Remarks of Richard C. Atkinson to the Regents of the University of California

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SUPPLY AND DEMAND FOR SCIENCE AND ENGINEERING PhD's: A NATIONAL CRISIS IN THE MAKING

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I have been asked to discuss the projected supply and demand of PhD's in the natural sciences and engineering over the course of the next several decades -- and the implications for faculty recruitment. Excluded from my critique are PhD's in the behavioral and social sciences and in the humanities. The situation in those fields is probably not too different from what I will describe today. However, for several reasons, predictions about the natural sciences and engineering are easier to make and probably more reliable than for other fields.

The conclusion to be drawn from my analysis is that there is a growing imbalance between supply and demand -- an increasing demand for PhD's that will not be met by the supply. If corrective actions are not taken immediately, by the early years of the next century the annual supply of PhD's available to the nation's workforce will be about 10,500 versus a demand for about 18,000. This imbalance will have devastating consequences for colleges and universities and for business and industry.

I will not have time to discuss ways of dealing with the imbalance. All of you can appreciate the range of options available in the private and public sectors. However, I do want to state my bias regarding possible options. What might be called "market solutions" via the private sector can play only a limited role, will be too late in taking effect, and have the potential for undermining our economy and national defense. State and federal programs will be required, reminiscent in scale and character of the efforts in the years following Sputnik.

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* The data and analyses presented here are based on various documents and reports of the National Science Foundation, the National Academy of Sciences, and the National Academy of Engineering. For purposes of brevity, I have not cited individual sources in these remarks; anyone interested in specific references should contact me.

Demand for Natural Scientists and Engineers

According to Census Bureau data monitored and analyzed by the National Science Foundation, there were approximately 1,680,000 scientists and 2,240,000 engineers employed in the United States in 1986, compared with 840,000 scientists and 1,280,000 engineers in 1976. The employment of scientists and engineers has been increasing faster than total U.S. employment, accounting for 3.6 percent of the labor force in 1986 compared with 2.4 percent in 1976 (Slide 1).

What will be the demand for scientists and engineers over the next several decades? Analyses of past economic data by the Bureau of Labor Statistics indicate that demand is strongly correlated with GNP growth, particularly the growth of high-technology industries. Therefore, if past economic trends persist, we can anticipate

that the demand for scientists and engineers will continue to increase at least as rapidly as total employment, and probably more rapidly.

Demand projections for PhD-level scientists and engineers are particularly critical for research universities, both because they produce those PhD's and because they create part of the demand for them. Since 1977, demand for new PhD scientists and engineers in the non-academic sectors (mainly industry and government) has been increasing at a steady rate, while demand in the academic sector has been decreasing. That decline in the academic sector will reverse itself within the next five years, resulting in a sharp increase in demand for new PhD's in the early years of the next century.

Currently the country employs approximately 12,500 new PhD scientists and engineers per year -- 5,000 in universities, 6,000 in industry, and the rest in federal, state, and local government. Since 1977, an average of about 5,500 new PhD positions have been created per year in business and industry. Assuming that number remains constant and taking into account replacement positions due to retirements, non-academic demand for PhD's in the natural sciences and engineering should increase slowly but steadily growing to about 9,500 by the year 2004 (Slide 2).

Academic demand projections are more complicated for two reasons. First, an increasing number of academic retirements is anticipated, beginning in the next four or five years and continuing through the end of the century. Science and engineering faculties expanded rapidly with the upsurge in federal support following Sputnik, and many young people were hired during that era. That cohort of faculty is now approaching retirement age and will need to be replaced. The replacement of retiring faculty in the sciences and engineering will accelerate over the next 15 years, going from a rate of about 2,000 per year in 1988 to over 4,500 in 2004.

