for example, the Carnegie Foundation for the Advancement of Teaching (2007), which identifies 96 universities of very high research activity, the Center for Measuring University Performance (http://mup.asu.edu/index.html), which identifies the top 100 research universities, and the analysis of Graham and Diamond (1997). Geiger's (2004) listing of 99 universities has the advantage of tracking research university R&D performance over several decades, as well as attempting to control for the quality of doctoral education. The institutions named on these various lists overlap significantly. For purposes of the present discussion, the key point is that each of these analyses confirm that US academic R&D activity is "highly concentrated" in the top one-third of those institutions comprising the overall ARE.

3. State support represents direct support for academic R&D, which significantly underestimates state expenditures for academic research in public universities. Within US universities, expenditures for faculty salaries are traditionally listed in an accounting category termed "instruction and departmental research." Getz and Siegfried (1991) note that if half of these salary expenditures were to be assigned to university-supported research, which is consistent with national surveys on faculty time allocations, then they estimate that the top ninety-eight public and private research universities in the United States alone spent an additional $5.9 billion of general university funds on research in 1987–88. This figure represents over 10% of the total federal expenditures on research and development for the same period.

4. The federal government is responsible for the operation of five service academies or

colleges: the US Military Academy ("West Point," founded in 1802), the US Naval Academy ("Annapolis," 1845), the US Coast Guard Academy (1876), the US Merchant Marine Academy (1943), and the US Air Force Academy (1954).

5. Hatch Act. (1887), *U. S. Statutes at Large,* 314, 440.

6. Federal funding of agricultural research stations within US land-grant universities continues to this day under the Department of Agriculture. In contrast to the majority of federal support for academic research, it is not competitively awarded but, since 1935, has been allocated on a formula basis to eligible universities.

7. Geiger (1986) notes that the National Cancer Institute, established as part of the National Institutes of Health in 1937 by Congress, also competitively awards research grants and fellowships to medical schools with the advice of an external advisory committee of academic scientists.

8. It was also, just prior to World War II, a system already dominated by a small group of research universities. The first comprehensive federal study of the national science effort, published in 1940, revealed that some sixteen universities then graduated 58% of the nation's PhDs and were responsible for 50% of research expenditures (Geiger 1986).

9. Kleinman (1995) argues that the National Advisory Committee for Aeronautics (NACA), established by Congress in 1915 to coordinate and support aeronautical research in anticipation of World War I, served as a model for Bush in establishing the NDRC and then the OSRD. NACA was appointed by the president, dominated by part-time civilian scientists, and during the interwar years initiated the practice of federal contracts with universities to conduct military research.

10. By 1941 the NDRC had signed 207 contracts, which were awarded to 41 universities and 22 companies (Kleinman 1995, 62). The magnitude of the federal research effort is suggested by the number of university contracts let by OSRD in 1943–44, which was three times the level of all prewar university research (Geiger 1986, 264). The NDRC adopted NACA guidelines stipulating that no one should profit from this research and that contracts should support direct and indirect costs.

11. Geiger (1993, 174) notes that between 1958 and 1966 the NSF budget alone rose from $40 million to $480 million. However, this growth was dwarfed by federal appropriations to the National Institutes of Health (NIH), which grew from $98 million in 1956 to $1,413 million in 1967. Though a mission-oriented agency, the NIH expended most of its resources on basic research grants and graduate fellowships in the biological sciences, which were allocated to university medical schools and health research centers. By 1960 NIH had surpassed the Department of Defense as the primary supporter of academic research and by 1965 was larger than the next two smaller sources combined (Geiger 1993).

12. As noted in figure 10.3, universities and industrial firms also conduct basic research through Federally Funded R&D Centers (FFRDCs), such as the Lawrence Livermore National Laboratory, research that the universities and firms administer under their respective contracts with the federal government.

13. Table 10.4 is derived from the NSF FY2006 Survey of Research and Development Expenditures at Universities and Colleges. Because not all institutions responded and those that did respond did not fill in every category, these data are incomplete and do not correspond with data from other sources. However, the response rate was over 96%, and this survey

currently provides the most complete information on overall federal funding of academic R&D by field.

14. The NSF and other federal agencies prefer to describe their R&D allocation systems as “merit review with peer evaluation” (Hackett and Chubin 2003).

15. For example, it has been asserted that over the past decade the probability of being funded for a federal research submission has declined from 50% to 10% (Foltz 2000; Hackett and Chubin 2003).

16. The explanation for this shift is subject to debate. As pointed out below, it may not be due to the competitive allocation of federal academic R&D funds.

17. Almost 30% of academic earmarks went to five states and 47% went to ten states (Savage 1999).

18. As a measure of overall federal support for research universities, federal academic R&D is slightly misleading. The federal government also provides support for research facilities, scientific equipment, and doctoral fellowships, which is more clearly reflected in the NSF S&E budget (table 10.6).

19. Note that federal policy also indirectly subsidizes research facilities by making university bonds tax-exempt and university gifts and grants, which may be used for renovation and/or new construction, tax-deductible.

20. Research assistantships are the primary form of federal support in all fields except the medical sciences, in which fellowships and traineeships are dominant (COSEPUP 2005).

21. These assessments follow a long tradition in the United States of multidisciplinary rankings of graduate degree programs based upon reputational surveys (Webster 1992). Raymond Hughes initiated the first rankings in 1925.

22. In keeping with the Bayh-Dole Act, universities share licensing income with faculty inventors. On average, universities return 40% to the faculty inventor and 16% to the relevant department or school, although it is not uncommon for a department to return its share to the inventor’s lab or to permit the inventor to direct its share (Thursby and Thursby 2003).

23. The United States leads the world in the number of patents generated by universities (Polt et al. 2001).

24. Thursby and Thursby (2003) note the importance of university inventors being willing to provide time to licensees in order to increase the potential for successful transfer of technology.

25. Adams, Chiang, and Starkey’s (2001) frequently cited empirical study of the impacts of cooperative research centers on industrial laboratories also notes that the most important channels of cooperation were joint publications and faculty consulting.

26. The study focused on “public research,” that is, research from both universities and federal labs. However, Cohen, Nelson, and Walsh’s (2002) analysis of US patents revealed that university research was 5.7 times more likely to be cited than research from federal labs, although the difference was less pronounced in biomedical fields.

27. These data likely understate the decline, since the number of top students electing to take the GRE also decreased over this period, reflecting students’ desire to take professional school admissions tests instead (Zumeta and Raveling 2002).

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CHAPTER TWELVE

California

WILLIAM M. ZUMETA

California is a vast state, stretching some eight hundred miles from north to south, with a land area similar to that of Great Britain. It has high mountains, vast deserts, a stunning coastline, and great, highly productive farmlands. It is home to more than 36 million people, about one-eighth of the US population, and the number continues to grow rapidly. The demographics of this population have undergone remarkably rapid change in recent years. Whites now represent less than half the working-age population (ages 25–64), down from 71% in 1980, and their percentage is projected to be below 40% by 2020 (fig. 12.1). By that year adults of Hispanic origin are expected to constitute about 38% of the California workforce (up from 16% in 1980) and Asian Americans 17% (up from 6% in 1980).

California's economy is a dynamo. Its gross state product, similar to the GDP of France, would make it the fifth-largest in the world, were it a nation. In recent decades, the economy has become increasingly technology-based, although agriculture remains very important. The Silicon Valley south of San Francisco, the city of San Francisco itself and its more immediate environs, the vast Los Angeles metropolitan area, and the San Diego area are meccas for firms in the electronics, communications, information technology, biotechnology and other life sciences, and most recently, nanotechnology industries. The technology-based aerospace industry continues to be important in the Los Angeles area as well.

In the modern economy it is hardly surprising that these key industries are all knowledge-based and research-intensive. They have natural links to universities, since many of their employees are highly educated. They recruit from the universities, and many of them seek direct connections to and even financially support university research. Indeed, many of Silicon Valley's early companies were spin-offs

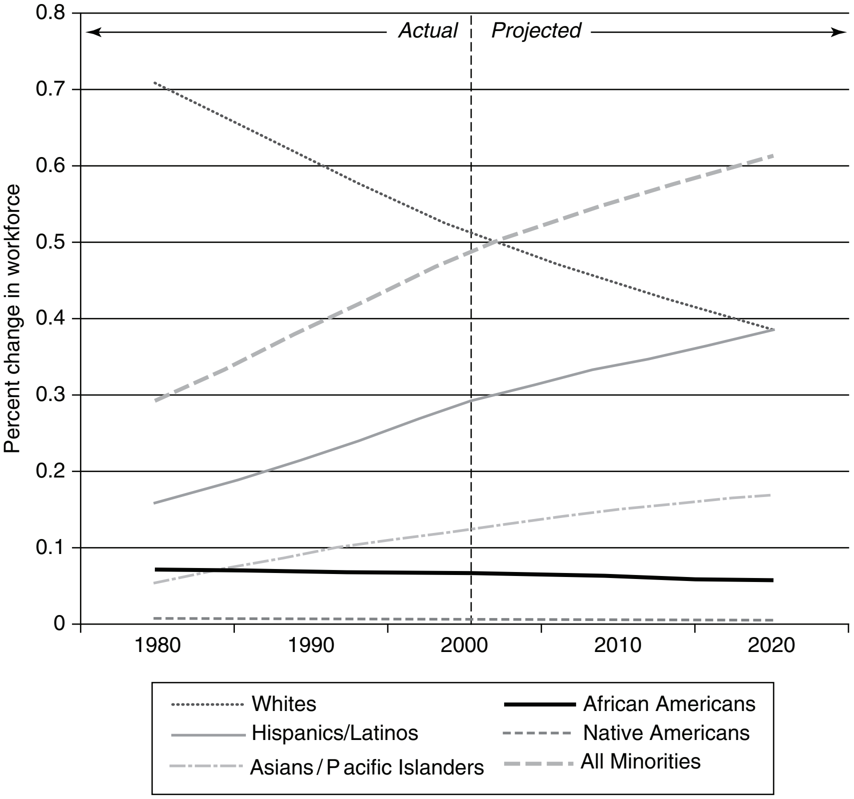

Fig. 12.1. Demographic trends in California's workforce, 1980–2020. *Sources:* National Center for Public Policy and Higher Education, 2005. Data is from US Census Bureau, 5% Public Use Microdata Samples (based on the 1980, 1990, and 2000 censuses) and US Population Projections (based on the 2000 census). *Notes:* Population projections are based on historical rates of change for immigration, birth, and death. Projections for Native Americans are based on the 1990 census. The census category "other races" is not included.

from Stanford University research, and this pattern continues today there and in other locales within the ten-campus University of California (UC) as well as in such academic powerhouses as the California Institute of Technology (Cal Tech) and the University of Southern California (USC).[1] The prosperous agricultural sector in California is also closely tied to university research and extension services, as has long been the case.

These two major trends—rapid population growth and demographic change and the shift in the economy toward knowledge- and technology-based industries—are key to comprehending the state's future; their intersection or lack thereof is another essential element. In short, the state will be faced with a workforce crisis before long if it is not able to do a far better job than at present of educating the burgeoning population groups of color and preparing them for the jobs its economy is creating (National Center for Public Policy and Higher Education 2005; Campaign for College Opportunity 2006). But efforts to do this and to provide for the elements essential to the health of the economically crucial research mission in California's universities must work through the state's political and policymaking processes. Here there are serious shortcomings and major challenges to be explored.

In this chapter I will analyze these issues with a primary focus on the research mission, defined broadly to include the fiscal health and prospects of the state's public research university system; the University of California and the status and future of its graduate programs; and issues surrounding the explicitly state-funded research programs in that university and outside it. I will proceed by first summarizing a bit of the relevant history of state policy toward public higher education in California, including the continuing importance of the 1960 Master Plan for Higher Education. I will look next at the current strains and pressures facing the state that affect its support of higher education and the University of California in particular, as well as some relevant policies of the state and the university itself. Then comes a brief look at the emergence of California's high-tech economy and its connections to academe, followed by an analysis of specific policies toward financial support, faculty salaries, and especially graduate education and prospects for future developments in these.

Next, a major part of the chapter is devoted to a description and analysis of the political economy of the large volume and wide range of explicitly state-initiated and state-supported research programs. In the language of Roger Geiger (this volume, chapter 11), these are largely "upstream" policies designed to support broadly defined research areas of interest to the state rather than "downstream" policies focused primarily on local technological applications. Most but not all of the state research programs are based at the University of California, including the unique new state entity called the California Institute for Regenerative Medicine (CIRM).

