The Numbers Game and Graduate Education

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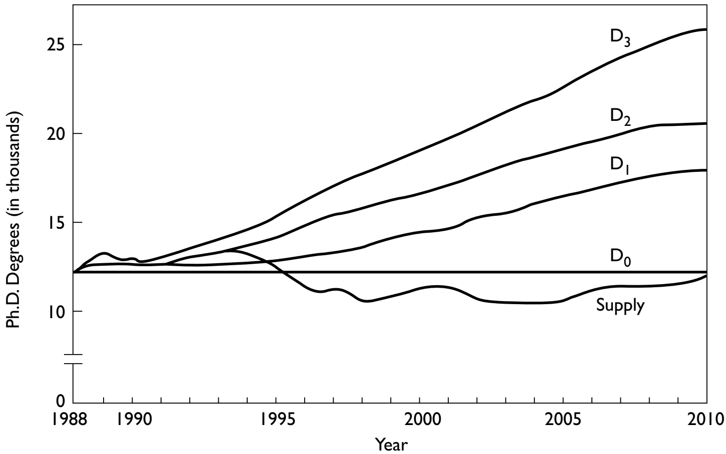
The National Science Board report *Science and Engineering Indicators, 1996* has a new section this year, entitled "Science and Engineering Labor Market."[1] It begins with the following statement: "The performance of the U.S. economy is the major determinant of current and future demand for scientists and engineers." I would argue that this statement represents a short-term perspective on the science and engineering labor market. Clearly, the current economy determines the flow of taxes, company revenues, and the number of individuals who will be hired at any given time. A long-term perspective, however, would focus on the importance of science and engineering as a driver of the future economy; the investments made in R&D today will be a dominating factor in the level of economic growth experienced in the future.

In your packet for this conference on graduate education in the biological sciences, you have an article on the supply and demand for scientists and engineers that I published in *Science* in 1990, based on work done in 1988.[2] This article reported on a National Science Foundation study that I was involved in, much like the study that Bill Bowen and a colleague at Princeton were doing at about the same time.[3] Bill and I were both projecting a significant future shortfall of Ph.D.'s. Bowen was looking at the humanities and the social sciences as well as the natural sciences and engineering. My paper was concerned only with the natural sciences and engineering and excluded the social sciences. The study began with the year 1988 and projected the supply of Ph.D.'s that would be trained in future years. That projection was made on the assumption that a certain percent of undergraduate students would go on for Ph.D.'s, and thus was based on the demographics of the twenty-two-year-old population. If you look back over the past twenty years, the proportion of twenty-two-year-olds who eventually earned a Ph.D. in science and engineering is remarkably stable.

Added to that was the assumption that the number of foreign students taking Ph.D.'s in the United States in future years would remain at the 1988 level. In 1988 we had a large number of foreign students taking Ph.D.'s, and the assumption was that this number wouldn't increase significantly. A further assumption was that 50 percent of the foreign students who earned Ph.D.'s in the United States would stay in the United States. And these assumptions led to the wiggly curve on the chart labeled "Supply of Ph.D.'s." You can see on the far left [of the chart] the actual number of Ph.D.'s produced in 1988. Supply was projected through the year 2010.

The D_0 curve was based on the assumption that the future demand for Ph.D.'s would remain constant. That is, whatever



Supply and demand projected to the year 2010 for Ph.D.'s in the natural sciences and engineering. Four demand scenarios are indicated by the D_0, D_1, D_2, and D_3 curves.

the demand was in 1988, that demand would stay the same out to the year 2010. Note that for the D_0 demand curve, it is not until the late 1990s that an undersupply of Ph.D.'s begins to occur.

But the constant D_0 scenario seemed highly unlikely for at least three reasons. First, yearly replacements due to retirements and deaths were expected to increase over the next two decades. Second, we considered it almost certain that college and university enrollments would increase in the late 1990s with the expanding college-age population, necessitating an increase in the number of faculty hired. Third, we assumed that if federal and private investments in R&D continued to grow at even moderate rates, the number of new Ph.D.'s required by industry would be well above the 1988 level. These three factors generate four cumulative demand scenarios, labeled D_0, D_1, D_2, and D_3.

