OPPORTUNITIES FOR CHINESE AND AMERICAN UNIVERSITIES IN THE KNOWLEDGE-BASED ECONOMY[(1)]

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It is a pleasure to be here on this occasion, the twentieth anniversary of the first agreement in history between the People's Republic of China and the United States for the exchange of scientists and scholars. That agreement was also the first document ever signed by the two governments, and I am proud that, as the director of the National Science Foundation, I was the signator for the United States. The exchange came at a very critical and sensitive moment. I believe history will show that the exchange of scientists and scholars played an important role in the developing relationship between the two nations. Some people may be less aware of that agreement than others, in part because shortly thereafter the doors between the two countries opened wide. But at the time the agreement was a key signal from both countries that they were ready to take a new direction in their dealings with each other.

Today, twenty years later, it is gratifying to see the growing interest that scientists and government officials in China have shown in the contributions of basic research to their country's overall development. This science policy seminar is a fitting tribute to the crucial role that scientific ties established two decades ago have come to play in the relationship between our two nations.

I believe that building a strong foundation of basic research will ensure China's future economic competitiveness. This approach has been used with success in the United States for over 50 years. How this focus on basic research evolved, and the role that research universities play in spurring American economic growth, are the principal themes of this lecture. I will conclude with some thoughts about the challenges Chinese universities face in today's knowledge-based economy.

The term "knowledge-based economy"--sometimes called the "new economy"--refers to a set of industries whose main products or services use information to decrease costs and create new opportunities for growth. Generally speaking, the industries of the new economy tend to produce jobs more rapidly and with higher salaries, increase productivity growth faster, and provide greater profits for employers than the "old" economy. These high-technology industries rely on a constant infusion of new knowledge to stay competitive, and the principal source of such knowledge is basic research. The California economy provides a striking example. Its recovery from the economic recession of the early 1990s depended on knowledge-driven businesses and jobs that didn't exist 15 or 20 years ago--biotechnology, telecommunications, and multimedia, for example.

The evidence regarding the relationship between research and development (R&D) and economic growth in the United States is overwhelming. As recently as the early 1970s, there was no substantial economic analysis of the relationship between investments in R&D and

economic development. When I served as director of the National Science Foundation in the 1970s, we were well aware of the lack of such economic data in making the case to the Congress for federal support of research. And we realized that most of our arguments about how R&D affected economic growth were based on little more than anecdotal evidence. 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 25 years, a substantial body of research has led to a development in economics called "new growth theory." This work was nicely summarized in a 1995 report of President Clinton's Council of Economic Advisors: 50 percent of the growth in the American economy in the last 40 years has been due to investments in research and development. Obviously, the private sector is a major driver of R&D, but federally funded research at universities also plays a key role. The report points out that when federal investments in university research increase, there is--with an appropriate time lag--a corresponding increase in private-sector investments. There is now a well-understood link between university-based research and industries' R&D efforts.

As I mentioned, the State of California provides one of the best examples of this linkage. In the early 1990s, the state endured one of the worst economic recessions in its history. California in prior periods had entered economic recessions later, and come out much earlier, than the rest of the United States. But in the 1990s this traditional pattern broke down. California suffered a brutal economic downturn fueled by tremendous cutbacks in defense and aerospace--a loss of jobs that resulted in a dramatic drop in the tax revenues of the state.

What has happened in the past few years? California has come storming back from the recession. Why? New jobs have been created at a fast rate. Where are those jobs coming from? From a particular type of activity: high technology. And these high-tech enterprises are not the vast IBMs and AT&Ts of the world. The companies that pulled California out of recession are small, entrepreneurial, high-tech ventures. These companies (and their technologies) can be traced directly to the research universities of California, both public and private.

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.

California succeeded in its remarkable economic comeback because it possessed four advantages essential to the new economy: 1) world-class research universities that encourage faculty--and allow them to benefit financiallly--when they are involved in research that leads to the development of new technologies; 2) a supply of entrepreneurs experienced in launching and developing high-technology businesses; 3) venture capital

and other sources of private investment in early stage business ventures; and 4) the accounting, legal, and other ancillary services needed by start-up companies.

I would like to mention a concrete example, one that I am familiar with because it began while I was chancellor of the San Diego campus of the University of California (UCSD). In the early 1980s, the San Diego region was in the midst of a painful economic transition created by the demise of many of its defense-related industries. It was clear that something needed to bridge the gap, but what? My colleagues and I decided that UCSD had to play a more aggresive role in regional economic growth, specifically in the high-technology and biotechnology areas. Our view was that small, high-technology corporations were the most likely candidates to fill the economic vacuum that followed reductions in defense contracts to many San Diego corporations. UCSD had specific strengths it could contribute to the high-technology sector: the campus is one of the nation's top recipients of federal research funding; it was home to strong science departments and an excellent school of engineering.