Finally, I offer a concluding assessment of this odd assortment of historical legacies, current policies, and policymaking mechanisms, giving attention to the factors underlying the challenges and prospects ahead for the state, the University of California, and its research mission. A key conclusion pertinent to the themes of this volume is that, large and resource-rich as it is, even California—a single state within a large nation—cannot efficiently pursue research policies in the same way a nation can. Fundamentally, the state's major research policies should be to maintain the quality and vitality of the University of California and the productive climate of interaction between UC (as well as other universities in the state) and research-intensive industries and employers. Secondarily, I also seek to point out how the state could take steps to improve its capacity to perform better in selected areas in which state-level policymaking could be most effective.

The Historical Legacy and Current Realities

California has a proud history of commitment to broad access and excellence in higher education. Granted constitutionally autonomous status from its founding,[2] the University of California was a leader in public higher education from early on. Although based in Berkeley (near San Francisco), it began developing outposts around the huge state early in the twentieth century. These eventually grew into ten campuses, including eight well-developed "general campuses" offering a wide range of undergraduate, graduate, and research programs; a specialized health sciences campus in San Francisco; and a new general campus recently launched in the agricultural Central Valley (at Merced). No other US state has anything approaching this large array of research institutions. The central administration of the university and especially the systemwide Academic Senate maintain and generally enforce common standards for faculty appointments and promotions and basic student qualifications throughout the system.

The standards are high, and the results have been impressive. In the most recent professionally based rankings of graduate program quality published by the National Research Council in 1995,[3] more than half of UC's 229 doctoral programs in the rated fields were ranked among the top twenty in the United States.[4] An aggregation of these discipline-based rankings found UC Berkeley placing higher than any other US university, public or private, and both UC San Diego and UCLA were in the top twelve.[5]

Table 12.1 shows more recent data pertinent to UC's academic and research quality: the rankings of the UC campuses in obtaining federal research and development funds, the vast majority of which are competitively awarded. In fiscal year 2005, three UC campuses ranked among the top dozen US universities by this measure, and the recent trends in UC's standing in these rankings over time are generally positive.[6]

A key juncture in California higher education history is represented by the 1960 adoption by the state legislature of the Donahoe Higher Education Act, California's famed Master Plan for Higher Education. In response to rapid in-migration from other states and the coming graduation from high school of a "tidal wave" of postwar baby boom children, a political free-for-all among state institutions seeking

TABLE 12.1.
Federal R&D spending and national ranking of UC campuses, 1997, 2000, 2005

	1997		2000		2005	
	$ (1,000s)	Rank	$ (1,000s)	Rank	$ (1,000s)	Rank
UC San Diego	238,569	6	326,037	5	463,946	8
UC Los Angeles	215,937	10	274,162	12	469,889	6
UC San Francisco	206,749	12	248,878	14	438,988	12
UC Berkeley	159,275	22	208,338	21	290,960	26
UC Davis	104,943	38	141,740	35	240,003	38
UC Irvine	64,293	74	88,274	67	161,524	56
UC Santa Barbara	64,915	73	80,754	69	103,955	88
UC Santa Cruz	24,005	132	25,959	135	62,301	121
UC Riverside	24,006	131	21,085	147	52,919	129
UC total	1,102,692		1,415,227		2,284,485	

Source: National Science Foundation/Division of Science Resources Statistics, Survey of Research and Development Expenditures at Universities and Colleges, FY2004 and FY2005.

Note: UC Total for 2005 includes $519,000 appropriated to the University of California Office of the President.

authorization to serve them began. UC and the State Board of Education worked together to develop a plan for the orderly expansion of public higher education that became the Master Plan. This plan codified a state commitment to provide free access to high-quality public higher education to all who were deemed able to benefit from it.[7]

In order to make these commitments manageable, the plan formally assigned the University of California, the State Colleges (now California State University [CSU]), and the California Community Colleges responsibility for educating different segments of the population. The University of California received responsibility for the most academically qualified undergraduates; for doctoral education; for professional education in the most prestigious fields, such as law and medicine; and for academic research. The other segments of the statewide system were to handle the large bulk of undergraduate demand: the community colleges were to be accessible to all, and the state colleges were to provide master's degree programs in certain fields.[8] Funding to achieve excellence in each segment's mission would presumably be allocated accordingly by the state.

During the 1960s California's economy surged, and the state indeed funded a vast expansion of the public higher education system. During the late 1950s and the 1960s, the University of California established three entirely new general campuses (Irvine, San Diego,[9] and Santa Cruz) and made three more much smaller operations into full general campuses (Davis, Riverside, and Santa Barbara). This was a remarkably ambitious effort to expand research-based public higher education throughout a large part of the state and to extend it to a substantial share of the population. It largely succeeded, although the abrupt end of the baby boom and major political and economic changes[10] in the late 1960s and early 1970s ended free tuition at UC and CSU and led to much slower growth of the new campuses than had been originally envisioned, especially in graduate programs. State policy, together with great economic prosperity, had permitted university leaders to greatly expand in a short period the base of the University of California, which the Master Plan called the primary state agency for academic research. During the 1970s and 1980s they were able to build substantially upon this base, albeit much more slowly, and they did it while maintaining high academic standards in both teaching and research.

RECENT STRAINS

The rapid demographic change in California's population that has already been described has had a number of indirect effects on the University of California. the resulting increase in the state's dependent population, together with the legacy of Proposition 13 and its aftermath, has strained the state government's finances (see note 10). The public schools have been largely overwhelmed by the numbers of students and the complexities of teaching large numbers from low-income and different language backgrounds (Schrag 2006). Both resources per student and student achievement have slipped. Relatively small proportions of Latino students (as well as African Americans, whose achievement has long lagged) are competitive for admission to the University of California, and the problem carries over to the graduate level. The clear need for better early preparation of these students has bolstered other forces at work to shift relative policy focus, including within the University of California, over the past decade and more toward undergraduate and even K-12 education at the expense of graduate study.

Yet, increasingly vital linkages between elementary and secondary (or K-12) education and the higher education segments remain weak, and they are not much better across the several postsecondary components of the state's educational system. As a result, California's high school graduation rates are low compared to the rest of the country and stagnant at best (National Center for Public Policy and Higher Education 2006). Most who do graduate are not fully prepared for college and require remedial classes. The vaunted community colleges enroll many students but graduate and transfer to universities distressingly few of them (Shulock and Moore 2007). The University of California and CSU systems evidently continue to do a very good job with the students they accept,[11] but without much more state money than has been made available in recent years, they are not enthusiastic about taking on a great many more. And no one at the state level has taken a statewide view of these problems and made system-level integration and performance, together with more funding, a political priority. An interested and determined governor could conceivably do this, but no governor has shown such an inclination for decades.

Like the rest of the United States, California experienced three deep recessions in recent years, in the early 1990s, again about ten years later, and a third beginning at the end of 2007. The first two hit harder and the effects lasted longer in California than in most other states. (The full dimensions of the most recent recession are unclear at this writing.) In the downturn of the early 2000s, the state took drastic measures to keep afloat financially, including deep budget cuts and long-term borrowing to balance its annual operating budget, the latter a highly unusual practice in US state government finance. The service on this debt is a continuing obligation, and an unfortunate precedent has been set. According to the legislature's fiscal analysis agency, the state faces a structural gap between projected expenditures and revenues of $4–5 billion per year through at least 2009–10 and a smaller deficit thereafter (California Legislative Analyst's Office 2006).[12] Competition for state operating budget funds is thus quite fierce. Entities like the University of California are poorly positioned structurally in this competition, because the growth of other major state expenditure items is protected by statutory formulas (e.g., education spending for K-12 and community colleges under voter-enacted Proposition 98) or is driven by federal and judicial requirements to fully fund caseload growth (in indigent health care and prisons) that do not apply to university enrollments.[13]

Figure 12.2 shows the dramatic impact of the earlier recessions on state support and overall financing of the University of California and makes clear that the period since 1990 has not been favorable fiscally speaking. In FY1990, before California felt the impact of the US recession that began later in the same year, UC received about $24,500 per full-time-equivalent student (FTES) from the state (in 2006 dollars). That figure dipped to $18,133 by 1995 and did not come close to the early 1990s levels again until 2001 ($22,916), the height of the "dot.com" economic boom. The subsequent downswing led to steady and cumulatively drastic cuts (a reduction of 38% from 2001 to 2005), so that state support in FY2007 was less than 60% of the 1990 level in real per-student terms.

As figure 12.2 illustrates, to mitigate the impacts of these swings, university policymakers, with the state's encouragement, turned primarily to tuition (called "fees" in California). Fee revenue per student more than doubled in real terms between 1991 and 1995 but after that declined somewhat as state support recovered and then surged. But between 2003 and 2006 there were sharp increases again as the state budget plunged, a total of 58% in fee revenue growth over just these three years. Thus, over the fifteen years from 1990 to 2006, fee revenues as a percentage of the

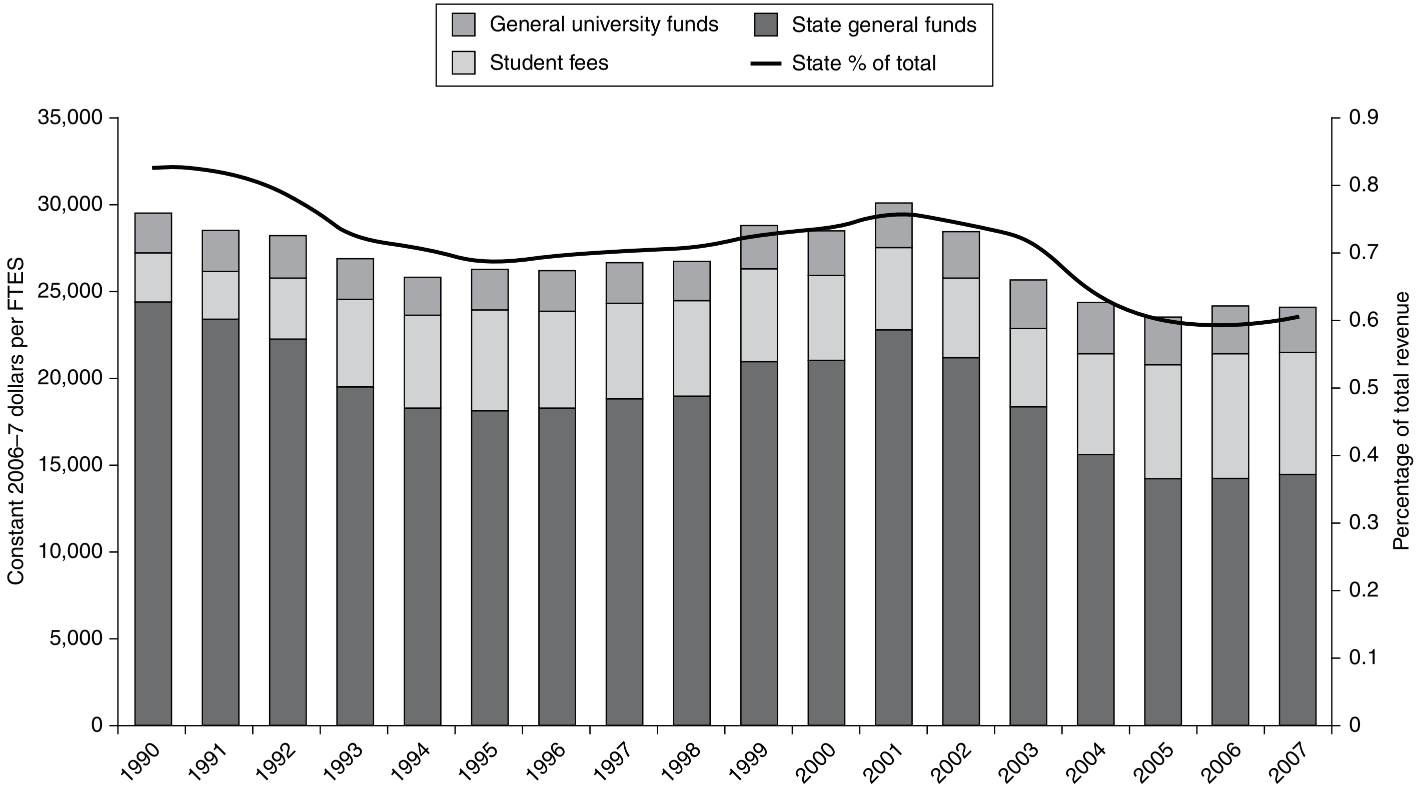

Fig. 12.2. UC state, university, and fee revenues per full-time equivalent student (FTES), FY1990–2007. *Source:* California Postsecondary Education Commission, *Fiscal Profiles 2006,* display 71. *Note:* Revenues for FY2006 and FY2007 are estimates. Total revenue excludes lottery funds.

total (state plus fee revenues) grew from just 9.2% to 29.3%. This certainly raises the possibility that the university is fast approaching the political limits of tuition increases as a source to sustain revenue growth, at least for a while.[14]

The fee increases clearly helped to stabilize the university's finances, but they did not fully stave off real declines in total revenue during the state's economic downturns, particularly in the early 2000s. The sum of state and fee revenues fell from $30,200 per student in 2001 to a nadir of $23,635 in 2004 in constant dollars (a 21.7% reduction). Total revenue per student in 2007 was 18.8% lower than the 1990 figure. It should also be noted here that about one-third of the increased fee revenues generated in recent years have not been spent on instruction or other core academic needs, but rather have been recycled into need-based student financial aid under the UC Grants program.[15] The instability in available funding, almost as much as the level, is clearly a major challenge for institutional leadership seeking to maintain the university's basic quality and effectiveness in all its areas of endeavor. The pattern of drastic increases in charges during hard times also impacts many students and their families adversely.

