

Job Market Effects on Scientific Productivity

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1. Introduction

Much of the discussion in science policy circles today focuses on the question of whether the production of basic knowledge is threatened by a shift of emphasis in the public sector towards facilitating technology transfer. There are at least two variants of the crowding-out hypothesis. One variant argues that in the changing university culture scientists and engineers increasingly choose to allocate their time to research of a more applied as opposed to basic nature.¹ Another variant of the crowding-out hypothesis is that the lure of economic rewards encourages scientists and engineers (and the universities where they work) to seek IP protection for their research results, eschewing (or postponing) publication, and more generally to behave more secretively than in the past.² Much of the work of BLUMENTHAL and his collaborators [1996] focuses on the latter issue in the life sciences, examining the degree to which university researchers receive support from industry and how this relates to publication. A related concern is that the granting of intellectual property can hinder the ability of other researchers to build on a given piece of knowledge. This anti-commons hypothesis, articulated by HELLER AND EISENBERG [1998] and DAVID [2001], postulates that the assignment of intellectual property rights discourages the use of knowledge by other researchers.

How changing property rights in science affect the production of new knowledge is clearly of great relevance to the future of scientific productivity. But there are other reasons to be concerned about the production of scientific knowledge. This paper focuses on these. To wit: who will do science? Will they work in an environment conducive to doing research? The premise of the paper is that researchers' productivity is affected by the environment in which they work and the conditions of their employment. For example, access to equipment and colleagues clearly affect productivity. Productivity is further enhanced by researchers' having a certain amount of autonomy. Moreover, a research horizon, facilitated by job security or funding security, encourages scientists to choose more risky projects than they might otherwise choose. And it doesn't hurt if scientists work in such environments when they are young. Research consistently finds evidence of a relationship between age and productivity [LEVIN AND STEPHAN 1991,

¹ The model examined by JENSEN AND THURSBY [2003] suggests that a changing reward structure may not alter the research agenda of faculty specializing in basic research.

² Clearly, these two variants are not mutually exclusive.

STEPHAN AND LEVIN 1992 and 1993, JONES 2005, and TURNER AND MAIRESSE 2005]. For what we might call journeymen scientists, the relationship is not pronounced. But for prize-winning research, there is considerable evidence of a strong relationship [STEPHAN AND LEVIN 1993]. While it does not require extraordinary youth to do prize-winning work, the odds decrease markedly by mid-life. STEPHAN AND LEVIN [1993] report that the median age that Nobel laureates commenced work on the problem for which they won the prize is 36.8 in chemistry; 34.5 in physics and 39.0 in medicine/physiology for the first 92 years that the prize was awarded. For the more recent period, they find that the median age in chemistry is 38.5; in physics it is 36.0 and in physiology/medicine it is 35.0 [STEPHAN, LEVIN and XIAO, unpublished data]. They conclude [1993, p. 397] “that regardless of field, the odds of commencing research for which a Nobel Prize is awarded decline dramatically after age 40.”

Research opportunities for young scientists affect not only the productivity of the current generation of scientists. They also affect the scientific enterprise in years to come, since the supply of new scientists is responsive to the job opportunities and job outcomes that the current generation experiences.

Historically, scientists and engineers received doctoral training with the goal of achieving a research position either at a university or, depending upon the country, a research institute. In some instances, scientists and engineers worked in large industrial research labs, although in the 20th century this pattern was more common in the U.S. than in Europe.

In many western countries today young scientists face problems obtaining research positions that have characteristics conducive to doing good research. Here we discuss problems facing young scientists, drawing examples from the United States, Italy, and Germany. We also discuss factors contributing to the dismal job outlook faced by young scientists today. We focus on those working in the fields of the physical, life and mathematical sciences, as well as engineers, excluding those working in the social sciences from our discussion.

2 Problems Facing Young Scientists

2.1 The Situation in the United States

Public sector research in the United States occurs primarily in the university sector, although some public research is produced at Federally Funded Research and Development Centers (FFRDCs) and at national laboratories, such as the National Institutes of Health. Within the university sector, by far the lion's share of research is conducted at what are known as Research One institutions, institutions such as Harvard, MIT, University of Michigan, University of Wisconsin, etc., classified by Carnegie as a "one" based on the amount of research funding that they receive and the number of PhD students that they educate. There is also a long tradition in the United States, as noted above, of scientists and engineers working in large industrial labs. Three noteworthy examples of such labs that flourished during the 20th century were those at Bell, DuPont and IBM.

Graduate students in the U.S. have a strong tradition, albeit the tradition is field dependent, of aspiring to a tenure track position at a research university. A survey of U.S. doctoral students in the fields of chemistry, electrical engineering, computer science, microbiology and physics during the academic year 1993-1994 found that 36% of the respondents aspired to a career at a research university; 41% aspired to a career in industry/government [FOX AND STEPHAN 2001].³ The preferences vary considerably by field; in microbiology and in physics more than 50% of the men preferred academic research positions as did 40% of the women surveyed. In chemistry and electrical engineering, which have a long tradition in the United States of employment in industry, a substantially lower percent prefer research positions in academe compared to research positions in industry or government.

The university sector in the United States has been characterized by a tenure system that determines, within a period of no more than seven years, whether an individual has the option to remain at the institution or is forced to seek employment elsewhere [STEPHAN AND LEVIN 2002, p. 419]. If the individual receives tenure, s/he is promoted to the rank of associate and subsequently full professor if the research record

³ The mail survey was administered by Fox to a national sample of 3800 doctoral students. The response rate was 62%. Respondents were asked "After receipt of your PhD, do you prefer to pursue an academic or nonacademic (industrial, government) career? The response categories were: (1) "academic with emphasis upon research;" (2) academic with emphasis upon teaching;" and (3) "nonacademic."

continues to merit promotion. Prior to being hired as an assistant professor it has become increasingly common to take a postdoctoral position.