We expanded the breadth of UCSD's basic research capacity, creating--in cooperation with industry--interdisciplinary research centers in such areas as magnetic recording, molecular genetics, wireless communications, and structural engineering. We reinvigorated our technology transfer programs in the science and engineering departments. And we created a program called UCSD CONNECT, which had as its goal not only technology transfer but also nurturing the business support infrastructure that has proven essential to small entrepreneurial firms. UCSD CONNECT draws on expertise across all campus departments and from all professional sectors. It has served to fill a critical gap in San Diego's business infrastructure, linking local high-tech entrepreneurs with financial, managerial, and technical resources.

What this means, for example, is that UCSD CONNECT will act as an agent on behalf of small companies to help them locate investors and find the research they need to develop new products. Working with start-up companies as early as the business plan stage, UCSD CONNECT will help an entrepreneur find contacts for raising capital, forming stategic alliances, gaining marketing and management expertise and technical advice. UCSD CONNECT is often referred to as an "incubator without walls" because it has nurtured so many successful businesses in San Diego.

UCSD CONNECT is just one example of the kind of help UC is committed to providing. There are similar efforts on every one of UC's nine campuses to bring venture capitalists and people from the industrial sector together with scientists and engineers on the campuses to move UC research ideas into application.

Two years ago, the University held a statewide conference on technology transfer, bringing people from UC together with colleagues in government and in industry to examine how we can do more to facilitate the transfer of technology. In response to the business community's concerns that California is not producing enough computer scientists and engineers, between now and 2005 we are committed to increasing enrollments in engineering and computer science (at both the undergraduate and graduate levels) by 50 percent across the UC system.

And we have established a program--the Industry-University Cooperative Research (IUCR) program, now in its fourth year--that seeks to identify the most promising research areas for new products that, in turn, create new jobs. The IUCR program builds research partnerships involving industry and UC faculty. Let me explain briefly how it works.

A UC researcher joins with a scientist or engineer from a private company to formulate a research proposal. A panel of experts drawn from industry and academia selects the best proposals for funding. Industry investments are partially matched with University funds. In just three years, the investments by industry and UC have totaled more than $100 million for new research undertaken by University faculty and students. An important feature of the program is the opportunity for graduate students to participate in research. It would be difficult to overstate the crucial link between research and graduate education in American universities. Graduate students participate in all aspects of faculty research projects. This experience is an essential part of the educational process for graduate students that produces both excellent young faculty for universities and R&D leaders for industry. In the case of the IUCR program, graduate students learn firsthand about industry's needs and its opportunities. And industry gets the benefit of some of the world's brightest young minds.

Two-thirds of the 323 companies currently participating in the IUCR are small businesses. A particularly valuable benefit for them is the opportunity to work with UC faculty on multidisciplinary research that would be difficult or impossible to pursue in the private sector. Research supported by the IUCR program lays the foundation for next-generation technologies; it provides hundreds of UC students participating in the research a window on future career opportunities. The six industrial sectors that currently participate--biotechnology, communications, information technology, microelectronics, multimedia, and semiconductor manufacturing--are all critical to the California economy.

There is growing interest in programs like these not only in California but throughout the United States. The impetus to greater linkages between universities and industry grows out of a longstanding American belief that universities should not be divorced from society, but should be involved in helping solve society's problems.

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 over 50 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. Bush's 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 of all, he asked "Who should fund the research and development effort of the United States?" Let me make a few distinctions here.

For simplicity of expression, I will use the terms basic research, applied research, and development. Basic research is not focused on applications; the terms "curiosity research" and "discovery research" are sometimes used to describe it. It is driven by a sheer interest in the phenomena rather than potential applications. But basic research may reach a stage where there is potential for application and accordingly a need for applied research and, in turn, the development of new products and processes. 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 provide adequate funding for basic research. In essence, he believed that private market mechanisms ensured that industry would invest in applied research and development, but that those same private market mechanisms would not generate adequate investment in basic research. Thus, he concluded 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; the private sector could be relied upon to perform that kind of activity. Who should perform basic research? The Bush concept, founded on the experiences of World War II, was that American universities should be the principal performers of basic research; and as noted above the federal government should provide the funds for that work.