Although the fee increases described above have affected undergraduates the most, in recent years UC's heavily oversubscribed professional schools, particularly in law, business, and the health sciences, have also increased their charges substantially. In the arts and sciences, a standard, much lower graduate fee rate linked to the undergraduate rate applies.[16] The recent hikes in graduate fees affect some students, but most graduate students in the arts and sciences have fees covered for at least part of their time in school by initial recruitment offers, by external fellowships, or as part of their compensation for service in teaching or research. Still, there are impacts on graduate students when they are not covered by one of these sources of support, and there are effects on the sources as well.

In particular, graduate fees have been rising to levels higher than agencies providing research and fellowship support are willing to pay in full, thus putting unfavorable competitive pressure on UC researchers or forcing them to consider cuts in graduate student salaries and stipends in order to cover fees. Budgets for teaching assistants (TAs) face similar dilemmas. If TA fees are fully covered from these sources, budgets for instruction go up without sufficient state funds to cover the increases. UC faculty and administrative officials are quite worried about the impacts of these pressures on the campuses' ability to compete for the best graduate students, especially in a state with very high living costs.

California's future fiscal outlook is not particularly positive. As mentioned, the state carried a kind of consumer debt forward from the early-century recession as a claim against future revenues. Its FY2007 operating budget was balanced by one-time revenues, and a substantial structural gap between recurring expenditures and revenues at current tax rates was projected at that time through at least 2010 (California Legislative Analyst's Office 2006). The economic crisis of 2008–9 rapidly brought to a head the structural problems in California's finances, with the projected gap between expenditures and revenues reaching a staggering $42 billion in February 2009. Since the state has little political appetite for permanent tax increases—indeed quite the reverse—higher education support seems likely to face continuing strong competitive pressures at best.

On the other hand, California's political culture has become highly populist in orientation, and hence, unpredictable. After the current crisis has passed, a voter initiative could conceivably be mounted—with the support of a governor who chose to make higher education a political issue, probably by linking it closely to economic competitiveness—to guarantee this sector a share of the state budget, as has been done for many other functions.[17] Almost certainly, though, such a guarantee would include the other public higher education segments and would require a commitment to additional undergraduate enrollments and moderation in student fees from UC as a quid pro quo.

In this fiscal context, certain policies of the higher education segments themselves may work to divert some of what state resources are available from support of UC's nine well-established campuses. First, the CSU system has long sought to lift the Master Plan's restrictions on its ability to offer doctoral degree programs on its own.[18] For just as long, the University of California has opposed this, fearing an expansion of CSU's mission that would divert scarce resources for advanced education. CSU finally succeeded in getting legislative authority to offer EdD degrees in 2005 and now seeks to broaden this permission to other types of professional doctorates. PhD programs could be next, and the ultimate result would probably be the fiscal dilution UC fears.

Another questionable policy decision was initiated by the University of California itself. For some years there has been concern inside and outside the system that the university was neglecting an important part of California where there was no UC campus: the Central Valley, the four-hundred-mile-long agricultural corridor where population has been growing rapidly. Not coincidentally, many Latinos reside in this area, and the university felt it could serve them better with a campus there. Hence, UC began planning in earnest for a new campus at Merced in the late 1990s. The campus, though far from complete, opened its doors in 2005 with the blessing of state policymakers. Building a new general campus with programs at all levels is a very expensive undertaking, and enrollments have so far fallen well below projections (Ashton 2006). Ultimately the university's strategy to go where the students are may be quite sound, but one wonders about the priority of undertaking such a large and continuing financial commitment in the present fiscal context.

In the long run, if for no other reason than simply to sustain its political and financial support from the state, the University of California surely needs to find ways to ensure that its student bodies are much more reflective of the changing ethnic complexion of the state. Reflecting very mixed feelings among the citizenry about this emotional issue, in 1995 the Regents of UC (the system's governing board) voted to end "affirmative action" policies that had permitted vigorous recruitment and acceptance of qualified students of color at both the graduate and undergraduate levels.[19] Soon thereafter the voters of the state passed a similar ballot initiative (Proposition 209) that applied to all its public colleges and universities. At UC, enrollments of minority students (except Asian or Pacific Islander Americans) at both levels declined for a few years after this prohibition took effect. The university made great efforts to find legal ways to reach out to underrepresented groups of students—even to help improve their prior educational preparation—and to evaluate applicants more "holistically," that is, not relying so heavily on prior academic performance and test scores alone. After a few years, enrollments of most minorities again began to increase, but the gains among African Americans at both the undergraduate and graduate levels have been very modest; their numbers remain below pre-1998 levels. Native American undergraduates were 28% fewer in 2005 than in 1998.[20]

UC has made serious efforts to increase minority representation in its student body, but it seems clear that the self- and then state-imposed inability to take race or ethnic origin into account in admissions has taken a toll on progress among Latinos and other seriously underrepresented groups, such as African Americans and Native Americans. Comparisons of enrollments of each of these groups as a percentage of all enrollments by level shows that Latinos have gained only 2.1 percentage points at the undergraduate level since 1991 and just 0.4 points at the graduate level in spite of this group's rapid population growth, while African Americans have actually lost ground at both levels. Only Asian Americans and the small "other" ethnicity category have made strong gains.[21] Clearly, more will have to be done to increase the rate of progress in the Latino category in particular if the university is to retain full political viability over time as California's population changes and this group moves toward majority status.

California's Economy and Its Links to Academe

California is a state oriented toward research, science, and engineering. Table 12.2 provides some statistics from the National Science Foundation that support this claim. The state ranks first in the United States in most gross measures of scientific and R&D (research and development) activities. Even allowing for its large population (about one-eighth of the US total) and economy (13% of US GDP), nearly all of the indicators in this compilation show California to be well ahead of national norms. Thus, it is not surprising that California's economy has long been linked to academe and public policies relating to it.

TABLE 12.2.
Science and engineering profile: California

Characteristic	CA	US	Rank
Doctoral scientists, 2003	76,410	566,330	1
Doctoral engineers, 2003	22,650	118,540	1
S&E doctorates awarded, 2004	3,499	26,275	1
Engineering (%)	22	22	n/a
Life sciences (%)	22	27	n/a
Social sciences (%)	17	16	n/a
S&E and health postdoctorates in doctorate-granting institutions, 2003	7,693	46,807	1
S&E and health graduate students in doctorate-granting institutions, 2003	51,989	507,247	1
Population, 2004 (thousands)	35,894	297,550	1
Civilian labor force, 2004 (thousands)	17,552	148,769	1
Personal income per capita, 2004 ($)	35,172	33,041	12
Federal spending			
Total expenditures, 2003 ($M)	219,706	2,024,246	1
R&D obligations, 2003 ($M)	17,410	91,359	1
Total R&D performance, 2003 ($M)	59,664	277,577	1
Industry R&D, 2003 ($M)	47,142	198,244	1
Academic R&D, 2003 ($M)	5,363	40,055	1
Life sciences (%)	58	59	n/a
Engineering (%)	13	15	n/a
Physical sciences (%)	11	8	n/a
Number of SBIR awards, 1999–2004	6,476	31,847	1
Utility patents issued to state residents, 2004	19,488	84,268	1
Gross state/national product, 2004 ($ billions)	1,551	11,744	1

Source: National Science Foundation/Division of Science Resources Statistics, Science and Engineering State Profiles: 2003–4.

Notes: SBIR = small business innovation research; S&E = science and engineering. Rankings and totals are based on data for the fifty states, the District of Columbia, and Puerto Rico. Reliability of estimates of industry R&D and of doctoral scientists and engineers varies by state, because sample allocation was not based on geography. Rankings do not take into account the margin of error of estimates from sample surveys. Data on doctoral scientists and engineers include only recipients of doctoral degrees from US institutions in S&E and health fields. The field percentages represent the largest three fields within the state.

THE STATE, THE UNIVERSITY, AND CALIFORNIA AGRICULTURE

For much of the first century after statehood, agriculture was California's leading industry, and it continues to be very important today, owing largely to the state's favorable climate and soils. In 1867, Governor Frederick Low helped bring together the supporters of the small, private College of California with the state officials responsible for the federal land grants under the 1862 Agricultural College Land Grant Act (the Morrill Act) to form what became, in 1868, the University of California (Scheuring 1995). The university has long had a close relationship to the state's farmers and, more recently, its agribusinesses, through research and development, degree-oriented education—both supported substantially by the state[22]—and Cooperative Extension (originally the Agricultural Extension Service), which provides a variety of outreach services and is jointly supported by federal, state, and local governments. While not unique to California, this extension model, taking university research findings directly to the users and maintaining close touch with their problems and needs, is generally considered a great success story in public science and technology policy (Rasmussen 1989). Among the notable successes of UC agricultural research was critical support of the now huge California wine industry through early research on grape diseases and the development of disease-free plants at UC Davis. Also, beginning in the 1940s, scientists at Berkeley developed very productive strains of strawberries that now represent the vast majority of those planted commercially. As of 1995, California strawberries accounted for about 80% of US production (Farrell 1995).

In recent decades, in response to trends in environmental and social awareness and criticism that it was too focused on the needs of its agribusiness clientele, UC's agricultural research and applied activities have shifted in significant measure away from pure production efficiency and toward development of sustainable practices and studies of the social impacts of technology as well as the problems of small-scale farmers and low-income farm workers (Scheuring 1995; Walker 2004). Yet, stringencies in state and federal general funding have also cut in the other direction by pushing faculty to look more to private funding and governmental project grants, many of which emphasize production and efficiency issues.

CALIFORNIA'S HIGH-TECH ECONOMY AND ITS TIES TO ACADEME

The roots of California's high-tech economy go back at least to early-twentieth-century aviation, when the likes of Glenn Curtis and Glenn Martin, Donald Douglas, the Lockheed brothers, John Northrop, and T. Claude Ryan were all pioneering in this field in Southern California—Douglas with the aid of aeronautics research at Cal Tech. The Los Angeles area in particular has become a world leader in what is now "aerospace" R&D and manufacturing.[23] Southern California's entertainment industry has also been a technology leader since the earliest days of both radio and television engineering, fields in which early pioneers had backing from members of the Stanford University community (Starr 2005).

Stanford played a leading role in the origins of the uniquely vibrant innovative complex of technology-oriented firms and spin-offs known as Silicon Valley. As early as 1909, Stanford was involved financially in the creation of a significant small company, eventually named Federal Telegraph Corporation, led by one of its recent engineering graduates (Sturgeon 2000).[24] A Stanford professor, Frederick Terman, worked on vacuum tubes and supported, with about $100 in university resources, the work of a graduate named Russell Varian, whose discoveries ultimately led to the radar used in World War II. Terman also taught and advised two young engineers named William Hewlett and David Packard. After the war, he became Stanford's dean of engineering and later its provost and senior vice president. Key policies of his were to bring promising inventors into contact with Stanford faculty, the creation of the Stanford Industrial Park in 1951 (the first tenant was Varian and Associates, from whom Stanford earned more than $2.5 million in licensing fees on patented inventions from its $100 investment), and the establishment of the Stanford Research Institute. Terman's fertile mind in both engineering and institutional design played a significant role in the creation of the hotbed of technology-oriented entrepreneurialism around Stanford and environs that is Silicon Valley. Stanford had an indirect role in the development of silicon-based semiconductor and microprocessing technology developed by new companies like Fairchild Semiconductor and later Intel (Starr 2005). Thus, though a private university played an important part, state policy had little to do with the emergence of Silicon Valley.