We knew the demographics of the workforce in 1988 and the age distribution of Ph.D.'s in that workforce, and therefore it was fairly easy to predict the expected increase in the number of retirements. If one assumed that for every Ph.D. who retired, a replacement would enter the workforce, the result is the D_1 curve. If you compare the D_1 curve with the supply curve, somewhere after the year 2000 you begin to see a significant divergence; an increase in Ph.D. production would have to occur in order to have an adequate supply.

Another factor was the number of undergraduates enrolled in universities. We could predict with assurance that there would be a significant increase in the number of college-age students by the late '90s. If one assumed that the ratio of faculty to students would be maintained at the 1988 level, then one would add to the D_1 curve and predict a demand for Ph.D.'s represented by the D_2 curve. Finally, assuming there would be growth in the number of Ph.D.'s required in the nonacademic workforce, it seemed sensible to add a growth factor of 4 percent, which cumulated to the D_3 curve. After all, the private sector workforce was expected to expand, and one would expect a correlated increase in the need for Ph.D.'s.[4] These four demand curves represented projections based on a well-defined set of assumptions. And depending on which curve you believed, you could get quite exercised about the projected shortfall. Once I published the 1990 paper, and once Bill Bowen published his work, considerable unhappiness ensued in the academic world as the job market began to deteriorate. The fact is, however, that both sets of projections did not identify significant shortfalls in the supply of Ph.D.'s until the late '90s.

What has happened since the publication of the 1990 *Science* paper? One unanticipated factor was the end of the cold war, with the resulting cutbacks in defense spending. Another factor was that the number of foreign students taking Ph.D.'s in the United States did not remain constant, as we assumed, but instead has grown at a significant rate. And in 1988 I thought a greater proportion of foreign students would choose to return to their country of origin than had been the case in the past, because those countries were becoming more competitive and more attractive for young Ph.D.'s. It turns out that the proportion that remained in the United States did not decline, but rather increased.

What else has changed? Colleges and universities across the nation haven't yet experienced the kind of increase in enrollments that will be coming. Further, the student-faculty ratio has not remained constant, but rather has deteriorated. For example, at the University of California, it has changed from a ratio of about 14:1 up to almost 19:1. I hope the student-faculty ratio will return to more favorable levels in the future, but for the moment it is a clear indicator that the nation is investing fewer resources in educating college students.

Another factor was the Immigration Act of 1990. This act specified categories of individuals seeking to immigrate who had particular skills and gave them added consideration. As a result of this legislation, a large number of foreign-trained Ph.D.'s have entered the U.S. labor force. Twenty-three percent of the Ph.D.'s employed in the United States today were born in another country.[5] We now have the highest percent in history of foreign-born Ph.D.'s in the United States workforce.

So the question is: Is there an oversupply of Ph.D.'s? Several weeks ago I read in the *New York Times Magazine* an article by a professor of history about the serious employment problems facing Ph.D.'s, particularly in the humanities, where the placement rate for new Ph.D.'s in history and English, for example, is less than 50 percent.[6] It was a wrenching article. Without question, there are disturbing problems in the humanities. Are there problems in science and engineering? That depends on whom you talk to. In physics, there is no doubt that we have a problem. But consider a field like engineering. If you're a Ph.D. electrical engineer or a computer scientist, there is an oversupply of jobs. In mechanical engineering, on the other hand, there is a shortage of jobs.

In recent years, the Science Indicators Report has included a new measure designated "involuntary/outside of field," meaning Ph.D.'s who cannot find appropriate work and have been forced to work outside of their area of expertise. The fields of geophysics, physics, and mechanical engineering are the three highest in terms of the percent of individuals who fall into the involuntary/outside of field category. The figure is 7.7 percent for geophysics and about 6.5 percent each for astronomy, physics, and mechanical engineering. (For a few other fields: biological science, 2.1 percent; computer science, 1.4 percent; and chemistry, 3.5 percent.)