The importance of tenure makes it crucial for young scientists to signal to older colleagues that they have the “right stuff” for doing research. A necessary component of this signal is the ability to establish a lab of one’s own. And while startup capital is generally provided by the institution [EHRENBERG, RIZZO AND JAKUBSON 2003], finding the funds necessary to run the lab (not only to buy supplies and equipment but also to hire graduate students, fund postdoctoral positions, and hire technicians) is the responsibility of the individual [STEPHAN AND LEVIN 2002, p. 419].

Typically the scientist applies to a research institute of the Federal government for a research grant, although some resources for research come from the private sector (such as the Howard Hughes Medical Institute) and some (and an increasing portion) come from the university itself. In 2001, for example, 59% of the funds for research in the academic sector came from the Federal government; 7.1% came from state and local governments, 6.8% came from industry, 7.4% came from other places and 20% came from universities themselves. (NATIONAL SCIENCE BOARD 2004, Chapter 5.)

The field that has grown the most rapidly in the United States is that of biomedical sciences. Growth has occurred both in terms of the number of PhDs produced and the amount of funding available for research. For example, PhD production in the slightly broader area of the biological and agricultural sciences grew from 2711 in 1966 to 6798 in 2000 [NATIONAL SCIENCE FOUNDATION 2002]. Funding from the National Institutes of Health doubled over a recent five-year period, going from \$13.648B in 1998 to \$27.181B in 2003.⁴ Here we examine the prospects of young PhDs trained in the biomedical sciences in the United States to be hired into a permanent position at a Research One university, as well as their prospects to get funding.

Figure 1 shows the dramatic increase in the number of PhDs age 35 or younger trained in the biomedical sciences in the United States. Data for the figure come from the Survey of Doctorate Recipients (SDR), a biennial survey overseen by Sciences Resources Statistics of the National Science Foundation and drawn from the sampling frame of the

⁴ http://www.faseb.org/opa/ppp/fed_fund/NIH_funding_trends_4x13x04_files/frame.htm

Survey of Earned Doctorates (SED), a census of all new PhDs in the U.S.⁵ We see that the number of PhDs 35 years of age or younger, trained in biomedical sciences in the United States, grew by almost 60% during the short interval of eight years, going from 11,715 to 18,671. We also see that the number of tenure-track positions has grown by only 7% during the same period, going from 1212 to 1294. Thus, the probability that a young person trained in the biomedical sciences in the United States holds a tenure track position has declined considerably in recent years, going from 10.3% to 6.9%.⁶ When we focus on Research One institutions, we see a similar pattern. We estimate that 618 PhDs age 35 or younger trained in the biomedical sciences held tenure track positions at Research One institutions in 1993 (5.3% of those 35 or younger). Eight years later, 543 (4.4%) held such positions.

The situation is not limited only to those under 35, as is readily seen in Figure 2, which shows the number of biomedical PhDs between 36 and 40 in tenure track positions to be almost flat during the period. More generally, the number age 55 and under holding tenure track positions has been fairly constant over the eight-year interval; the only growth has been for those greater than 55 years old.

Not surprisingly, young PhDs trained in the biomedical sciences are having difficulty garnering a first award from the National Institutes of Health, as shown in Figure 3. While in 1979 NIH made awards to almost 1200 principal investigators (PI's) 35 or younger, by 2003 the number had declined to approximately 200 [NATIONAL ACADEMIES OF SCIENCE 2005]. More generally, the average age at first major independent research support has increased from 37 in 1980 to 41.9 in 2002 for PhDs.⁷ The decline cannot be attributed to a lack of resources, given the tremendous amount of growth that occurred in the NIH budget during this period. Nor can it be attributed to a decline in supply of young investigators (see Figure 1). Neither can it be attributed to the quality of the proposals submitted by those 35 or younger. NIH data indicate that the success rates for new funding are highest for those 35 and younger than for any age

⁵ The SED is administered to all PhD recipients. The SDR is administered to a sample drawn from the SED. The tabulations presented here use weighted data from the SDR.

⁶ Increasingly faculty are hired into non-tenure track positions that have the title of assistant, associate or full professor. The number of young individuals holding such positions grew from 389 to 527 in 2001. Including this group with the tenure track group, the probability of being in a faculty rank position has declined from 13.7% to 9.7% during the 1993-2001 period for those 35 and younger.

⁷ First independent research support consists of either an R01 grant or, in earlier years, an R29 award.

group; the second highest success rate is for those 36 to 40. Rather, the decline reflects the older age at which young researchers obtain a first permanent position from which they can apply for funding.⁸ The funding situation was of sufficient concern for the National Academies of Science (NAS) to appoint a committee, chaired by Nobel laureate Thomas Cech, to study the issue. Their report, entitled “Bridges to Independence,” was issued in 2005.

More generally, the success patterns reflect the changing composition of PhD employment at U.S. universities. Specifically, universities increasingly are hiring more part-time and non-tenure-track faculty; they employ more and more post doctorates and staff scientists. For example, the percent of biomedical PhD.s working at universities and employed in non-tenure-track positions grew from 26% to 33% in the eight-year period 1993 to 2002. This matches a national trend across disciplines and universities. Figure 4 shows the ratio of full-time non-tenure-track faculty to full-time faculty at Research One institutions [EHRENBERG AND ZHANG 2005, Table 3A.1]. The data are displayed for both public and private institutions. In both instances, we see a substantial increase over time. For example, at public institutions, the ratio, which was .245 in 1989, had climbed to .375 by 2001; in private institutions it had started at .312 and eventually increased to .434 by the year 2001.⁹ .