Meanwhile, UC Berkeley contributed to the development of usable atomic energy under the leadership of physicists Ernest Lawrence and J. Robert Oppenheimer but was not much involved in its commercialization. The San Diego area was an early player in biotechnology, and this had much to do with the presence of the scientific prowess of the UC campus there. The rapid development of this campus in the 1960s, at a very high level of quality from the outset and with a focus on the life and other sciences, was a deliberate public policy step by the state and university leadership (Kerr 2001).[25] Biotechnology companies have since sprung up as well around the university's Bay Area campuses (UC San Francisco and UC Berkeley) and in the sprawling Los Angeles metropolitan area, where several UC campuses are located. Early in the twenty-first century California boasted no less than 40% of the nation's research and manufacturing in biotechnology (Starr 2005).

It is no accident that research- and technology-oriented industries tend to locate in proximity to leading research universities. Firms in these industries seek such proximity in order to facilitate access to relevant academic research and, even more importantly, to university researchers and students. Firms may employ faculty members as consultants and occasionally lure one away to lead a corporate lab or project, but the real prize is often access to students and new graduates with fresh ideas and entrepreneurial zeal. As in the early days in Silicon Valley, in crucial fields like computer software and biotechnology, small firms begun by academics and/or recent graduates have played a key role in the development of new products and processes and thereby have affected regional economic development. Thus, beginning in the 1980s, state policymakers around the country have taken a renewed interest in trying to seed these kinds of developments in various direct ways, with mixed results (see Geiger this volume, chapter 11). Here, as Geiger and other analysts suggest is important in understanding long-term impact, I first take a broad view of the role of state policy in supporting the research base.

It is important to remember, though, that California is increasingly a bifurcated society. Its high-tech economy is becoming increasingly dependent upon immigrants from Asian countries, some of whom probably will not stay as opportunities improve in their homelands. Critically, most of the large and fast-growing Latino population group sees only a very distant connection between elite universities like UC and their own immediate needs. The university and the state need to break out of the Proposition 209 straitjacket to begin building deeper bonds with this group and prepare them for the contemporary economy and society. Yet, as Schrag's (2006) analysis suggests, whites will likely continue to resist competition for prized university spaces from both Asians and eventually Latinos, especially when anything that could be interpreted as ethnic preference is involved. Unless successfully addressed, these demographic cleavages will eventually erode support for the university and thus for a key engine of research-based growth in the state's economy.

State Policies of Direct Importance to Academic Research Capacity

THE HISTORICAL LEGACY

Very likely, the state's earlier support of the development of the University of California's eight general research university campuses and the health sciences campus (UC San Francisco) at a high level of academic quality is the most important policy underlying the state's academic research capacity. As suggested above, the key policy challenge now is how the state can afford to continue to sustain this base adequately while also supporting the development of a tenth campus, UC Merced, without resorting to tuition escalation. Such an escalation would be risky to both its commitment to broad citizen access to higher education of the highest quality and to its political standing in an increasingly diverse state.

Another core state policy with a long history is the autonomy of the University of California that was enshrined in the state constitution when the university was founded (Stadtman 1970). Many observers believe that the legal independence of UC from the state and the tradition of providing most of the institution's annual state appropriation in a single or a few budget line items (albeit with many specific expectations and understandings underlying) have played a key role in supporting the university's high academic quality standards (Douglass 2000; Glenny and Dalglish 1973; Trow 1993). These basic academic autonomy norms appear to remain strong—a good thing in view of the nimbleness required in an era of heightened global academic competition. This is all the more true in a polity characterized by tendencies toward political meddling and overregulation that are clearly manifested in state budgetary and other relations with the other segments of public higher education.

More broadly, this autonomy has been interpreted to permit the university substantially more control over its finance, purchasing, contracting, and personnel policies than is typical of American public universities. Of particular importance are two major finance policies: the university's appropriation from the state and its tuition-setting authority. As suggested, the University of California's state appropriation is provided with very few line items directing how the money is to be spent, although there are negotiations with state officials that create understandings about this, and the institution is subject to state audits. The university's Board of Regents retains the authority to set tuition (fee) rates, even for state resident students. Although there are discussions with state officials about fee rates in the context of negotiations about state appropriations, the university's legal control of fee-setting gives it considerable leverage, because elected officials generally do not wish to see fees rise too fast, as usually occurs when state support is considered inadequate. While this tactical game applies most prominently to undergraduate fees, graduate and professional fees are also part of the negotiations.

FACULTY SALARIES

The most basic resource for developing and maintaining academic quality and research capacity is, of course, a quality faculty. The state and the University of California developed such quality in large part by being willing to pay premium salaries to attract and retain top faculty (Kerr 2001). This aspiration is nicely illustrated by the official institutional comparison group that UC and the state use to calibrate where average UC salaries should be. Unlike most public research universities, the University of California has an official peer group that includes four of the top private universities (Harvard, Yale, MIT, and Stanford) in addition to several strong public universities (Illinois, Michigan, SUNY-Buffalo, and Virginia).[26]

The peer group is indeed strong, but the state's recent performance in actually funding the university's faculty salaries to this level is another matter. Table 12.3 shows the actual percentage salary increases provided in each year from 1990–91 through 2005–6 and the percentages that would have been needed to attain parity with the average faculty salaries in the peer group.[27] After a much better performance in the 1980s, in only four years of the most recent sixteen was the actual increase equal or nearly so to the parity level: in 1990–91 and in three years during the state's economic boom in the late 1990s and very early 2000s. In all the other years, the peer parity target was substantially higher than the amount the state provided for faculty salaries. After 2000–2001, the gap widened considerably so that, as of 2006–7, a 14.5% increase would have been needed to reach parity with the average of the eight official peer universities' salaries. It is also worth noting that UC faculty received no salary increase at all for three consecutive years in the early 1990s and did little better during the economically difficult years from 2001–2 to 2004–5. These trends are cause for serious concern about the university's ability to continue to attract and retain faculty equal to the best in the country.

GRADUATE ENROLLMENTS

Strong graduate programs and abundant graduate students are crucial to the success of university research programs. For many years, though, the University of California was unable to expand graduate enrollments as it wished because of financial constraints imposed by the state and pressures to expand undergraduate enrollments as the higher priority. During the halcyon days of the university's expansion, the state paid a premium in its appropriation for each additional graduate student enrolled, that is, a substantially larger amount than for undergraduates. Although this premium was eliminated by the state budget authorities in the 1970s, the UC administration, with its constitutional autonomy and independent funding sources, was able to continue it at a reduced level for considerably longer. Eventually, in the 1990s, the premium payment for graduate enrollments was eliminated entirely. That, plus the state's fiscal travails already recounted, made it virtually impossible to expand graduate programs substantially.[28]

Figure 12.3 illustrates the stagnancy in systemwide graduate enrollments during

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TABLE 12.3.
UC salary increases compared to parity with official peer group, 1991–92 to 2005–6, in percentages

	Peer Parity Figure	Actual Salary Increase
1991–92	3.5	0.0
1992–93	6.7	0.0
1993–94	6.5	0.0
1994–95	12.6	3.0
1995–96	10.4	3.0
1996–97	10.3	5.0
1997–98	6.7	5.0
1998–99	4.6	4.5
1999–2000	2.9	2.9
2000–2001	3.0	3.0
2001–2	3.9	0.5
2002–3	6.9	0.5
2003–4	9.2	0.0
2004–5	9.3	0.0
2005–6	13.9	2.0

Source: California Postsecondary Education Commission, Faculty Salaries at California's Public Universities, 2006–7, 3.

the 1990s while undergraduate numbers grew by 16%, all in the middle and latter parts of the decade (1994–2000). From 2000 to 2005 however, graduate enrollments started climbing for the first time in decades, increasing nearly 20% over these five years, compared to 12.7% for undergraduates. Much of this increase was the product of two initiatives: one to double graduate enrollments in engineering and computer science, inspired by Governor Pete Wilson with considerable corporate encouragement; and the second, also largely externally driven, to sharply increase the university's output of teachers and administrators for the public schools.[29] In many other fields there was little change even in the recent period. UC administrators think that the fiscal and political climate is such that new graduate programs and substantial enrollment increases need strong external interest to generate the political and financial support to be viable. This usually means that specific fields, often those of clear economic relevance, must be emphasized.[30]

In addition to some targeted state support and reallocations from other parts of the budget, the recent gains in graduate enrollment have been financed in part by increased fee (tuition) revenue from undergraduates as well as from graduate students, particularly graduate professional students. Faculty and administrators generally feel that the limits of this strategy have been reached. The necessary cross-

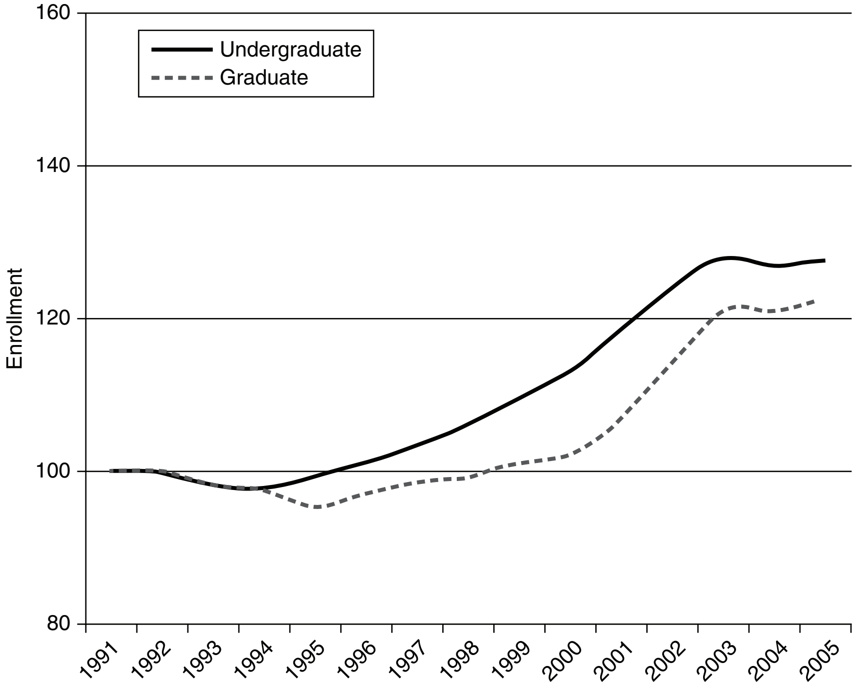

Fig. 12.3. Trend in UC undergraduate and graduate enrollments, 1991–2005 (indexed to 1991 = 100). *Source:* California Postsecondary Education Commission On-line Data System (accessed October 3, 2006).

subsidies among fields are unpopular internally, and those from undergraduates to graduate programs could become politically problematic. Also, grants and instructional budgets must be charged for much of the higher fees, which these budgets must cover for graduate student research and teaching assistants. Finally, graduate students who are unsupported must pay the higher fees, which usually means higher loan debt. This will eventually make recruiting the best students difficult.

Scope and Range of State-Supported Research in California

Having provided essential background on California's historical policies with regard to higher education and UC, including its recent challenges that have led to flagging support of the core human infrastructure underlying the research mission, I now turn to an examination of the state's policies toward research. While nearly all of these involve the University of California in some way, a recent development is that not all of the state's academically oriented research is now overseen by UC. The entire picture is a fascinating one and in many ways typically Californian.

First, it is important to note again that the Master Plan designated the University of California as the primary academic research agency of the state. This status has been taken quite seriously over the years, so that the university has been assigned a number of research-related tasks—only partially compensated financially—that might best be described as technical assistance to state agencies. Two prominent examples are assisting with various aspects of the research program of the state environmental protection agency and participating in the regular review of the impacts of proposed changes in health benefits in the state's public assistance and social services programs (Auriti 2006). This role appears to be more extensive than that typical of public research universities in the United States. The university and the state have gone as far as to set up a California Policy Research Center that performs over $1 million per year of research and policy analysis for the state and gets considerable attention from the UC vice provost for research, who sits on its board. Within the center are several ongoing applied research programs on such topics as access to health care for low-income populations, the Welfare Policy Research Project, and the UC Latino Policy Institute. The center also maintains a technical assistance capability for responding to policymaker requests in a wide range of fields and supports an annual grants competition for UC faculty interested in researching topics of importance to the state.

As described earlier, the University of California is also the state's land grant university under the federal Morrill Act and thus has special responsibilities and resources for agricultural research and extension services. While many other states also have land grant universities with such responsibilities, the function is quite important in California given the continuing importance of its agricultural sector. Moreover, in California these activities are not limited to a single campus as is usually the case elsewhere.[31]

According to UC figures, the university received about $189 million in state support for research[32] in FY2006, of which $173 million was for direct research costs. The total peaked at $201 million in FY2002, but in the subsequent state budget reductions, it was cut back to a low of $186 million in FY2005 before recovering a bit.[33] Using 2004 for comparison purposes (the latest year for which federal data were available at the time of writing), UC's state research support represented almost 8% of its federal plus state R&D funding.