Then there was a third part to Bush's analysis. He believed that basic research should be funded through a peer-review process. Individual scientists should make proposals for research projects and a group of peers--leading scientists from around the country--should evaluate these proposals and decide 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 submit proposals that request funding for specific research projects. A scientist's proposal is then sent to other scientists for their evaluation and judged competitively against other research efforts. This evaluation--the peer review process--is the critical factor in ensuring that the best science is funded.

Those were Bush's arguments: Applied research and development should be funded and conducted by the private sector; basic research should be performed in universities and be funded by the federal government via a peer-review process. The Bush model created a sea-change for American universities. Before World War II, universities were peripheral to the R&D enterprise. Today they are at the center of American research activities, 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. I do not believe it is an overstatement to say that when the history of the last half of the twentieth century is written, the role research universities have played in the American economy will be regarded as one of our greatest accomplishments.

In recent years, there has been much discussion in the United States about the need for a new national science policy, on the premise that Bush's 50-year-old vision cannot provide a blueprint for the twenty-first century. It is true that some of the arguments in Bush's report are now questionable, some of the issues he considered important are of interest

only to students of the period. What remains pertinent is his vision of the role of government in research, including his assertion that the federal government has both the authority and the obligation to support basic research. More boldly, by arguing for the primacy of basic research supported according to norms set by scientists themselves, Bush implicitly asserted that universities defined the U.S. research enterprise. Bush gave them pride of place at the center because, as he argued, they had the potential to energize the entire system.

In spite of these remarkable successes, there is a concern in the United States today that federal funding for basic research will decline as the government struggles to balance its budget. The President of the United States and the Congress have reaffirmed their commitment to keep the federal budget balanced and to use a part of the surplus to reduce the national debt. Although some of the predictions about draconian cuts in federal funding for research have not so far materialized, this remains a matter of concern to universities throughout the nation.

The potential erosion of federal support for academic research is worrisome precisely because of the central role universities play in the overall R&D effort. Could industry take their place as the vital center of the American research enterprise? The evidence suggests not. As recently as a decade ago, several large U.S. firms performed significant basic research in their corporate laboratories. Today, virtually all industrial research focuses on the solution of specific problems, often by building on the results of university research. AT&T and IBM have essentially pulled out of basic research; both companies have come to the view that they are not wealthy enough to support basic research--at least not at the level they once did. In the United States we are relying more than ever on universities for the basic research that will ultimately 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 university scientists; only 27 percent are authored by industrial scientists.

I am more optimistic than many of my colleagues that the federal government will find a way to continue funding university research at a reasonable level. Most political leaders in the United States who have thought about these issues--Democrats and Republicans alike--have concluded that support of our research enterprise is critical to the national interest, and therefore sound federal policy.

In its simplicity and flexibility, Bush's report remains a model for science policy in the United States. But does Bush's model have any relevance for contemporary China and its universities?

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, more and more nations are coming to the realization that their universities are priceless sources of ideas that can create jobs, give birth to new industries, and stimulate the productivity growth that will enable them to create a better life for their people.

Among China's advantages today are growing encouragement for private enterprise and entrepreneurship within the country, and increasing interest among foreign investors in China's strengths in such areas as software, materials science, and biotechnology. One example of this interest is Microsoft's and Intel's decision to establish research centers here. Most important of all are the incredible resources China possesses in its universities and in its talented young people. Many of these young people have studied at foreign institutions and have experiences that will be very valuable to them in today's international marketplace.

This point brings me back to where I began--to the importance of international exchange in educating new generations of scientists and engineers who can function effectively in other countries and other cultures. This science policy seminar will surely reveal new directions our countries need to take, but it is also a wonderful reminder of how far we have come from those tentative contacts of 20 years ago.

We are living in one of history's most productive eras 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 explosion of knowledge, and the effort to link intellectual discovery more closely to applications has major implications for economies around the world. Universities are key to this effort.

Let me conclude by pointing out that in the United States, the nation's most distinguished research universities are members of an organization called the Association of American Universities. The AAU includes 62 universities--not a large number in comparison with the 3,700 institutions that make up the American higher education system. (It should be noted that six of the AAU institutions are campuses of the University of California.) But, for reasons I have explored in this paper, these 62 institutions have an impact on America's prospects far out of proportion to their numbers. In a world in which scientific knowledge doubles every 12 to 15 years, research universities are clearly an important element in any nation's economic strategy. And impressive as their past accomplishments have been, the possibilities are so plentiful, and the potential is so enormous, that the most exciting days for research universities lie not behind us but ahead.

1. [1]Paper delivered at the China-U.S. Joint Science Policy Seminar, Beijing, People's Republic of China, October 25, 1999.