It should be noted that postdoctoral appointments are usually not included in this data since the postdoctoral position is generally classified as a training position and hence is generally not processed as a hire. During this interval, the number of individuals working in postdoctoral positions has increased dramatically [MA AND STEPHAN 2005], going from 23,000 in 1991 to 30,000 in 2001.¹⁰ Ma and Stephan find the propensity to take a postdoctoral position to be inversely related to demand for positions in academe. For example, they find the probability to be negatively and significantly

⁸ Researchers typically hold a position for two or three years before submitting a grant proposal. One reason for this is that the grant application must show evidence relating to prior results.

⁹ The tabulations are based on data from the biennial IPEDS Fall Staff Surveys.

¹⁰ RICHARD FREEMAN (unpublished presentation) estimates that the ratio of postdoctorates to tenured faculty positions in the life sciences went from .54 in 1987 to .77 in 1999, an increase of 43%.

related to the per cent change in current fund revenue for institutions of higher education.¹¹

Several factors explain these hiring trends. First, cutbacks in public funds and lowered endowment payouts clearly affect hiring. Second, salaries of tenure-track faculty are higher than those of non-tenure-track faculty and research shows [EHRENBERG AND ZHANG, 2005] that this leads to a substitution away from tenure-track positions. Third, funding for non-permanent positions such as staff scientist is available in research grants. The high cost of start-up packages also plays a role in explaining these trends. A survey of start-up packages by EHRENBERG, RIZZO AND JAKUBSON [2003] finds that private Research One institutions spend on average \$403,071 on the start-up packages for assistant professors, while public Research One institutions spend on average \$308,210. Given these sums, when universities do hire in the tenured ranks, they are tempted to recruit senior faculty away from another university, rather than hire an as yet untested junior faculty member. The financial risk is considerably lower. While the start-up packages are generally higher at the senior ranks, the university gets an immediate transfer of grant money, because the senior faculty generally bring existing research grants with them when they come.

Despite this situation, many young scientists persist in aspiring to a traditional academic career. GEOFF DAVIS'S recent survey of postdocs found that the overwhelming majority of those looking for a job, were "very interested" in working at a research university.¹² While any sample of postdocs is inherently biased towards those preferring such employment, as the above statistics indicate, the odds that the respondents will achieve a tenure-track position are not good. Does this mean that young scientists act irrationally in training for a position in academe?

The academic labor market in the United States has been characterized by STEPHAN AND LEVIN as building upon a series of implicit contracts [2002]. Graduate students and postdocs enter a program and provide some "surplus" for the lab through their work as a research assistant or postdoc, and then leave the institution to begin a

¹¹ They also find the propensity to be positively related to the size of the PhD's cohort, suggesting that other things equal, as supply of new PhDs increases, recent PhDs are more likely to take postdoctoral positions.

¹² Davis reports that 1110 of the 2770 respondents indicated that they were looking for a job. Among these, 72.7% were "very interested" in a job at a research university and 23.0 were "somewhat interested."

research career. The professor has an incentive to not cheat on the arrangement. If the student is kept too long, or educated too poorly to be considered employable by a future dean, or provided poor information concerning job outcomes, in theory the professor will cease to be able to attract top graduate students and the source of labor, compensated well below its opportunity cost, will dry up.

This system, which loosely resembles a pyramid scheme, works reasonably well as long as there is a growing demand for faculty positions. But for this to occur, funding for science must not only grow, but must grow sufficiently fast to absorb the growing workforce of scientists. Such a tremendous growth in resources is something that the U.S. system has been unable to provide, particularly in recent years.

But still the system survives and young scientists continue to be recruited into PhD programs. STEPHAN AND LEVIN [2002] argue that three factors have allowed it to persist: (1) the demand for college education by the baby boomers in the 1960s and 1970s, which provided fuel for the system to expand; (2) the concept of “postdoctoral study” and (3) the eagerness of foreign nationals to study in the U.S. While the first factor is no longer relevant, the second and third are. The postdoctoral position provides relief for the system in several ways. First, by providing employment opportunities for newly minted PhDs it provides professors an “out” by allowing them to place their students more easily. Second, recipients realize that the postdoctoral position enhances their research record and thus permits them to signal their research capabilities. Finally, and perhaps unwittingly, it diffuses the role that placement plays in recruiting students to study. If applicants to graduate school inquire about job placements in academe, they can be told that academe no longer recruits faculty directly from PhD. programs, but instead, only considers applicants with postdoctoral experience. The professor is, so to speak, “off the hook.” The large presence of foreign nationals diffuses even more the role that placement plays. Rarely do foreign nationals applying to graduate school inquire about job prospects. In an international context, their prospects are significantly higher as a result of studying in the U.S. than they would be if they were not to study in the U.S.

Thus, many of the self-correcting mechanisms that might otherwise result have failed to take place.¹³

2.2 The Situation in Italy

Public sector research in Italy occurs in the university sector and at public research institutions (PRIs). Within the PRI sector, the National Research Council (CNR) employs approximately 80% of all PRI researchers.¹⁴ Tenured positions at universities exist at three levels: researcher, associate professor and full professor. Universities also employ contract researchers as temporary employees. Researchers at CNR are hired either into temporary contract positions or into tenured positions (Ricercatore or Primo Ricercatore).