A very wide range of research programs receive state support across the vast ten-campus University of California system. Of course, mission-oriented state agencies, such as the state department of agriculture and the California Environmental

Protection Agency, support specific research studies. But much of the state money goes to support substantial, ongoing research programs. A number of these were prompted by the legislature or by ballot initiative, as is explained below.

THE SPECIAL RESEARCH PROGRAMS

One important and long-standing set of state research programs is dubbed the Special Research Programs. Included are three specific state-supported programs on HIV/AIDS (established in the early 1980s), tobacco-related disease (established in 1988), and breast cancer (approved in 1993). The HIV/AIDS program was begun in the early years of what became the AIDS pandemic, on the initiative of UC San Francisco and UCLA medical school faculty who recognized that research was needed to understand and combat the new scourge. California's effort largely predated research support on this topic by the National Institutes of Health, the nation's major medical research support agency. The faculty involved in the program then worked with the powerful Speaker of the Assembly,[34] who was from San Francisco, to get legislation passed authorizing and funding a research program at the university. Aware that the problem was beyond solution by faculty at two campuses alone, and to ensure that the highest-quality research was funded, the university initiated an external competition, with peer-review processes, to fund AIDS research at California universities and institutes. They also used the state support as seed funding to begin developing proposals for larger-scale federal support. The state's support has now continued for a quarter century and, unlike the case of the other two Special Research Programs, provides core institutional support for centers as well as project grants.

Whereas the HIV/AIDS research program is funded through the state's General Fund budget, much of the funding for the tobacco-related disease and breast cancer programs comes from statutorily designated shares of state cigarette-excise-tax revenues. The tobacco disease program was created as part of a ballot initiative in 1988, and the breast cancer program was established five years later by the legislature as a result of advocacy by breast cancer activists and a key legislative champion. The same powerful Assembly speaker who championed the HIV/AIDS program became a supporter and pushed through the legislature a further increase in the cigarette tax to fund the breast cancer program. Its first grants were made in 1994.

Collectively, the three Special Research Programs received some $37 million in state funds in 2006–7.[35] At the peak in 1997–98, their total state support was more than $80 million (fig. 12.4). Over their lifetime the Special Research Programs have received more than $700 million in state support and have awarded close to three thousand grants (Gruder 2007).[36] As the graph shows, however, the support for the

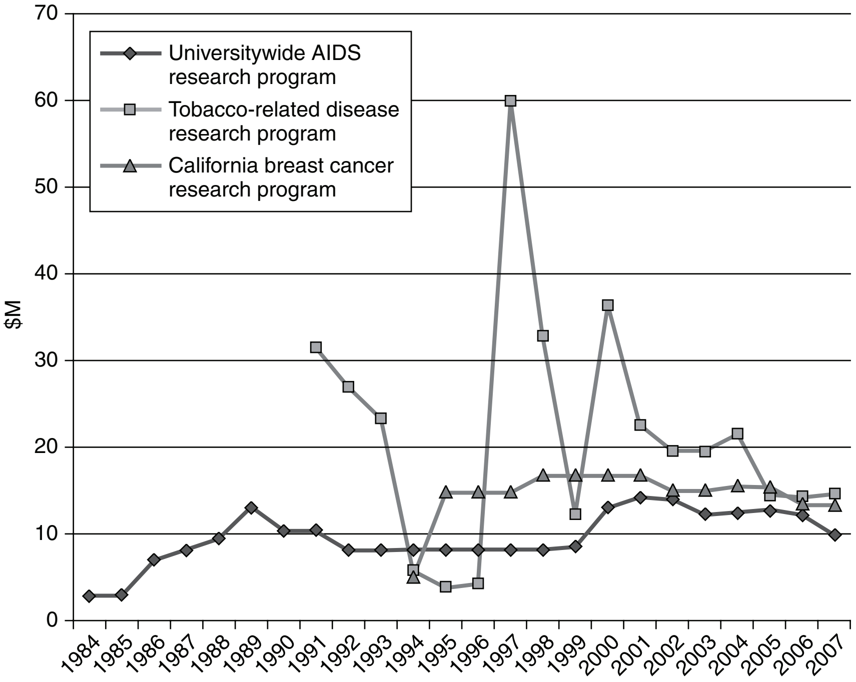

Fig. 12.4. Annual Special Research Programs (SRP) appropriations, FY1984–2007. *Source:* University of California, Office of the President. *Note:* Data in this figure have not been adjusted for inflation.

tobacco-related disease program has been subject to dramatic swings, and all three programs have experienced erosion of the real value of their state support over time. The funding problems of the tobacco and breast cancer programs are largely attributable to the erosion of cigarette tax revenue as antismoking programs in California have proven remarkably effective.[37] A proposed tripling of the state cigarette tax (from $.87 to $2.60 per pack) was on the November 2006 general election ballot; if it had passed, it would have provided a large infusion of funds to these two research programs and created yet another program.[38] The measure failed by a 52% to 48% margin.

The HIV/AIDS program's budgetary ups and downs and general slow decline in real terms are a function of its having to compete for state general funds in the face of much larger, often formula-driven budget competitors and the vicissitudes of the state's economy. It never had a designated revenue stream like the two excise-tax-supported programs. The SRP's executive director reports that the programs are all actively involved in efforts to either broaden their revenue sources or restructure their strategies to ensure continuing impact with declining constant dollar budgets (Gruder 2007).

INDUSTRY-UNIVERSITY COOPERATIVE RESEARCH PROGRAMS (IUCRP)

In 1996, driven largely by an initiative of (then) UC president Richard Atkinson,[39] a new program was created with both state ($5 million in the first year) and UC ($3 million) support.[40] It is called the Industry-University Cooperative Research Program, or now more commonly "UC Discovery Grants." The idea is to leverage corporate support in five targeted research areas by offering the state and UC funds as a match for corporate grants to UC researchers working closely with industrial partners. The purpose of the grants is less seed funding than support for projects with discrete targeted outcomes that may range across the spectrum from basic research to "proof of concept" as a prelude to new product or process development.[41] The targeted areas are biotechnology, electronics manufacturing technology, digital media, network communications, and information technology for the life sciences. In addition, a much earlier state-corporate research matching program in microelectronics (MICRO), dating back to the early 1980s, was brought loosely under the IUCRP umbrella.

MICRO receives about $5 million in state funding per year. State funding for the other programs was quickly ramped up from the initial $5 million in 1996, when only the biotechnology program existed, to a peak of $17 million in 1999 for all the programs. The university's annual contribution, having served its initial purpose of helping to bring in state funding, remained at its original $3 million level. The IUCRP suffered cutbacks in its state support in the economic downturn of the early 2000s, so that currently it receives about $14.7 million from the state. Corporate support overall has more than matched the state and UC contributions. According to the IUCRP leadership, all the programs continue to attract many quality grant applications from UC-industry partners, though the IT-in-the-life-sciences program—the one most recently developed—has had some trouble attracting the expected level of interest.

CALIFORNIA INSTITUTES FOR SCIENCE AND INNOVATION

Still another notable state venture into research at UC is the program called California Institutes for Science and Innovation, or "Cal ISIs." This effort began officially in 2000 as an initiative of Governor Gray Davis, with important support from influential corporate leaders and at least one UC regent acting independently. The state's economy was riding very high at the time, and the governor was intrigued by the idea of developing at the university large-scale interdisciplinary research programs relevant to the state's economy. The result was a proposal for substantial state support for three such multicampus institutes in specific fields identified by the governor and the key supporters. The university insisted on a broader competition, with campuses or combinations of them submitting proposals that then went through both external and internal peer-review processes. Initially three institutes were approved and funded, and a fourth followed soon thereafter. The four California Institutes for Science and Innovation now operating are

- California Institute for Quantitative Biological Research; the lead campus is San Francisco, with collaboration from Berkeley and Santa Cruz.
- California Nanosystems Institute; the lead campus is Los Angeles, with collaboration from Santa Barbara.
- California Institute for Telecommunications and Information Technology; the lead campus is San Diego, with collaboration from Irvine.
- Center for Information Technology Research in the Interest of Society; the lead campus is Berkeley, with collaboration from Davis, Merced, and Santa Cruz.

State funding for the four institutes totaled $400 million over four years, which went mostly toward buildings and other capital assets. Acquisition of federal and private gifts and grants was a requirement for receiving the state funds, and the institutes have built substantial physical and human infrastructure and supported considerable research. However, as the main institute buildings neared completion, concerns arose on the affected campuses and in the systemwide Academic Senate about the institutes' ongoing operating funding, since the state has provided only about $5 million annually for this (Coleman 2007).[42] Somewhat surprisingly in light of the history of the institutes as a Davis administration initiative,[43] the university persuaded Governor Arnold Schwarzenegger to seek $19.8 million in his FY2008 budget proposal for core operating support for the four institutes. The university hopes eventually to see the state's core support increase to around $35 million per year, but the 2008 budget passed by the legislature again provided only about $5 million (UC Office of the President 2007).

OTHER STATE-FUNDED RESEARCH PROGRAMS

Although it is difficult to compile a complete inventory, there is a substantial list of other state-funded research programs within the UC system, including several often politically controversial labor studies centers, occupational health research centers, the Ernest Gallo Clinic and Research Center at UC San Francisco, and the

MIND Institute at UC Davis. The last is illustrative of the way new state research programs are often initiated. It is a multimillion-dollar institute created in 1999 for research on neurodevelopmental disorders, largely through the efforts of affluent and influential parents of autistic children.[44] They had help from campus leaders and a key supportive legislator (Associated Press 1999). For a few years there was also a state-supported research program at UC San Diego on the medicinal uses of marijuana, but this politically controversial effort has fallen out of favor and is no longer funded by the state.

In addition to research programs run through the University of California, the state has in recent years created other mechanisms for administering certain research programs that utilize UC researchers to carry out some of their work. In these cases researchers at other California universities and nonprofit institutions are also eligible for grants, which is true in only some of the UC-run programs. One example was a program created with state general funds in the booming 1990s to research "gender-related cancers" other than breast cancer. This program was established as a result of lobbying from advocates for research on particular types of cancer (e.g., ovarian cancer but not cervical cancer). Prostate cancer was included before passage, in part to broaden political support. Governor Pete Wilson, who had to sign the legislation to make it law, directed that the program be administered by the State Department of Health Services rather than the University of California. The program ran for several years with UC researchers receiving grants from it, but its funding was eliminated during the state budget retrenchment in the first years of the present century. It was slated for a rebirth had the ballot initiative to raise the tobacco excise tax, Proposition 86, been passed by the electorate in November 2006.

THE CALIFORNIA INSTITUTE FOR REGENERATIVE MEDICINE

The most notable case of a state research program operated outside the auspices of UC, however, is that of CIRM, the California Institute for Regenerative Medicine. This institute is an autonomous state agency created by a November 2004 ballot initiative, the campaign for which was spearheaded by Robert Klein II, a wealthy real estate developer who is for personal and family reasons a strong supporter of stem cell research. He had the support of a small group of very wealthy and influential friends, including corporate leaders. Since the Bush administration had largely stymied federal support for this potentially pathbreaking medical work, with typical California hubris, Klein and his supporters felt that the huge state should take the matter into its own hands.[45]

In media-frenzied California, it is now not at all unusual for wealthy, media-savvy individuals with an issue that can appeal to the public to propose ballot initiatives, pay most of the costs to get them on the ballot, advertise widely, and sometimes get them approved by the voters. The stem cell research initiative was a tall order; the topic was controversial, and the bill to the state's taxpayers would be $3 billion over ten years, funded by bonds to be serviced from the state's general funds. Yet, it was approved by a substantial margin (59% to 41%). Significantly, the initiative's drafters did not propose that the institute be part of the University of California, but rather chose to set up a new public entity, CIRM, in order to maintain more control. Klein himself is chairman of the board and is widely reported to "effectively manage the agency" (Hamilton 2006), although a respected neuroscientist served as president and chief scientific officer until early 2007.[46]

The emotional politics surrounding stem cell research in the United States largely hamstrung the fledgling institute for more than two years. Both anti-stem-cell-research advocates and fiscal conservatives challenged CIRM in court and prevented it from utilizing any state funds beyond an initial $3 million loan (Hamilton 2006; Schwarzenegger Orders 2006).[47] Yet, during this period the institute managed to hire a staff of nineteen, to occupy a headquarters building in San Francisco, and in late 2006 to make $12.1 million in training grants to 169 young researchers[48] at sixteen California institutions, the majority at nine different UC campuses. All this was made possible by multimillion-dollar private gifts raised by founder Klein and his friends. Later, they raised larger sums, some $32 million, from philanthropists by issuing, with the state treasurer's approval, "bond anticipation notes" to be repaid to the lenders from the state's bond proceeds once the bonds were sold and the funds released (Bole 2006).