The second factor that enters into the projected demand for faculty is college enrollments. Beginning around the year 2000, while colleges and universities are scrambling to fill positions created by faculty retirements, they will suddenly be faced with increasing enrollments (Slide 3). Since William Bowen, former President of Princeton University and now President of the Mellon Foundation, is coauthoring a book for publication next fall dealing with the effects of academic retirements and student enrollments. (William Bowen and Julie Anne Sosa. Prospects for Faculty in the Arts and Sciences. Princeton University Press. Fall 1989.)

1980, the number of 18- to 24-year-olds in the U.S. population has been decreasing. However, starting in the year 2000, the number of people in that age bracket will increase sharply. Assuming that the percentage of the age group entering college does not change appreciably and assuming current faculty/student ratios, academic demand for new PhD scientists and engineers will almost double between 1988 and 2004 to about 8,500 per year.

In summary, prudent assumptions indicate that in the early years of the next century the United States will need about 18,000 new PhD's per year in the natural sciences and engineering to meet the demands of business and industry and the demands of colleges and universities.

Supply of Natural Scientists and Engineers

Where will these PhD's come from? Most immediately, of course, the new PhD's needed during the next 15 years will be drawn from entering college students who choose to major in science or engineering. However, as Slide 3 indicates, the college-age population from which those majors will be drawn will continue to decrease for the remainder of the century. For that reason, increasingly higher proportions of college students would have to select science and engineering majors just to maintain the current rate of baccalaureate degrees granted (Slide 4). Between 1960 and 1980, the number of 22-year-olds with baccalaureate degrees in science or engineering fluctuated around 4 percent. In 1988 it reached a level of 5.3 percent. That rate would have to rise to 6.3 percent by 1996 simply to maintain the current number of baccalaureate degrees.

What about PhD production? The number of PhD's awarded annually in the natural sciences and engineering by U.S. universities more than tripled between 1959 and 1971, from slightly over 4,000 to about 13,500. Starting

in 1971, the number declined to about 11,000 in 1978 and then began a steady increase to about 14,500 for the current year. From 1989 forward, the number of PhD's is projected to decrease more or less steadily until about 2006 (Slide 5).

I'll explain the assumptions underlying those projections in a moment. However, first let me explain why the number of PhD's has increased in recent years. As you can see in Slide 6, the percentage of PhD's awarded to foreign citizens has been increasing in all fields of science and engineering. In 1988, foreign citizens were awarded about 30 percent of the PhD's in the physical sciences, 50 percent in mathematics, and 60 percent in engineering. If we assume that PhD's awarded to U.S. citizens persist at the 1986 rate (i.e., 2.25 per thousand for 30-year-olds) and if we assume that foreign citizens continue to receive 5,000 PhD's per year, then we arrive at the projections shown in Slide 5: a decreasing number starting this year or next, down to a level of slightly more than 12,000 per year by 2004. Since 5,000 of those new PhD's will be granted to non-U.S. citizens, it is certain that not all 12,000 will be available for employment in the United States. As working conditions improve in other countries, a decreasing percentage of foreign-born PhD's will remain in the United States to make up the shortfall between demand and supply.

In order to simplify this presentation, I have treated supply and demand projections for PhD's in the aggregate, not taking into account differences among scientific fields. There are, in fact, significant differences among fields and a more complete discussion would require that we address these differences. For example, over the last half dozen or so years, the number of PhD's awarded in biology has been increasing, while those awarded in physics and mathematics have been on a steady decline. The magnitude of the differences is illustrated in Slide 7, which presents data for PhD's in mathematics. Since 1970, the number of PhD degrees in mathematics earned by U.S. citizens has declined by nearly 50 percent; the majority of mathematics PhD's awarded by U.S. universities now go to foreign citizens.

Implications for Universities

Slide 8 combines the predictions for supply and demand to illustrate the shortfall. In this slide, we assume that 70% of the foreign students receiving PhD's will remain in the United States -- an estimate made by the National Science Foundation. Note that the shortfall under these conditions is about 7,500 per year during the first decade of the next century. If academia were to recruit successfully all of the PhD's it needed, then there would be a remainder of 2,000 to serve industry, business and government needs of 9,500. On the other hand, if industry and business were to hire all the PhD's they required, then there would be only 1,000 left to meet the academic needs of 8,500. The more realistic scenario is that neither sector will bear the full brunt of the projected shortfall and that both will have serious shortages.

