

RESEARCH UNIVERSITIES AND THE WEALTH OF NATIONS

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It is a great pleasure to be back in China. I first came here in 1978 as director of the National Science Foundation (NSF) to explore the possibility of an exchange of students, scholars and scientists between our two countries. The Chinese government had expressed an interest in such an exchange; the White House was taken by surprise but quickly agreed to talks with one proviso—that such an exchange would require a formal “memorandum of understanding” signed by the two governments. What has been called the Nixon-Kissinger ping-pong diplomacy occurred earlier, but had not lead to a normalization of relations. The Chinese initially insisted on an informal arrangement for an exchange, but eventually agreed to a government-to-government program. I wish I had time today to give you an account of our negotiations. Suffice it to say that each side had a great deal to learn from the other. I signed the exchange memorandum for the United States; it was the first document ever signed by the two governments. Soon thereafter, our exchange program became part of a more comprehensive agreement on science and technology that Chairman Deng and President Carter signed on the chairman’s historic visit to the United States in January 1979.

One of the changes I have observed in China over the years is an increasing commitment among government and education officials alike in building a strong foundation of basic research. I believe this approach has considerable wisdom. It is one that the United States has used since World War II with great success. How this approach evolved, and the role universities play in spurring American economic growth, is the theme of my remarks today; thus the reference in the title to the 1776 *magnum opus* of Adam Smith.

The economic evidence about the relationship between research and development (R&D) and economic growth is overwhelming. As late as the mid-1970s, there was very little economic theory or data about investments in R&D and economic development. When I served as director of the NSF in the late 1970s, we were well aware of the lack of such economic analysis when making the case to the Congress for federal support of research. Accordingly, we initiated a special research program at NSF focused on just that issue—the relationship between investments in R&D and the growth of the American economy. In the intervening years, a substantial body of research has been conducted. This work was nicely summarized several years ago in a recent report of the President's Council of Economic Advisers: 50% of the growth in the American economy in the last 40 years has been due to investments in research and development. The private sector is a major driver of R&D, but federally funded research at universities plays a key role. The report points out that when federal investments in university research increase, there is—with an

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expected time lag—a corresponding increase in private-sector investments. There is now a well-researched link between university-based research and industries' R&D efforts.

The State of California provides an excellent example of this linkage. In the early 1990s, the state endured one of the worst recessions in its history. In prior periods, California had entered recessions later and came out earlier than the rest of the nation. But this traditional pattern broke down. California suffered a major economic downturn fueled by cutbacks in defense and aerospace—a huge loss of jobs that resulted in a dramatic drop in the tax revenues of the state.

What has happened in the intervening years? California is once again a thriving economy, recently becoming the fifth largest in the world. It is an economy that has remade itself with a diverse set of companies, heavily focused on knowledge-intensive products. An increasing number of companies are entrepreneurial in origin and high-tech in character. These companies (and their technologies) can be traced to the research universities of the United States—but particularly, the ten campuses of the University of California, the California Institute of Technology, Stanford University, and the University of Southern California.

Biotechnology, for example, a booming industry in California, traces its success—in fact its very existence—to research programs that came out of the state's universities. Digital telecommunications is another case in point. It could not exist at its current scale and scope without the California universities that produce the research and educate the engineers and scientists essential to keeping this industry on the cutting edge. The internet, multimedia, computers, and software are yet other examples.

The principal role of the research university is in the area of basic research and the training of the next generation of scientific and technical talent; nothing in my remarks today should be interpreted as contradicting that statement. Nevertheless, starting in the 1970s it became increasingly evident that research universities needed to establish greater linkages with industry to ensure that research findings were effectively transferred into the commercial sector. The University of California is very much aware of its responsibility in this regard. For example, the university regularly holds statewide conferences on technology transfer, bringing people from the university together with colleagues in industry to examine how we can do more to facilitate technology transfer. We have also established a program at the university—the Industry-University Cooperative Research (IUCR) program—which seeks to identify the most promising research areas for new products that, in turn, create new jobs.