Anticipating successful resolution of opposition lawsuits, Governor Schwarzenegger ordered the state's finance officials to provide the institute with a $150 million loan early in 2007 in anticipation of release of the bond funds (Hamilton 2006). CIRM officials initiated their first research grant competition in fall 2006 and awarded $45 million in grants in February 2007 (Stem Cell Research 2007). Shortly thereafter, CIRM awarded another $75.7 million in research grants, and $48.5 million in capital funding was awarded in June 2007 (Somers 2007a). A further $220 million in capital grants was expected to follow shortly after the sale of the first set of bonds authorized by the initiative and now freed up by the courts (Somers 2007b).[49] So, the flow of new state funds for research in this field has begun, and it will be very substantial.

In addition to the lawsuits—claiming, among other things, that the line of stem cells CIRM proposed to acquire had patents too broad to be legal and that its operations as an independent state agency were illegal—CIRM's critics dogged its processes for developing intellectual property policies and ethical guidelines for the research. State legislators and agencies have become involved because many feel that revenue from intellectual property—such as new pharmaceuticals, stem cell lines, and processes that could be used in R&D or manufacturing—resulting from research supported by the state should be owned by it, at least to the point of recouping its investment (Somers 2007c).

CIRM officials feel that such claims by the state would be unrealistic in the marketplace and that research and corporate partners would be unlikely to participate on this basis. The University of California, which has played a role in helping CIRM establish policies, generally supports CIRM's position.[50] One knowledgeable UC official even expressed concern that some state officials and the press seem to believe that revenues from CIRM's future intellectual property should play a substantial role in paying off the Proposition 71 bonds that finance the institute. The insiders think that this is an unrealistic expectation, given past experience with unpredictable and uneven intellectual property revenue streams. Another politically potent expectation is that any new drugs or treatments resulting from CIRM's research would be "affordable" to Californians (Somers 2007c), also a demand that could deter potential partners.

CIRM's intellectual property policies, adopted in 2006, reflect a compromise position in which the institute is free to grant intellectual property rights to its grantees (as is the case with federally funded research grants to universities) but retains rights and responsibilities to the public interest, such as "march in" rights when a licensee is slow to develop useful products with the CIRM-funded intellectual property (IP), requirements for publication and sharing of biomedical materials, and requirements that nonprofit grantees use their share of IP revenues for scientific research or education. Also, the IP policies require that exclusive licenses to CIRM-funded intellectual property be granted "only to organizations with plans to provide access to resultant therapies and diagnostics for uninsured California patients. In addition, such licensees will agree to provide to patients whose therapies and diagnostics will be purchased in California by public funds the therapies and diagnostics at a cost not to exceed the federal Medicaid price" (CIRM 2006a, 17).

In short, the CIRM venture is highly politicized. Yet, the University of California, like the leading private universities in California, is clearly anxious to participate. UC San Francisco and UC Irvine as well as private Stanford University and the University of Southern California (USC) have already made large capital and hiring commitments in order to be prepared for the time when the spigot of CIRM grants opens fully (Hamilton 2006).

Strategy and Politics in State-Supported Research

The state seems to have no overall plan or strategy in research and technology development and does not appear to be capable of or much interested in developing one. The variety of programs described above, which developed in a more-or-less ad hoc fashion and accreted over time with some signs of overlap and no real coordination or apparent overarching strategy, are suggestive evidence of this. When one looks inside California government, there is little to be found in the way of institutional structures supportive of strategic or even coordinated policymaking in this area.[51] The legislature has no science and technology policy committees or specialized staff resources that might facilitate taking a broad, strategic view. Facing strict term limits, California legislators have little time to learn about complex science or technology and research policy issues and have generally weak political incentives to specialize in this area.

Business, a logical ally, tends to be fragmented in California and surprisingly weak in influence in the capital. Rather, to make a mark in a few years before being forced "up or out" by term limits, legislators are often better advised to focus on fields like health or education that are more easily understood and can produce regular tangible benefits for constituents. These more established policy arenas also provide more valuable political resources, such as a potential committee chairmanship, access to a well-informed staff cadre, and more-or-less guaranteed media coverage.

A similar gap in appropriate institutional structures appears in the executive branch. In the budget crisis of the early 2000s, the state eliminated its Technology, Trade, and Commerce Agency, which had included, for a few years, a Division of Science, Technology, and Innovation.[52] Only a small remnant of this unit remains at the state Department of Business, Transportation, and Housing. The only other science- and technology-oriented agency is the California Commission on Science and Technology, a small, state-chartered though privately funded entity with an advisory role but limited capacity and visibility.[53] The governor's office itself has never had a formal science and technology strategy or analysis capability, depending instead largely on input from stakeholders.

Governors have only rarely shown an interest in broad strategic thinking about science and technology or research issues. The current governor, Arnold Schwarzenegger, has shown some interest, especially once it became clear that the state's economy had fully recovered from the recession-induced budget straits that dogged his predecessor. Governor Schwarzenegger has advocated strongly for stem cell research and has been supportive of CIRM. He has recently shown considerable interest in environmental issues, alternative energy sources, and nanotechnology. His signature initiative is an ambitious greenhouse-gas-reduction program, enacted into law as Assembly Bill 32 in 2006. He has asked the University of California to work with the California Energy Commission and the State Air Resources Board to develop targets and benchmarks for emissions reductions (CCST 2007b).

In 2007, Governor Schwarzenegger packaged as a "$95 Million Research and Technology Initiative" his support of $19.8 million in increased state operations support for the California Institutes for Science and Technology; $30 million in lease-revenue-bond funding for a new energy-nanotechnology building for Lawrence Berkeley Laboratory's Helios project (a solar energy technology project); $40 million in similar bond funding for Berkeley's Energy Biosciences Institute, which helped the campus win a $500 million commitment over ten years for this from the energy giant British Petroleum; and a $5 million commitment of matching funds for the University of California's bid for federal support to build the world's first Petascale computer, a project expected to cost $200 million in total.[54] It appears that this was less an executive initiative in the classic sense than a way of packaging the governor's responses to the University of California's requests for modest support of its research funding priorities in what was then a relatively favorable budget climate.[55]

A few years earlier Schwarzenegger's predecessor, Gray Davis, had access to a large budget surplus and became interested—with no small help from individuals connected to the University of California—in the California Institutes for Science and Innovation (Cal ISI) initiative, which could be considered a strategic research initiative. But, the vicissitudes of the California economy and politics being what they are, nearly all the money and the governor himself were gone within a few years. It is notable, though, that Governor Schwarzenegger supported this initiative in his FY2008 budget proposal rather than allowing it to wither, as often happens when gubernatorial administrations change. In the end, the increase in appropriations was not supported by the legislature, however.

The impact of ups and downs in the economy on state budgets is one important factor that makes it harder for states than for the federal government to develop consistent science policies: states face much stronger norms of budget balance than does the national government, often necessitating deep cuts in "nonessential" state programs during downturns. The political vicissitudes, at least in their intensity, are more specific to the California environment. Governors in California can be recalled by the voters (although Davis's recall was the first one in the state's history), and the state's politics are generally more polarized and mercurial than is true elsewhere.[56]

Indeed, one aspect of the state's politics makes coherent S&T (science and technology) and related policymaking arguably nearly impossible: the ascendancy of the initiative process. California voters can make their own policies at the ballot box, trumping any carefully laid plans of the governor, the legislature, or the University of California. The number of such ballot initiatives has grown dramatically in recent decades, and many of them bear little or no relation to the programs of leading elected officials. Examples directly affecting academic research go back at least to the cigarette tax initiatives of the 1980s and early 1990s that provided the (not very satisfactory) funding source for UC's tobacco-related disease and breast cancer research programs. More recent examples include both CIRM itself and the failed 2006 initiative to raise more revenue for targeted research from higher cigarette taxes.

Whether the initiative route is used or not, the policymaking vacuum created by the lack of legislative or executive strategic capacity in S&T and research policy sets the stage for ad hoc and often politically driven policymaking processes to hold sway. In the majority of cases it seems that the state-supported research programs at UC were created more by the impetus of individual legislators and citizen advocacy groups, often with the help of individual faculty members operating outside the purview of established university review and priority-setting processes, than as part of either state or UC strategic thinking.

Strategy, Politics, and Challenges within UC's State-Supported Research Programs

The University of California is populated by smart people who very much want to do serious science and institution-building. In dealing with the state in cases where the latter offers—by ballot, gubernatorial, or legislative initiative—a new research program not necessarily high on UC's priority list, the university's administration seems to make an effort to shape the terms of the program to make it compatible with academic norms and values.[57] The early history of the HIV/AIDS research program already recounted is one such example. Another is President Atkinson's insistence on an open competition for the California Institutes for Science and Innovation, complete with several stages of peer review of proposals, rather than simply accepting the ideas for the institutes of Governor Davis and the project's early supporters. Most recently the university has sought to influence the governance arrangements and basic policies of CIRM to help ensure appropriate scientific and ethical review procedures in this controversial area of research as well as what it regards as realistic policies regarding intellectual property. In at least one important case, UC itself took the initiative when President Atkinson developed the basic idea for the Industry-University Cooperative Research Program and, with industry help, persuaded the state to help fund it.

Although sometimes the parameters of state-funded programs are not subject to much negotiation, as in the case of initiative-created programs and some others that have aspects of a crusade in their enactment (e.g., the breast cancer research program, the MIND Institute), the university tries to guide even these as best it can to produce quality science and useful results for the state. Where the enabling legislation and the politics of oversight permit, university program managers generally seek to devise—or guide oversight boards toward—strategies that emphasize gaps in the federal research portfolio in the field or topics of special interest in light of the state's population groups, industry mix, or natural systems. This is not made easier, however, by mandates, such as one for the breast cancer program: to find a *cure* for this affliction.[58] Some programs explicitly seek to broaden their impact by emphasizing seed grants (or institutional support for research centers, in the case of the HIV/AIDS program or the Institutes for Science and Innovation) that can be used to support competitive proposals for much larger federal funding. Others, such as the IUCRP and the ISIs, seek to maximize their impact by requiring corporate funding matches and active partnerships.

Serious challenges for research managers are created, however, by California's mercurial, polarized, and increasingly populist politics and the intense glare created by its media, not to mention its fiscal rollercoaster. New mandates for research programs can emerge unpredictably from the political process, and so can sharp budget cuts or even program eliminations that have little to do with the quality or productivity of the research. Thus, program managers must spend a good deal of effort on managing publicity and relations with key stakeholders and on keeping tabs on external politics. The state-supported research programs are thus subject to a high degree of political accountability but remarkably little *performance* accountability.[59] Not only is it hard to find any sign of serious performance oversight from Sacramento—which might not be desirable anyway in regard to academic research, if the oversight was not expertly done—but the university itself seems to have done little to evaluate these programs through its normal periodic academic review processes.[60] The IUCRP is not subject to the five-year academic reviews normally required of UC's multicampus research programs.[61]

It may well be that, in some cases, this lack of oversight makes it possible for good R&D managers, working with a well-constructed structure of advisory boards, peer-review panels, and high-quality researchers, to simply do their work efficiently with UC's strong internal academic quality standards serving as the primary form of accountability. Yet, it is clear that in some cases the political pressures have permeated rather deeply into these structures. A case in point is the breast cancer research program. Created by ballot initiative, the statute specifies some of the research priorities, including the mandate to seek a cure, and disease advocates (along with scientists) serve not only on the advisory body that determines broad priorities, but also on the panels that review individual research proposals.[62] They may bring not only unrealistic expectations, but also nonscientific penchants about causes and remedies that they want to see researched. Although they are supposed to defer to scientific reviewers on questions of pure scientific merit in proposals, the odd mix of scientists and passionate advocates with political and media connections on the boards and panels is a considerable challenge to manage, while ensuring that the most significant and sound science is pursued.

Yet, the breast cancer program has faced fewer budget challenges than either the HIV/AIDS or the tobacco program, in part because the advocates are so committed to the program and are seen as a formidable bloc. The tobacco program has been less able to ward off attacks on its budget. The HIV/AIDS research program has experienced attempted raids on its budget and successful skewing of its research priorities by pressures to allocate large resources to the testing of drugs for treating patients and the investigation of a particular, high-cost treatment approach (organ transplantation) that was not widely accepted as a high scientific priority.