The job prospects of young PhDs within the university sector have been bleak in recent years and indeed, since 2003 a “no new permanent position” policy has been in effect. This has resulted in a situation in which the share of temporary researchers at universities has reached 50% in some instances, with young people being heavily concentrated in temporary positions [AVVEDUTO 2005]. Figure 5 shows the age distribution for faculty holding tenured positions at Italian universities in 2004. The average age of researchers is 45; those in associate professor positions is 51.7 and those in full professor positions is 58. What is not shown, but worth noting, is that the average age of researchers has increased by more than two years during the seven-year interval from 1997 to 2004.

The situation is no better within the CNR, where a “no new permanent position” has been in effect since 2002. The high number of retirements coupled with the hiring freeze has led to a disproportionate number of young scientists in temporary positions; the share of temporary researchers has grown to over 50% and the average age of the CNR researcher is now above 47. Figure 6 shows the age distribution for CNR

¹³ U.S. students, as opposed to international students, increasingly find careers in science and engineering to be not to their liking. Considerable concern has been expressed in policy circles regarding this decline in interest.

¹⁴ The other public research institutions in Italy are the National Institute of Nuclear Physics (INFN) and the National Institute of Health (ISS).

researchers in tenured positions. The average for those in the position of Ricercatore is 42; for those in the position of Primo Ricercatore it is 55.¹⁵

One response to the poor job prospects for young PhDs in Italy has been for young scientists to leave the country to find employment. A 2002 CENSIS survey of 1996 Italian researchers working abroad found that the common reason for leaving Italy is lack of access to and progression in a career in the Italian scientific environment.

2.3 The Situation in Germany

The article by SCHULZE AND WARNING in this book points to the softness of the academic labor market in Germany. For example, Figure 1 of their chapter shows that the number of professors at German universities peaked in 1993 at about 23,000 and has been, with few exceptions, steadily declining ever since. In 2004, the last year for which they report data, the number stood at just slightly over 21,000. The decline is not due to a decline in the number of students. The authors show that during the same period the number of high school graduates increased significantly. They calculate that the ratio of professors per 100 high school graduates “has deteriorated significantly from 11.26 in 1996 to 9.43 in 2004” [Section 3.2].

The decline has come at the same time that the number of Habilitationen, a requirement for obtaining an appointment as a professor at most institutions and in most fields, has grown dramatically.¹⁶ To wit, since 1992, when approximately 1300 Habilitationen were produced annually, the number had grown by 2004 to approximately 2200 per year. In terms of Habilitationen per 100 professors, there has been more than a 66% increase during the period.¹⁷ Using a back of the envelope type of calculation, SCHULZE AND WARNING estimate that the ratio of new applications to job openings rose from roughly 3/2 to 5/2 during the 14-year period that they analyze.

¹⁵ The average age of tenured new hires at CNR has increased from 30 to 35 since the late 1980s; the average age of non-tenured new hires is 33.6.

¹⁶ The typical academic career path in Germany involves preparing the Habilitation. After completion, and pending availability of a position, one is hired into a C3 position which must be at an institution other than where the Habilitation was prepared.

¹⁷ The situation is reminiscent of that in the U.S. with post docs. While the number of tenure-track faculty positions has grown minimally during the last ten to fifteen years, the ratio of postdocs to faculty has grown dramatically (see footnote 10). The incentive to recruit individuals to prepare the Habilitation is similar to the incentive to recruit graduates to hold a post doc position. Both are cheap and productive.

It is not only that the job prospects for individuals who have recently received their Habilitationen are poor at German universities. It is also the case that, if and when they do receive a permanent position and the research autonomy that comes with a permanent position, they are around 42 years of age [MAYER 2000]. MUSSELIN [2005], in her comparison of French, U.S. and German academic career paths, notes that among the three countries studied the age of obtaining a permanent, tenured, position is oldest in Germany. Moreover, the opportunity to be autonomous has not been possible for young scientists in Germany, since independent untenured positions have not existed for young scientists.

Recently Germany has instituted reforms that could have a significant effect on the academic labor market. Specifically, while heretofore individuals could generally not be appointed to a professorial post until they had obtained the Habilitation,¹⁸ the reforms mean, depending upon the state, that the Habilitation could disappear and the post of junior assistant professor would then be accessible directly after the doctorate. Contracts for the junior professor are for three years and renewable one time.¹⁹ In certain ways, this system resembles that of the United States. However, it will not necessarily follow that being hired into a junior position (and renewed) provides for entrée into the position of professor. This will depend not only upon the quality of one's work (as in the U.S.) but also upon availability of posts at the professor level. While positions can be cut in the United States, it is uncommon for an untenured faculty member who merits promotion to be denied tenure and promotion because the position no longer exists. Rather, the position will persist and can be changed from that of an assistant to that of an associate or full over the course of the scientist's career.

A second reform measure involves a move from the "C" to the "W" system. Although the reform was ostensibly designed to provide for performance-based salary increases, it arguably may not succeed in accomplishing this goal. A major component of the change is the way in which base salaries are negotiated. Under the C system, faculty having a competing job offer could negotiate a higher salary at their home institution.

¹⁸ There are exceptions to the Habilitation requirement. For example, one could submit equivalent academic achievements, such as publications, and in technical universities many professors do not have a Habilitation.

¹⁹ In certain cases junior professors can be tenured if they change universities after completing the Ph.D.

The resulting raise was permanent and included in the base used for the computation of pensions. Under the W system, the base salary has been lowered with the idea that performance-based supplements would be possible. The supplements are in principle for a limited period of time. Only if they have been granted for five or more years do they become permanent, although the latter is subject to negotiation.