Let me explain briefly how the IUCR works. UC researchers join with scientists or engineers from a private company to formulate a research proposal. A panel of experts drawn from industry and academia selects the best projects for funding. At least half of the funding for each project comes from industry, with the remainder from the university.

There are many benefits of the IUCR to California companies. One benefit is the involvement of graduate students in every aspect of the research the company sponsors.

Industry gets the benefit of some of the world's brightest young minds while graduate students learn firsthand about industry's needs. And because the program targets specific, next-generation research in areas of California's greatest strengths and opportunity, it is a significant element in the state's strategy for maintaining its economic leadership.

Another example is an initiative by the California state government several years ago to establish four institutes on campuses of the University of California to foster industry-university collaboration.

- *California Institute for Telecommunications and Information Technology* (Cal-IT2), based at UC San Diego in collaboration with UC Irvine, focuses on digital wireless telecommunication.
- *California NanoSystems Institute* (CNSI), based at UCLA in collaboration with UC Santa Barbara. Its purpose is to promote the transfer of nanosystems innovation to the marketplace.
- *Institute for Bioengineering, Biotechnology and Quantitative Biomedical Research* (QB3), based at University of California-San Francisco in collaboration with UC Berkeley and UC Santa Cruz. Its purpose is to develop mathematical and computer models to integrate our understanding of biological systems, from atoms and molecules to cells, tissues, organs, and the entire organism.
- *Center for Information Technology Research in the Interest of Society* (CITRIS), based at UC Berkeley, which sponsors research on information systems that have a direct impact on the economy and quality of life; for example, boosting transportation efficiency; advancing diagnosis of disease; and expanding business growth through richer personalized information services.

These institutes are now up and running and are supported by a combination of industry, state, and federal funds. They already are yielding many examples of the benefits of cooperative research between industry and universities.

My examples are from the University of California, but other American universities are pursuing similar agendas. The incentive for industrial firms to enter into cooperative research agreements with universities was significantly enhanced by passage of the Bayh-Dole Act of 1980. Prior to passage of this legislation, rights to results from research supported by the federal government had been vested with the government itself. However, the government rarely if ever sought to exploit or license research results that do not emerge from its own laboratories. Therefore, potentially useful products and processes that might have been derived from the results of federally-funded research never emerged. The Bayh-Dole Act changed that situation significantly. The terms of that legislation granted rights to federally-funded research results to the organization that had conducted that research, most prominently universities. Thenceforth, private firms could negotiate to share the rights to research results with potential university partners, providing a strong incentive which did not previously exist. It is worth noting that the idea and impetus for the Bayh-Dole Act evolved out of the NSF economics research program mentioned earlier.

As research universities began to grow accustomed to working in research partnerships with private industry—and to appreciate the tangible and intangible returns on such research partnerships—they instituted additional mechanisms to exploit promising research results of their faculties. Many individual faculty members conducting research in US universities have started their own companies to develop and market their results. Between 1988 and 2003, US patents awarded to university faculty increased from 800 to 3200. Research universities themselves have created Technology Licensing Organizations (TLOs) to patent the research results of their faculties and to license those results to private firms. Because the Bayh-Dole Act vests rights to federally funded research results in universities rather than individual investigators, universities have instituted their own criteria for sharing financial returns from such research results with the responsible faculty members. TLOs provide a ready means to get university research results off the shelf and into the productive, commercial sector.

The United States is unusual in the degree to which it relies on universities to perform basic research. The roots of this phenomenon date back to World War II. Near the end of the war, President Roosevelt turned to his science advisor, Vannevar Bush, for advice about the future of American science. Vannevar Bush (no relation to George W. Bush) is one of the great individuals in U.S. history, known for his contributions as a statesman of science. His report, which appeared shortly after President Roosevelt's death, was entitled "Science: The Endless Frontier." As the title suggests, Bush viewed science as a vast frontier of opportunities to serve virtually every aspect of the national welfare. His report set the stage for the modern era of science and technology in the United States.