The California Institutes for Science and Innovation faced the usual types of questions about skewing of academic research priorities to meet the interests of industry, but the issues became more acute as the institutes built substantial infrastructures that needed continual financing, while lacking much ongoing, earmarked state operating support. If the efforts by the university and the governor had been successful in securing this support, tensions would likely be considerably alleviated. Faculty concerns about these institutes have been manifest in the Academic Senate, and it will be illuminating to see how the Senate-initiated program reviews of them, now begun, turn out.

The UC Discovery Grants Program (IUCRP) faces a different kind of internal management problem. California, however large, is a state, not a nation. Under some pressure to see that its long-stagnant state dollars are spent mostly on grants, the program uses only peer reviewers from within the University of California, who serve without compensation. Since three rounds of grants are made each year within fairly narrowly specified fields, it is hard to vary the peer-review panels sufficiently. This schedule also makes for some potentially serious compromises with the assumption of anonymity at the heart of the peer-review system, an assumption that is much more plausible in a more broadly based (i.e., national) system. Thus, reviewers are provided access to the applicant's vitae and grant track record. [63] It is also probably possible in many cases for applicants to surmise who their reviewers are likely to be. Over time, even without any explicit collusion, a mutual "back scratching" pattern of application approvals could easily develop within this closed system. In addition, individual judgments by one or two researchers about the merits of another academic or of a particular research direction or approach may come to play too great a role. These potentially serious problems, though not currently discernible, may be difficult to avoid given the constraints the program faces.

The State Role in Technology Transfer

The University of California, which performs some $3 billion worth of externally funded R&D each year, has a substantial technology transfer operation, as would be expected. The university grossed about $110 million in revenue from patent-related activities in 2005–6, of which more than $52 million was distributed as discretionary revenue to the campuses (University of California 2007). The balance covers legal and administrative costs associated with technology transfer and is also used to reward inventors and their departments by established formulas. These are fairly modest amounts in relation to UC's total research budget, but all significant discretionary revenue is especially valuable when budgets are tight. According to technology transfer officials, the university's goals in its technology transfer policies are not primarily financial, but rather are intended to ensure that university research benefits the public and fosters the advancement of nonprofit research generally, for example, by permitting other researchers to use data, methods, cell lines, software, and the like on reasonable terms.

Until fairly recently, the state of California was not a large player in UC research and did not have much to say about technology transfer policies, which were largely seen as being between UC, the federal government, and corporations.[64] Recently, as state research support has grown, there has been much more state interest in intellectual property and related issues and the associated potential revenue streams. There is no overarching state policy, however. Different supporting agencies ask for different things and are not necessarily consistent over time. The legislature has become involved at times, but there is still no consistent policy. The Davis administration authorized a commission to study what the state's policies should be. This commission reported shortly after Governor Davis was removed from office (California Business, Transportation, and Housing Agency 2003), and Governor Schwarzenegger has evidently not paid much attention. The legislature subsequently requested a report from the California Council on Science and Technology, which sought to

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"lay the groundwork for an informed discussion on building a comprehensive set of state policies governing the creation and administration of IP developed with state support" (CCST 2006, 1). These reports generally make sensible suggestions about standardizing state intellectual property policies. The problem seems to be that there is no body competent to receive them or motivated to act on them at the state level.

As a result of the debates surrounding CIRM's intellectual property policies, UC officials fear that the state may become increasingly aggressive in asserting ownership rights to inventions and copyrights derived from research it has funded.[65] The state seems to be moving toward seeking a guarantee of "recoupment" of its costs on projects that generate significant revenues. The university is concerned about this trend, for it feels it needs this revenue to help fund the costs of technology transfer efforts—which, as noted, are designed more to achieve public diffusion goals than to make money—on the many projects with public benefits from such transfer that do not generate revenues.[66] State agencies also sometimes seek to assert ownership of data generated in state-funded research projects. The university has resisted these attempts vigorously in order to be able to utilize such data in future research—either its own or that of other nonprofits—but results of negotiations with state agencies have varied as to precise terms.

Of particular concern to the university are some of the technology-transfer-related issues recently debated in the context of getting CIRM up and running. Although the ballot Proposition 71, which created CIRM, does not state that revenues from its intellectual property must be dedicated to helping service the state general obligation bonds that support it, such an expectation has grown in political and media circles. The University of California, in providing comments to CIRM and its advisers regarding intellectual property policies for the institute, sought to damp down this expectation, fearing that it would create unrealistic expectations, undesirable incentives, and difficulties in securing private-sector participation. The university may also be concerned that it might find itself subject to similar pressures in regard to its own state-supported research. Further, political efforts to ensure that pharmaceuticals and therapies created from CIRM research are judged affordable to Californians could, if regulations are too tightly drawn, also deter corporations seeking to license CIRM technologies. Finally, although CIRM is planning to assert "march in" rights (i.e., to declare licensees in noncompliance with terms of their license agreements)[67] similar to those in federal law, UC is concerned that CIRM may come under political pressure to interpret these more aggressively than federal agencies have, thus creating further hesitancy in the minds of potential licensees.

These concerns may apply specifically to CIRM at the moment, but given the scope and visibility of that enterprise, its policies in this fluid field could easily influence those of the state and even the federal government.

Assessment of the State-Supported Research Programs in California

California is a large, varied, and complex state with particular research needs for which it turns to its world-renowned public university for help. The state's Master Plan for Higher Education in 1960 declared the University of California the state's primary agency for academic research, and this designation has been taken seriously. While some of the research on broad human afflictions like breast cancer and tobacco-related disease that the state pays for might, in an ideal political economy, be financed at the federal level, there is little doubt that the considerable additional state investment adds social value, even if not exclusively for Californians. In this huge and traditionally optimistic state, Californians often have the hubris to think that they can cure cancer or AIDS or develop powerful new therapies from human stem cells on their own—and indeed perhaps they will.[68] In reality, most of the state research programs give particular attention to state needs and to the fact that they can often best serve by strategically complementing much larger federal efforts in their fields.

The fact that the passions and priorities of the public can be made known directly at the ballot box in California has almost certainly generated more state tax money for research than would have been forthcoming through more conventional political processes, especially in light of the limited capacity of the state's governmental institutions in this sphere. In the unique case of stem cell research, where ideological disputation has stymied the federal effort, California voters have, in the view of many, performed a valuable function by stepping into the breach. The sheer size of their contribution may well move the field forward significantly and also help retain leading researchers in the country, until the federal government is ready to assert its customary leadership role.

On the negative side of the ledger regarding the state's role in supporting research, there are a number of points to make. Feller (1997), Geiger and Sá (2005), and Geiger (this volume, chapter 11) have pointed out some of the limitations of states as instruments of science and technology policies, and California's efforts seem to suffer from all of these in addition to unique challenges of its own. Most fundamental perhaps is that California, like other states, lacks "honest broker" institutions comparable to the National Science Foundation or the National Institutes of

Health at the federal level, with strong norms of scientifically based selection of both priorities and projects within broad research fields. After long and generally very successful experience, these norms are widely accepted by national political leaders, sufficiently to create a strong counterweight to the inevitable political pressures that tend to distort priorities and push toward excessive, politically driven geographic spread of grants at the expense of peer-review processes.[69] The presence of respected oversight agencies with such norms also makes it more difficult to de-emphasize or terminate sound research programs when administrations change than is the case when research programs are less insulated from politics. The University of California seems to do its best to perform this broker role but cannot be fully effective when it is a research performer as well as a broker and is so dependent upon the goodwill of state politicians for its core institutional financial support.

A second major challenge for state research and science policies is the instability in state budgets, which, combined with structural rigidities that work against "discretionary" research programs in budgetary competition, can often lead to abrupt cuts or even elimination of programs for reasons unrelated to their value or productivity. While the fluctuations of capitalist economies are at the root of budget instability, state-supported programs suffer more from ups and downs than federally supported ones simply because there are laws and usually strong norms against deficit spending in state finance that do not apply at the federal level. California's revenue structure, with its heavy dependence on volatile capital gains taxes, is particularly prone to dramatic fluctuations. Political polarization and legal limits on the length of service of elected officials (just six years in the Assembly and eight years in the state Senate) in California add to instability and generally make it more difficult to sustain a stable environment for complex programs with long-term horizons, such as those that support research.

Feller (1997) and Geiger (this volume, chapter 11) both suggest that states are much less well equipped than are national authorities to demand accountability from science and technology programs, since at the state level the programs are driven largely by the priorities of the politically influential. This is certainly the case in California, where the pressures on research programs for political accountability are all too clear but the constituency for substantive accountability is remarkably weak.[70] Even the University of California has done relatively little to formally review the performance of state-supported research programs to date, and there seems to be little or no pressure from Sacramento to change this.

Unlike at least a few other states, California seems particularly unable to generate broad strategic—as opposed to ad hoc and politically driven—thinking about state research policy. Surely high-technology-oriented California could benefit from such thinking. While occasionally governors have moved in this direction and could do so again—indeed, Governor Schwarzenegger has shown some such inclinations—there is little guarantee that a governor's plan, however well conceived, would long survive his or her term of office. And there are no permanent, competent institutional structures in either the executive or the legislative branch to help develop or sustain any such hypothetical state R&D strategy. Interestingly, the initiative process could conceivably help with continuity in the sense that an initiative can provide a permanent, statutory basis and revenue source for a program as well as a sense of political mandate that may survive quite a while. In general, though, the politically saturated initiative process would seem an unlikely vehicle to enact a comprehensive research or science policy strategy for the state.

Finally, as the discussion of the challenges facing peer review in the UC Discovery Grants program suggests, even a state as large as California faces difficulties in sustaining sufficiently broadly based peer-review processes, which are fundamental to effective research programs. The independent California Institute for Regenerative Medicine plans to work around such problems by utilization of national (and even international) advisory groups and peer-review panels. This may prove expensive to this now well-funded agency but is surely well worth the expense. However, such a strategy may not be practical for many state research programs for which the funding is small and for which there are powerful incentives to spend most of it on the research itself, narrowly defined.

Conclusion

California's policies regarding research and the academic infrastructure that largely supports it are clearly a mixed bag. They certainly reflect both the history of the state and its current fiscal and political climate. The latter is both volatile and problematic for the academic enterprise and the state's research initiatives.

In terms of core financial support for the University of California, the historical legacy has created an unusually strong base, but recent trends have been corroding the edges and probably beyond. The immediate future is problematic, as the state's general fiscal policies are probably unsustainable; a new and particularly deep recession is now under way; and the university may be near the political limits of large tuition increases and cross-subsidization, particularly of graduate education by undergraduate tuition revenue. Although recent, widely publicized accountability concerns related to compensation of its executives have not helped, the more serious long-term threats to the university, in light of this sober fiscal environment, may be the financial dilution threatened by the need to develop the new Merced campus and the aspirations of the much larger California State University system to initiate doctoral education. Most importantly, it can be persuasively argued that the state's highest priority needs in education policy are at the K-12 and undergraduate levels, where the performance of the burgeoning populations of color is seriously lagging. If not corrected, this weakness will ultimately impact the university's graduate programs and research capacity. In this rapidly changing demographic environment, UC's medium- and long-term capacity to serve the state is further hindered by the limitations created by the voters in Proposition 209. This ballot initiative severely hampers UC's ability to diversify its student bodies, both undergraduate and graduate, in the direction of the ethnic composition of the state's young population.

Given this context, it is not clear that UC's graduate programs will be able to get much additional priority, even in the face of real concerns about their competitiveness in funding graduate students. Programs that can best compete for emphasis and funding will likely be those with demonstrably close connections to state workforce and economic needs, which may mean that those in science- and technology-oriented fields will do tolerably well. If so, at least the research mission in those fields would be supported, but seriously uneven health and development across graduate fields within the institution may result.

The research programs that the state explicitly funds are, overall, impressive in range and level of state support. Many undoubtedly produce significant results in scientific terms and in progress toward certain state objectives, although evaluation mechanisms are very weak outside of traditional scholarly assessments. Besides lack of evaluation, the main problem with these programs is their politicization.[71] Although the politically driven birthing processes of most of the state research programs may produce more resources for research (at least for a while) than would otherwise be forthcoming, they also create serious challenges for ensuring strategic prioritization, sensible allocations within programs, and even on occasion appropriate peer review of individual project proposals.

For all its problems, the University of California remains a great and very broad and deep system of public research universities, infused by strong quality norms and academic values. The taxpayers—not limited to residents of California—doubtless get their money's worth from the vast bulk of the state-funded research at the university. There are many ways in which the results could be made still more impressive, but progress is mainly dependent upon more effective state political leadership and institutional reform—especially building of state science and technology policymaking capacity—on research and related matters. It is far from clear that these will be forthcoming anytime soon.