The W system has the potential of reducing mobility and penalizing productive faculty since for C4 professors it is almost impossible to obtain a competitive W3 job offer. Moreover, not only is the W salary lower, but by switching to a W position, the professor gives up the moderate increases in salary that accompany the C position. Thus, it is likely that the switch will make employment at German universities less attractive for productive academics and increase the incentives to go abroad.

2.4 The Situation Elsewhere

This situation is not unique to Italy, Germany, and the United States. In France, for example, restrictions have led to poor job prospects for scientific employment in the public sector, which makes up half of R&D employment [EUROPEAN COMMISSION 2004, p. 34]. The number of contract researchers doubled during the 1990s in the United Kingdom. Most European countries are also experiencing a brain drain. By way of example, 75% of the 15,158 Europeans who received their PhD in the U.S. between 1991 and 2000 indicated that they preferred to stay in the U.S. after the Ph.D. to establish their career. About 50% indicated that they had a firm offer of employment [SCIENCE AND TECHNOLOGY INDICATORS 2003, chapter 3.]

To summarize, young scientists today in many western countries have difficulty getting the type of research position—one that provides for autonomy and a sufficient time horizon—that they anticipated getting when they began their studies. They end up working for long periods in a postdoctorate fellowship or in temporary positions as staff scientist or contract researcher. If and when they do get a position that provides for autonomy they are older.

This situation has negative effects on scientific productivity. First, and foremost, is the loss in productivity of what the young could have discovered if they had had increased autonomy and a longer horizon. A second effect is the loss in terms of the

negative signal such outcomes send to younger people that science may not be a choice career. To quote MICHAEL TEITELBAUM of the Alfred P. Sloan Foundation (unpublished 2005), “Bad job prospects reinforce lack of interest.” The preface to “Bridges to Independence” [NATIONAL ACADEMY OF SCIENCE 2005] makes the case by imagining the year 2029 and a NAS committee assigned to trace the root causes of the U.S.’s fall from preeminence in biomedical sciences. “It was not difficult for the NAS Committee in 2029 to trace the root causes of the U.S. fall from preeminence in biomedical sciences. American college students had always paid close attention to what their peers had to say: The stories of a decade-long post-baccalaureate training period characterized by long hours and low pay were discouraging enough, but when coupled with the slim chance of advancing to an independent research position before the age of 40, few of the most talented American students were enticed” (pp. vii-viii). The European Economic and Social Committee observed with regards to the document “Towards a European Research Area:” “One reason for the current lack of new recruits in science and technology is that a few years ago a very large number of young scientists—even those with excellent qualifications—were unemployed.” (EUROPEAN ECONOMIC AND SOCIAL COMMITTEE CES 595/2000 p. 15.).²⁰

3. Shortage

Despite these facts, it is common for policy groups on both sides of the Atlantic to declare an impending shortage of scientists and engineers. A 2003 report issued by the NATIONAL SCIENCE BOARD [2003] concluded that “Analyses of current trends [in U.S. science and engineering workforce] indicate serious problems lie ahead that may threaten our long-term prosperity and national security.” A 2003 European Commission Communication, “Investing in research: an action plan for Europe” concluded that “Increased investment in research will raise the demand for researchers: about 1.2 million additional research personnel, including 700,000 additional researchers, are deemed necessary to attain the objectives, on top of the expected replacement of the aging workforce in research.”

Predictions of shortages exacerbate the problem. Encouraging individuals to enter a career when prospects are poor can have serious longer term consequences.

²⁰ Referenced p. 34 European Commission 2004.

Moreover, such forecasts diminish the credibility of the organization declaring the shortage, as the National Science Foundation learned all too painfully in the 1980s.

4. Positions in Industry

In recent years the employment of scientists and engineers in industry has grown rapidly in the United States, as indicated in Figure 7. In chemistry and engineering more than 50% of all PhDs work in industry and have for a considerable period. Although the percent is considerably lower in math/computer sciences and the life sciences, it has grown rapidly in recent years, tripling in the case of math and computer science and doubling in the case of the life sciences. Moreover, it would be incorrect to think of these jobs as only concentrated in development work. A considerable amount of fundamental research is performed in industry in the United States. One manifestation of this is that industry authors were listed on approximately 10% of all scientific articles published in the U.S. in 2001 [NATIONAL SCIENCE BOARD, 2004, Table 5-40]. Many of these articles are coauthored with colleagues in academe.

Employment in industry is a less salient option for European scientists. This is partly due to the lower rate of spending on R&D in Europe. For example, on average the EU spends approximately 2% of GDP on R&D; 55% of this is performed in industry. By way of contrast, the U.S. spends 2.9% of GDP on R&D; 64% is performed in industry. Japan spends 3.0% on R&D, 74% is performed in industry. Moreover, the prospects for employment growth in industrial R&D in the EU are not encouraging. The consequences relating to the privatization of research labs of state industries is a case in point. Case studies of labs in Italy and France that have recently been privatized suggest that privatization has shifted the research focus of these labs away from the generation of new knowledge in the national interest to creating value for the company and its clients “by emphasizing the assessment and integration of external knowledge” [MUNARI 2002]. Outsourcing of research is also an issue but the outsourcing is not solely directed towards Asia and countries that have a “cost advantage.” Table 1 presents data on R&D expenditures of European majority-owned affiliates operating in the United States (Bureau of Economic Analysis data). We see that over a short span of five years the amount spent by Europe (current dollars) has grown by more than 67 percent and over the 10 year period by 150 percent. A good example of the trend is the recent decision of

Novartis to relocate its research headquarters to Cambridge, Massachusetts, in order to take advantage of the research synergies in the vicinity of MIT and Harvard universities. When it opens, Novartis will employ 400 research scientists; its plans call for it to hire an additional 1000 researchers in the next five years.