The point is that Ph.D. employment is very much a field-by-field issue. A close friend of mine took a Ph.D. in astronomy—a first-rate degree and a first-rate talent. He now runs a software company. You can imagine his history: As an astronomer he did a great deal of work on instrumentation, which involved sophisticated computer programming. He tried for many years to land a regular faculty position, but eventually gave up. He then started his own software company and has done spectacularly well. Is he inappropriately matched to his Ph.D. program? Was it a mistake for the United States to invest in his training in astronomy? I think not. And the biotech business would not be thriving in California if we did not have a steady flow of Ph.D.'s from our universities.

Despite problems in a number of fields, therefore, it is disturbing to hear some people make the blanket statement that we are training too many Ph.D.'s. Certainly physicists and scholars in the humanities will resonate with that notion. But to jump to the conclusion that the nation faces an across-the-board oversupply of scientists and engineers is inaccurate and misleading.

This doesn't mean we can't improve the preparation of Ph.D. students. I'm enthusiastic about the National Research Council's recommendation to reduce time to degree. I also support the idea that the training of Ph.D.'s should be more versatile so that they have greater opportunities in the job market. And the council's recommendation for a national employment database for science and engineering Ph.D.'s should be an immediate priority. Such a database would be invaluable to faculty advisors and to students as they plan their future. Further, if it were accessible on the Internet, we would quickly realize that the information we're collecting is inadequate. We'd begin to expand and refine our database and have more relevant information. So I support the council's recommendations, particularly as a way to match more closely societal needs with the training of Ph.D.'s in various subfields of science and engineering.

The University of California is a major player in graduate education. We produce about 10 percent of the nation's Ph.D.'s. Until this year, we have had a formula-driven budgeting process for graduate enrollments that makes little sense in the current environment. To greatly simplify, from about 1960 until this year, the number of doctoral students in a given discipline was principally determined by the number of undergraduates in that discipline. A large number of psychology undergraduates translated into a large number of psychology graduate students. The formula wasn't quite that simpleminded—and did take account of field-to-field differences—but that was the basic idea. With much discussion among the faculty and little public fanfare, we've changed our budgeting process. The change takes effect this year. No longer will we tie the number of graduate students to undergraduate enrollment, field by field. We now have a budget process in which departments will not lose budgetary support if they cut back in their graduate enrollments. Until last year, departments had to have large numbers of graduate students in order to receive the full set of rewards that the system had to offer. We are now changing our budgetary system so that the number of Ph.D. students in a department is driven more heavily by the job market and employment opportunities.

Let me conclude by saying that the training of Ph.D.'s to meet the nation's needs is one of the most important questions facing higher education, now and into the twenty-first century. We must be very careful about how we think about graduate education and the marketplace—taking into account both short-term and long-term perspectives. We would do ourselves and the nation a disservice if we came to a blanket generalization that our research universities are producing too many Ph.D.'s. The problem is too complex and too important to the nation's future to yield to simpleminded solutions.

NOTES

This paper was presented at the Conference on Graduate Education in the Biological Sciences in the Twenty-first Century, San Francisco, October 2, 1996.

1. National Science Board, *Science and Engineering Indicators, 1996* (Washington, D.C.: U.S. Government Printing Office, 1996).

2. Richard C. Atkinson, "Supply and Demand for Scientists and Engineers: A National Crisis in the Making," *Science* 248 (April 27, 1990).

3. W. G. Bowen and J. A. Sosa, *Prospects for Faculty in the Arts and Sciences* (Princeton, N.J.: Princeton University Press, 1989).

4. To save time, I have provided a very cursory explanation of these projections. My original article in *Science* should be consulted for a more detailed account.

5. National Science Board, *Science and Engineering Indicators, 1996.*

6. Louis Menand, "How to Make a Ph.D. Matter," *New York Times Magazine,* September 22, 1996.