What were the arguments that Vannevar Bush put forward? First, he asked "Who should fund the research and development effort of the United States?" Bush argued that applied research and development should be done by the private sector, by industry. But he also argued that the private sector would not ensure an adequate investment of funds in basic research. In essence, he believed that private market mechanisms ensured that industry would invest in applied research and development, but those same market mechanisms would not ensure adequate investment in basic research. His argument—which has been well supported by subsequent economic research—was that a company's investment in basic research could often generate results that were just as valuable to a competitor company as to the company making the investment. Further, the eventual payoff for basic research might well be too far into the future. There was no question about the societal returns for basic research, but there was not the same return to the specific company making the investment. Thus, he proposed that the funding of basic research was an obligation of the federal government.

The second question he asked was "Who should perform R&D activities?" Applied research and development, he said, is a private sector responsibility and should be performed by the private sector. Who should perform basic research? The former Soviet Union carried out research in institutes run by the central government. The French have the centrally administered CNRS programs. The Bush concept, based on the experiences of World War II, was that American universities should be the principal performers of basic research; and that the federal government should provide the funds for that work.

There was a third part to Bush's analysis. Namely, that basic research should be funded through a peer review process. Individual scientists would make proposals for work they thought was valuable. Peers—scientists from around the country—would evaluate these proposals and the evaluations would determine which to fund and which not to fund. Federal science agencies in the United States do not provide unrestricted block-grant funding to universities. Rather, individual scientists (or groups of scientists) submit proposals that request funding for specific research projects. A scientist's proposal is then sent to other scientists for their evaluation. This evaluation—the peer review—is the critical factor in ensuring that the best science is funded.

There were other aspects to Bush's proposal regarding military research and federal research laboratories. But the core ideas were: the federal government should fund basic research, while applied research and development were the responsibility of the private sector; basic research should be performed in universities and decisions about funding made via a peer-review process. The Bush model created a sea-change for American universities. Before World War II, universities received virtually no funding from the federal government for research and were peripheral to the R&D enterprise of the United States. Today they are at the center of the American research system, thanks in large measure to an extraordinarily successful partnership with the federal government. As a result, both the research enterprise itself and the U.S. economy have prospered. When the history of the last half of the twentieth century is written, the vital role research universities have played in the American economy will be regarded as one of our greatest accomplishments.

Research universities in the United States include private universities and those supported by state and local governments. The best of these institutions compete with one another for faculty, for students, and for research funds. The country's top universities usually have funds to support the research of newly-attracted faculty for perhaps one or two years. However, the bulk of their research support is from grants awarded to individual faculty members or research groups most often from the federal government, but also from private foundations. In the American system, federal grants are awarded to individual faculty members within universities rather than to the universities themselves. The competition among faculty members for research funding is an important factor in fostering the quality of university research.

Could industry take the place of research universities in the American research enterprise? The evidence suggests not. As recently as the 1970s, several large U.S. firms performed significant basic research in their own corporate laboratories. Today, virtually all industrial research focuses on the solution of specific problems. In the United States we are relying more than ever on universities for the basic research that will fuel our economy. A recent statistic sums it up: seventy-three percent of the papers cited by U.S. industry patents are based on publicly supported science, authored principally by academic scientists; only 27 percent are authored by industrial scientists.

In its simplicity and flexibility, Bush's report remains a model for science policy. But does Bush's model have any relevance for contemporary China? I believe it does.

Obviously, no model can be imported wholesale from one country into another. China is finding its own way and its own solutions to the challenge of putting knowledge to work in the economy. But however solutions differ, the evidence is overwhelming that research universities are priceless sources of ideas that create jobs, give birth to new industries, and stimulate economic growth.

We are living in an incredible era of intellectual discovery. From agriculture to medicine, from aerospace to computing, science is experiencing a series of revolutions that are remaking our ideas of what is possible. These revolutions are occurring on the campuses and laboratories of research universities every day. We have only just begun to tap the possibilities of this knowledge explosion, and the effort to link intellectual discovery more closely to applications has major implications for economies around the world. Research universities are key to this effort.