5. Conclusion

Young scientists today have difficulty getting the research positions they anticipated at the time they began their training. Many end up holding postdoctorate positions for long periods or as staff scientists, contract researchers or adjunct faculty. When they do get a permanent position, they start out at a considerably older age than did their mentors.

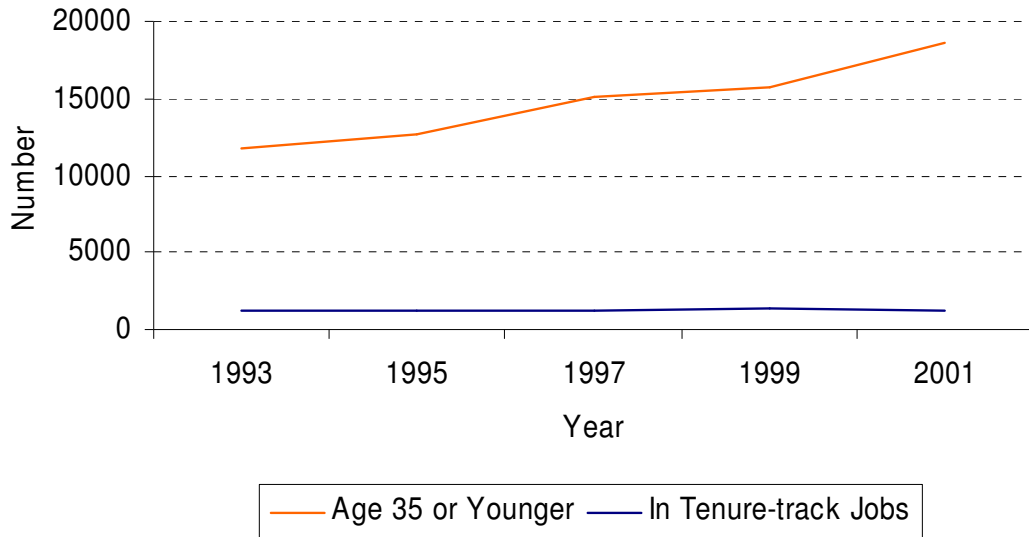
There is much angst in western countries today concerning the prospects for economic growth. The role of scientific productivity in economic growth is widely appreciated. From time to time this angst focuses on problems of the supply of scientists, with the argument that economic growth will be jeopardized if supply fails to keep pace with projected demand. Here we have argued that the problem is not a lack of supply. Instead it is weakness in demand. Decreasing budgets and increasing relative costs have led the public sector to hire fewer scientists—especially into permanent positions. Industry, especially in Europe, has been slow to hire scientists and engineers. The future of science is its ability to attract new generations of scientists and to employ them in a research environment that fosters creativity. Unless fundamental problems giving rise to these employment issues are addressed, we risk the possibility of seriously diminishing scientific productivity in the West.

This risk is occurring in the context of growing competition in an increasingly global economy. Non-western nations are aggressively training and hiring scientists and engineers. The number of PhDs awarded in China, for example, increased more than five-fold between 1995-2005 [FRENCH 2005]; that in India and Korea has also grown dramatically. The ability of a country to innovate and grow relates in part to having a scientific workforce that is generating new ideas. Both Europe and the U.S. are educating large numbers of PhDs. Some of these are “native.” Others come as foreign students. Unless Europe and the U.S. provide work environments in which these scientists and engineers can flourish and be productive, they risk losing the scientific

edge from which they have historically profited. The public sector needs to examine ways to enhance the hiring of scientists and engineers into positions that provide a productive work environment.²¹ Temporary, piecemeal jobs, which have become increasingly the norm in many countries, are not the solution. Research requires a sufficient time horizon and a degree of autonomy. Countries seeking to enhance productivity need to provide such opportunities for scientists when they are young. Age may not be a fever chill, but prize-winning work is rarely begun when scientists are past the age of 40.

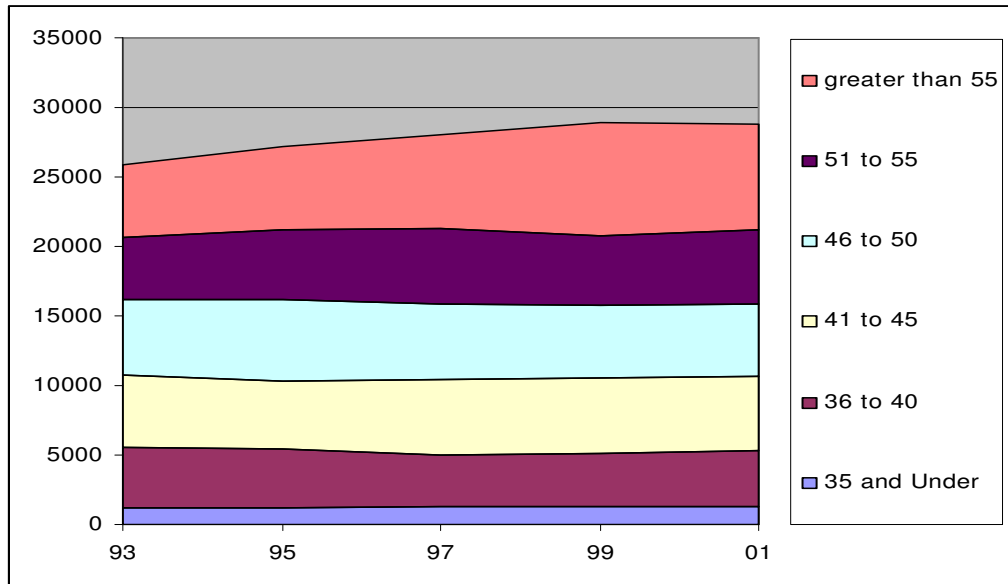
²¹ By way of example, rather than directing Federal research funds in the U.S. to the support of temporary positions such as post docs and staff scientists, ways should be explored to allocate some of the funds to more permanent positions at universities.