NOTES

An earlier draft of this chapter was presented at the Conference on the Public Interest and the Academic Research Enterprise at Seville, Spain, November 11, 2006. I wish to acknowledge excellent and very diligent research assistance from Deborah Frankle.

1. Stanford, Cal Tech, and USC are all private institutions, while the multicampus University of California is public.

2. The roots of this state institution's remarkable academic prowess are often attributed to its constitutionally guaranteed autonomy from the state government (Glenny and Dalglish 1973; Pelfrey 2004; Stadtman 1970; Trow 1993), which largely exempts it from direct state controls over personnel and contracting, allows the university's Board of Regents to set tuition, and provides its operating appropriation with few direct fiscal controls. Of course, there is some pragmatic negotiation with the state authorities over how much money is needed and how it will be spent, and tuition decisions are influenced by how much state funding is expected.

3. Goldberger, Maher, and Flattau 1995. A new national quality assessment study is now under way.

4. Cited in Pelfrey (2004, 77).

5. Cited in Pelfrey (2004, 77). All the other universities in the top dozen were private.

6. The newest campus, Merced, did not exist in the years shown in table 12.1. It should be noted that Berkeley, Riverside, Santa Barbara, and Santa Cruz are all hampered in these rankings by their lack of a medical school. Federal R&D support from the largest federal granting agency, the National Institutes of Health, increased much more than support in other scientific fields over most of the period shown.

7. Good accounts of developments during this period are provided by Stadtman (1970), Kerr (2001), and Pelfrey (2004).

8. A student aid program was also established to support state resident undergraduates attending private colleges and universities. These "Cal Grants" served to divert a substantial number of students from the public systems at considerable savings to the state. California now has well over one hundred private colleges and universities, including a number of very strong institutions.

9. San Diego had a long history as a UC research installation but had only begun to educate a few graduate students in the sciences when the decision to develop a full general campus (at a new site) was made (Kerr 2001).

10. Key events were student unrest on the UC campuses, the election of Ronald

Reagan as governor, and the recession of the early 1970s with its aftermath of slow growth and high inflation. By 1978 the state experienced a "tax revolt" and passage of the property-tax-limiting Proposition 13 ballot initiative, which has hamstrung its finances ever since. See Schrag 2006, especially chapter 2, which is aptly titled, "Dysfunction, Disinvestment, Disenchantment."

11. The undergraduate completion rates in these two systems are among the best in the country for public institutions of their type.

12. Projections in early 2009 put the state's budget deficit in the tens of billions.

13. Other states are in a broadly similar predicament, but California's voters have created more than the typical number of constraints.

14. This seems particularly likely in a state with a stronger-than-usual policy commitment to access and in particular to low tuition (fees). In FY2007, the governor used improved state revenues to "buy out" scheduled 8% undergraduate fee increases for UC and the CSU system (Gledhill 2005).

15. There have been some variations in this percentage over time, but for most years since 1995, policy has been for the university to use one-third of incremental fee revenue for need-based financial aid. Overall, about 27% of tuition and fee revenue is spent on such aid (Alcocer 2006).

16. In 2006–7, the general rate for California resident graduate students was $6,162 for the academic year, compared to $5,409 for undergraduates. Non-state-resident graduate students nominally are charged much more, but what they actually pay varies greatly by field.

17. This would be dubious fiscal policy, for the state's General Fund budget is already excessively constrained by such "earmarked" funding streams.

18. The Master Plan permitted joint doctorates between California State University and private universities. Only a few such programs exist, however.

19. The ban took effect with the fall 1998 entry cohort.

20. Enrollment figures came from the California Postsecondary Education Commission On-line Data System, www.cpec.ca.gov/OnLineData/OnLineData.asp.

21. The large percentage increase in the "other" category seems to reflect rapidly changing views about race and ethnicity in America with increasing immigration and intermarriage.

22. Federal and private funds are also important in supporting research in the agricultural sciences.

23. Lockheed Corporation also has substantial R&D and manufacturing operations in the Silicon Valley area of northern California.

24. The company developed some of the technology for wireless telephone and telegraph services on the West Coast of the United States and became an important

Navy contractor before and during World War I. Stanford's High Voltage Laboratory and several of its professors played important roles, and in turn the lab received donations from the company (Sturgeon 2000, 21–22), an early example of a mutually productive relationship between academe and corporate R&D.

25. To be sure, the state and the regents acted in response to aggressive prompting from business and scientific leaders in San Diego led by Roger Revelle (Kerr 2001; Starr 2005).

26. The State University of New York–Buffalo is the only one in the group that seems somewhat anomalous. It ranks far below the others in receipt of competitive federal research and training funds.

27. The parity levels are estimates necessarily made before some of the schools have announced their annual salary increases, so there is some inaccuracy.

28. California's historical ability to import highly educated people could conceivably have played a role in the state's unwillingness to finance expansion of costly graduate programs. (In general, the state-dominated US system of financing public research and graduate universities with a national reach may suffer from tendencies toward underinvestment by state patrons who feel they cannot capture all the benefits of their investments.) At present, there is more concern that historical patterns of in-migration of the highly educated may be stifled by a combination of federal immigration restrictions and the state's high urban cost of living.

29. Other fields with notable increases over this period were health sciences and professions, business, and both the physical and the life sciences (California Postsecondary Education Commission On-Line Data System, accessed October 18, 2006).

30. Faculty (i.e., the Academic Senate) are more wary, though, preferring that the university set its own academic priorities in this matter as in others.

31. Although the center of UC's agricultural research and education activities long ago migrated from the Berkeley campus to UC Davis (originally the site of the University Farm), Berkeley continues to house programs in the agricultural sciences. Additionally, there remains considerable activity at the Riverside campus in southern California, originally the site of UC's Citrus Experiment Station.

32. As is customary, this does not count the less targeted but in all much larger state support for research that is built into the workload expectations (i.e., division of time between research and teaching) of state-supported faculty.

33. The total will likely rise substantially now that the California Institute for Regenerative Medicine (CIRM) is fully operational and releasing its grant funds (see below).

34. The Assembly is the lower house of the bicameral state legislature.

35. It should be noted that researchers at other California universities and non-

profit institutions receive many of the grants under these UC-run programs. As of 2007, the share of SRP grants held by non-UC institutions was just under 50% (Gruder 2007).

36. Moreover, since one explicit purpose of many of the grants is to "seed" projects that will attract larger-scale federal or private funding, the total expended on the projects is likely considerably larger.

37. The tobacco-related disease program has also been adversely affected by the state's diversion of a portion of the funds earmarked for research to the state Department of Health Services to support the department's cancer registry database (Gruder 2007).

38. The executive director of the Special Research Programs (Gruder 2006, 2007) reported that the tobacco program would have particularly benefited from additional funding as its support has declined more while proposals received have increased sharply in recent years. He asserted that the quality of proposals is such that the program could readily fund at least twice the current number of grants to support scientific projects that peer reviews of applications indicate are rated "outstanding" or "excellent" using NIH criteria.

39. Atkinson had formerly been director of the National Science Foundation and also chancellor of the UC San Diego campus, a university with a strong science and engineering emphasis and close ties with industry.

40. History and data in this paragraph and the next came from an interview with Julie Stein, acting director, IUCRP (Stein 2006).

41. In terms of Geiger's upstream-downstream distinction, the IUCRP is probably the one California research policy that strays somewhat from the general upstream policy thrust, but it would still best be classified as midrange rather than downstream in its primary orientation.

42. The university's Office of the President also provides about $5 million from internal funds.

43. Governor Gray Davis, a Democrat, was recalled (turned out of office) by voter referendum in 2003; at that time Republican movie star and former world champion body builder Arnold Schwarzenegger was elected governor. Evidently, the university considered the institutes' operating costs item a high priority in its budget request, and Schwarzenegger was able to package this support as part of a Governor's Research and Innovation Initiative in his FY2008 budget proposal (see http://gov.ca.gov/index.php?/press-release/5004).

44. The 2000–2001 state budget included $34 million for capital and other costs of the institute.

45. The states of Connecticut, Illinois, Maryland, New Jersey, and New York

have launched stem cell research efforts of their own, though on a smaller scale (Fischer 2007; Hamilton 2006; Schwarzenegger Orders 2006).

46. Dr. Zach Hall resigned in April 2007. One reason he cited was the ill will created by disagreements within CIRM's complex governance bodies over the extent of public involvement in processes for oversight of capital projects (Somers 2007d).

47. CIRM's two-year courtroom odyssey likely came to an end in May 2007 when the California Supreme Court declined to review a lower court decision upholding its constitutionality (Somers 2007b). Under the US legal system, however, creative legal assaults on different grounds cannot be ruled out.

48. Fifty-four of the researchers supported were graduate students (CIRM 2006b).

49. The state treasurer announced the sale of the first $250 million in bonds in early October 2007 (California state treasurer 2007). However, after the legal triumph, there remained disagreement within the CIRM governance structure about how much should be spent on capital grants to universities and how such grants should be distributed (Brainard 2007). In December 2007, CIRM was forced to disqualify ten grant applications because letters of support for them were written by deans who also serve as CIRM board members; it was judged that an unacceptable conflict of interest was involved. Another case of intervention by a board member in a grant application has provoked audits by the Fair Political Practices Commission and the state auditor (California Rejects 2007).

50. Streitz (2006). Streitz suggested that a state policy of outright ownership would deter corporate interest in partnering with CIRM or licensing intellectual property resulting from its research, just as such efforts at the federal level had done when they were attempted.

51. The discussion on institutional structures over the next several paragraphs draws on Barbour 2005. The general finding of lack of capacity for science policymaking is consistent with Geiger's (this volume, chapter 11) characterization of state incapacity in this area.

52. Barbour (2005, 22) reports that during its brief life, this unit had a mandate to "track, support, inform, and provide coherence to state S&T policy" and "guided initiatives in biomass, next-generation Internet, rural e-commerce, high-tech manufacturing, and aerospace, among others."

53. CCST depends on membership dues provided by major scientific institutions and corporations in the state, together with foundation grants solicited for some individual projects.

54. CCST 2007a; Governor Schwarzenegger's State of the State 2006. UC San Diego was also a finalist for the BP Energy Biosciences Institute and would have received the $40 million in bond funding had it been successful. UC's Lawrence

Berkeley and Lawrence Livermore Laboratories and the San Diego campus were all involved in the Petascale computer bid.

55. Geiger (this volume, chapter 11) suggests that such gubernatorial behavior in S&T policy is typical.

56. See Schrag 2006, chapter 2, for an insightful analysis of the reasons for this. He ties much of it to the rapidity of massive demographic and economic changes described earlier.

57. On occasion the university has even turned down state offers of support for research programs it did not feel were a good fit, but such action would be unlikely once a program is legislatively enacted. The University of California is, after all, the primary state agency for academic research, according to the Master Plan, and is also dependent to a considerable degree on legislative goodwill for its general financial support.

58. An interviewee told of a conversation at the outset of this program in which the legislative champion asked a university vice president whether he judged that the cure would take three years or four. The program spends about $15 million per year (see fig. 12.4), a very small amount in comparison to the sum of federal and private efforts.

59. This is not to say that the programs themselves do not make efforts to measure their performance. The IUCRP maintains the Economic Research Unit that surveys companies, researchers, and students about the impacts of its grants and publishes the results.

60. A recent exception is the process for academic reviews of the Institutes for Science and Innovation, which was initiated only after considerable agitation by the Academic Senate.

61. There is some measure of internal accountability, however, in that the IUCRP steering committee includes members of the university's committees on research and budget (Stein 2007).

62. Such advocates must be from outside California, but their local counterparts are invited to observe the panel meetings.

63. Discovery Grant applicants must also have a liaison and at least a one-for-one dollar match pledged from a California firm.

64. An exception was in agricultural research, which, as explained earlier, has a long history of state involvement.

65. It should be noted that this thrust runs generally counter to the post-Bayh-Dole-Act policies of the federal government.

66. The state has long declined to pay for any of the costs of the technology transfer function.

67. Examples of such terms might include requirements for due diligence by the licensee in utilizing the technology to create therapeutic products; mandates to provide Californians with "affordable" prices for such products; and requirements for payment of specified percentages of license revenues in royalties to the state.

68. This, of course, could only be true in a limited sense, for even a "breakthrough" advance would owe much to the published science from all over the world that has gone before.

69. The growth of non-peer-reviewed earmarks in the federal academic and science budgets in recent years is, to be sure, a worrisome trend. Notably, though, the Democratic congressional majority elected in November 2006 largely rejected such earmarks in its first major appropriations legislation.

70. This seems all the more paradoxical in light of the professionalism of the state governmental staff and the high level of sophistication of the state's intelligentsia generally.

71. Of course, these two shortcomings are related. The political stakes undermine incentives for objective evaluation.

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