Of course these demand projections could be overly optimistic. For example, if the average growth rate in the GNP were to decelerate markedly over the next 15 years or if high-technology industries flounder badly, then fewer PhD's would be needed outside academia. Likewise, if the percentage of 18-year-olds enrolling in college were to drop markedly or if federal funds for university research were drastically curtailed, then academic demand would be less than projected.

We would have to make very pessimistic assumptions about the economy and/or the national research and education enterprise in order to reduce the projected shortfall for PhD's on the demand side. Therefore, steps need to be taken to increase supply. One approach is to convince more college freshmen to major in science and engineering. In that regard Slide 9 is instructive, since it shows that research universities are the primary source of baccalaureate students in science and engineering who go on to the PhD. Therefore, if research universities are going to have the supply of PhD's needed to fill available positions, they will have to redouble their efforts to produce scientists and engineers at the bachelor's level.

Looking further ahead, individuals who receive their PhD's in 2004 are in junior high school this year. Slide 10, prepared by the National Science Foundation, summarizes alternative strategies for reducing the PhD shortfall. For example, if, in Fall 1992, 63,000 additional high school seniors were to enter college determined to major in science or engineering, then the number of PhD's derived from that additional cohort would bring the 2004

production level up to the 1988 level. This production level would require that 11,000 additional graduating seniors in science and engineering enter graduate school in the year 1996 rather than seeking immediate employment. Since each strategy taken alone is overly optimistic, a combination of strategies at all levels of the educational "pipeline" will be required to maintain the supply of PhD's at the current level. And as I've already indicated, supply at the current level will be far short of demand by the turn of the century.

Dilemma for Higher Education

The need to replace a large number of retiring faculty, combined with an increasing demand in the public sector, suggests that academia will have serious problems in recruiting faculty in the near future. This will have differing impacts on the various sectors of higher education. The top research universities may be able to compete for the best people, although the competition will be acute. Second-tier institutions probably will experience serious difficulties in attracting and holding faculty.

This projected faculty shortfall has been called a "seed corn" problem because it is the scientists and engineers in the academic community who do our basic research and train future generations of scholars and researchers. To maintain adequate numbers, universities will have to compete in the market place for talent. However, a bidding war between industry and academia would serve neither well and would have serious consequences for the nation's economy and defense. If higher education cannot attract talented scientists, we will be in danger of losing our intellectual capital. At best, we will end up with a faculty of lower quality and with too few of those to go around.

Many options need to be considered in dealing with this problem. One that we should pursue immediately is the establishment of a National Fellowship Program for Graduate Students similar to the NDEA programs created after Sputnik. The program should provide appropriate incentives for college students considering graduate work; a fellowship of $25,000 per year for four years of study would be a strong attractor for potential PhD students. To deal only with the shortfall in the natural sciences and engineering, at least 3,000 new fellowships per year would be needed. The cost of such a program at steady state would be $300 million per year. This is a small investment for the United States, given the seriousness of the problem. Do we, as a nation, have the ability to address the problem in a timely manner, or will we delay until it is too late?

Let me close by restating a few of the numbers mentioned earlier. If we do not take action now to increase graduate enrollments, the number of PhD's produced in the first decade of the next century will be about 12,000 per year. Of those, 5,000 will be non-U.S. citizens; if 70% remain in the United States, then we will have a supply of about 10,500 PhD's per year.

Conservative estimates indicate that we will need at least 18,000. The shortfall of 7,500 is greater than the number of U.S. citizens projected to receive PhD's. As the data indicate, the onset of the gap between supply and demand will be rather sudden and will begin to become apparent in about five years. Steps to deal with the shortfall should have been taken years ago. Since we are starting late, our efforts will have to be even more vigorous.

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