Figure 1
Biomedical Ph.D.s Age 35 or Younger in United States



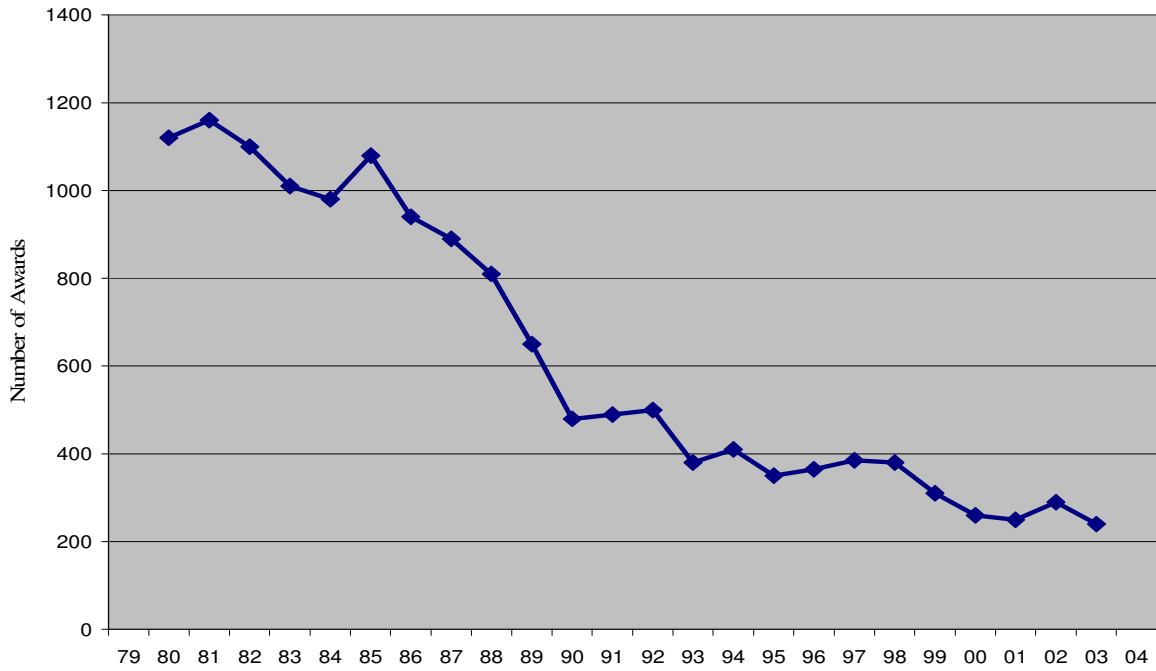
Source: Computations, SDR (see text)

Figure 2
Tenure Track Biomedical Faculty by Age: United States



Source: Computations, SDR (see text)

Figure 3
National Institute of Health Awards To Those 35 and Under, United States



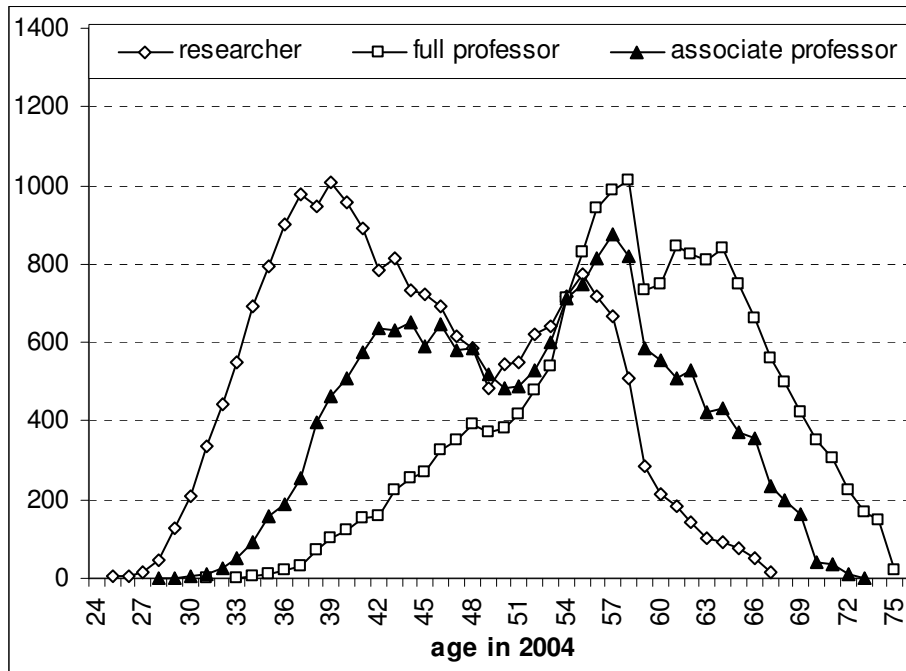
Source: National Academies of Sciences [2005]

Figure 4
Full-time Non-tenure-track Faculty/Total Full-time Faculty
at Research One Institutions: United States



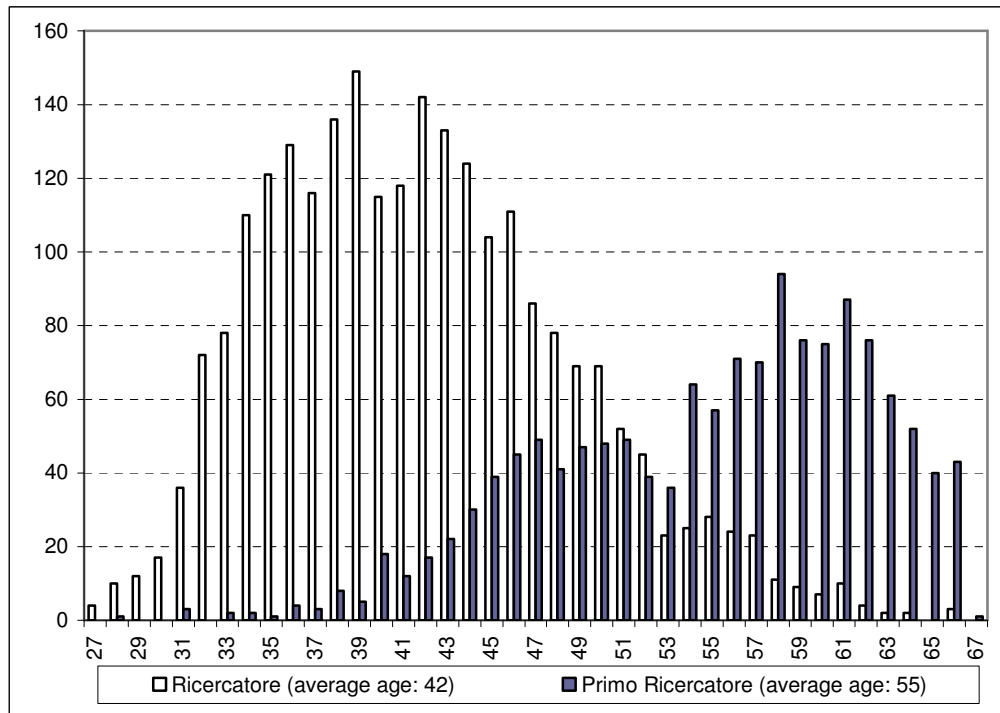
Source: Ehrenberg and Zhang [2005]

Figure 5
Age of Tenured Academics in 2004: Italy



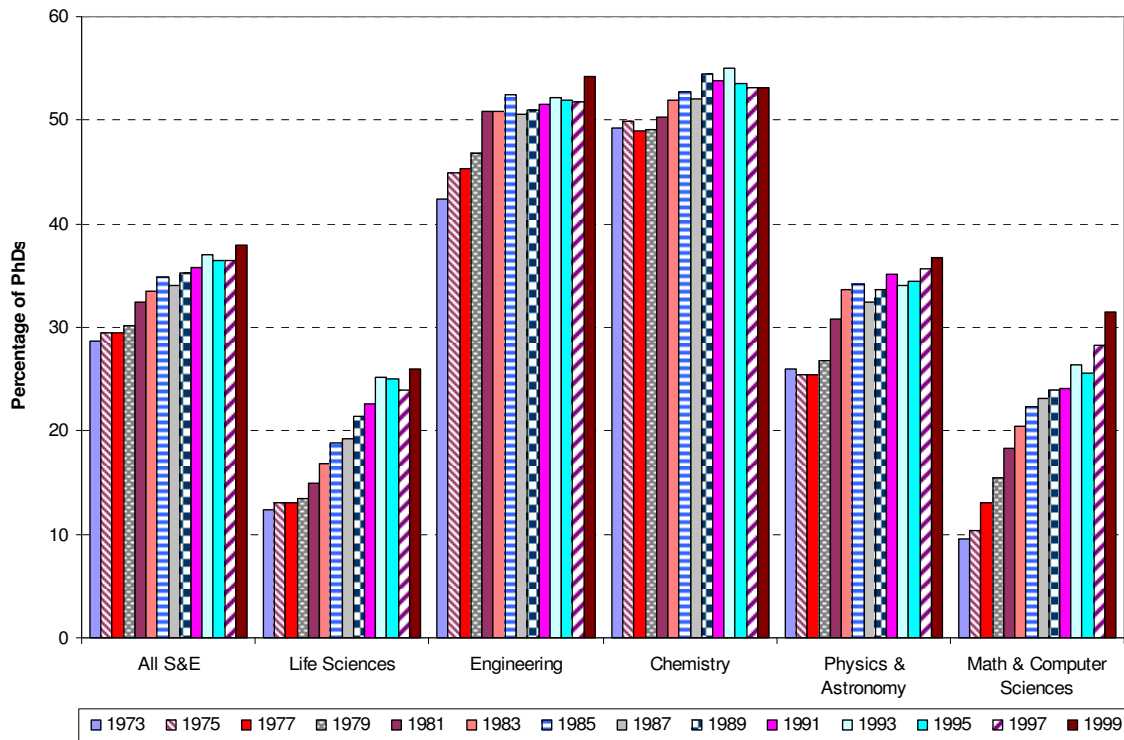
Source: MIUR (Ministry of Italy for University and Research, http://www.miur.it/scripts/visione_docenti/vdocenti0.asp)

Figure 6: Age Distribution of CNR Tenured Researchers in 2004: Italy



Source: National Research Council of Italy

Figure 7
Percent of U.S. PhDs Working in Industry, by Field, 1973-1999*



*For those five or more years since receipt of PhD and 65 or younger. Source: SDR tabulations (see text)

Table 1
R&D Expenditures of Majority Owned European Affiliates in United States
(Billions U.S. dollars)

	1992	1997	2002
Total	8.3	12.3	20.7
Germany	1.8	2.9	5.7
U.K.	2.1	3.0	5.5
Other	4.4	6.4	9.5

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