Chapter 10: Conclusion

> We accumulate knowledge rather by subtracting error than by adding truth.
>
> -- Otis Dudley Duncan[1]

This book was motivated by a policy debate about the current and future states of American science. As described in Chapter 1, the alarmist view, well represented in the 2007 NAS report *Rising Above the Gathering Storm,* asserts that the United States is in desperate need of more and better trained scientists to meet new challenges posed by an increasingly globalized and competitive world.[2] The opposing view, discussed in Chapter 9, argues that, far from facing a shortage, the United States has a glut of young scientists with weak employment prospects. A broader debate is whether or not we should be concerned that American science is in decline, as summarized in two other reports critiquing the NAS report.[3] In this book, we have carefully evaluated the claims made previously by various authors with the best data currently available to us. While our evidence does not support the claims of either a glut of young scientists or an impending shortage, we found causes for concern in some areas of American science.

The Big Picture

Is American science in decline? Our answer is a qualified no, based on a body of empirical evidence regarding its various aspects as presented in the preceding chapters. Taken as a whole, the evidence dispels the pessimistic myth that, relative to its recent past since the 1960s, American science is in serious trouble. Specifically, we have found the following:

(1) The scientist labor force in the U.S. has grown in size (Chapter 5).

(2) Public interest in and support for science in American society has remained high (Chapter 6).

---

[1] Duncan (1994).

[2] National Academy of Sciences et al. (2006); Atkinson (1990).

[3] RAND (2007); Lowell and Salzman (2007).

(3) American high school students are doing more course work and performing better in mathematics and science than in the past, although their interest in attaining science education has shown a moderate decline (Chapter 7).

(4) American universities have been producing new graduates in science at the bachelor's, master's, and doctoral levels in increasingly large quantities, although the number of science degrees awarded to native-born men has been stable (Chapter 8).

(5) Most graduates with science degrees in the U.S. have found jobs related to their training, contrary to the glut proponents' claim that there are already too many scientists in America today (Chapter 9).

At the same time, however, we have also found evidence that should cause concerns about American science and thus must qualify our initial conclusion. Our concerns relate mainly to three aspects of American science: earnings, academic science, and international competition. Although these three aspects may be related,[4] we lack the requisite data to establish causality between them and will thus discuss them separately.

The Earnings Factor

An analysis of earnings, reported in Chapter 5, shows that those of scientists have fared poorly since the 1960s. On an absolute scale, scientists' earnings have virtually stagnated after adjusting for inflation. On a relative scale, scientists' earnings have significantly declined in comparison to those of some other high-status, high-education professions (such as medicine or law). Given an increasing trend in economic returns to education and skill in the general U.S. labor force since the 1980s,[5] this is a surprising and perplexing phenomenon, one that may well signal a less healthy state of American science today than previously, as declining earnings should have a negative effect on the number of individuals who decide to become – or to remain – scientists.

---

[4] For example, it has been argued that immigration of scientists may suppress the earnings of scientists by increasing their supply relative to a fixed demand (Borjas 2005; North 1995).

[5] Fischer and Hout (2006); Goldin and Katz (2008); Heckman and Kruger (2003).

***Academic* Science in Decline?**

Academic scientists make up only a small proportion of practicing scientists in the U.S., but their positions as leaders in scientific research make their fate important for the future quality of American science. Thus, we need to be concerned about the fact that the share of American science doctorates going on to academic positions has declined. Furthermore, among those in academia, there has been an increase in postdoctoral appointments and a decline in full-time faculty positions. As we shall see in the next section, newly-minted American science doctorates face increased competition from scientists trained abroad. Thus, the postdoctoral period lengthens the time until young scholars become independent researchers, while the likelihood of transitioning to a tenure-track position has declined. The heightened costs of scientific training, combined with heightened competition for rewards, may make the already high-risk enterprise of scientific careers in academia unappealing to many young Americans.

The current practice of American science, particularly academic science, is also not without critics within the scientific community. The main focus of their critiques is the fear that the current funding system at the federal level, notably at the NIH and the NSF, discourages innovation. As we discussed earlier, innovation is a key feature of science, as important scientific advances are made only by going beyond conventional wisdom. Why would the current funding model discourage innovation?

As we explained in Chapter 3, American science became Big Science in the post-World War II period, in which many researchers began teaming up to work on large, well-funded projects. In such a system, junior scholars are typically hired as postdocs or research associates to deliver results on large projects funded by a grant made to a senior researcher. Such projects are typically funded, however, only after being approved by committees of other senior researchers operating within an evaluation system called “peer review.” The peer-review system has long been standard practice at both the NIH and the NSF, and some scientists defend it as essential to science as a resource-allocating mechanism.[6] However, the peer-review system has been criticized by some scientists as stifling innovation by encouraging

[6] For a review and a critique of the peer review system in science, see Chubin and Hackett (1990).

conformity and continuation of proven paths. A 2005 National Research Council report evaluating the postdoc system openly criticized the peer-review system this way:

> The system placed too much emphasis on the number of papers published, too little on whether really important problems were even being tackled. Because requests for grant funds from new investigators were evaluated on the basis of "preliminary results," most funded research became constrained to well-worn research paths -- those previously pursued by the new investigators when they were postdoctoral fellows in established laboratories. In short, innovation was the victim of a system that had become much too risk adverse [sic].[7]

Whether or not the current peer-review system actually puts American science at risk in the future is not something we have sufficient expertise to judge. Suffice it to say that some prominent scientists have raised this issue as a potential internal threat to American science.[8]

The Science Race in a Global Context

Our study has revealed that American science now faces increasing competition from abroad, manifested in three forms. First, as shown in Chapters 5 and 8, much of American science today relies on the scientific talents of immigrants, in the form of both immigrant scientists and science students in American universities. Second, given the substantial economic resources of the United States, American schoolchildren, as compared with children in other countries, achieve only mediocre scores on international tests of science and mathematics (see Chapter 4). Lastly, an increasing share of research activities worldwide are now being conducted in other countries, particularly in East Asia (see Chapter 4). If this trend continues, it could lead to the gradual erosion of America's longstanding dominance in world science.

---

[7] National Research Council (2005, p. viii).

[8] Note that the above-quoted passage was written jointly by Thomas R. Cech, a Nobel laureate and then President of Howard Hughes Medical Institute, and Bruce Alberts, then President of the National Academy of Science.

However, as we argued earlier in this book, science has been a globalized enterprise from its inception. Scientists around the world have historically had access to the works of American scientists, especially in basic science, and Americans continually benefit from the work of foreign researchers. Ironically, the very success of American science means that it has improved, both directly and indirectly, the lives of people in other nations, some of which have begun to emulate the success of American science. Those countries, such as China, for example, have achieved rapid improvements in education and research infrastructure and now hope to narrow the science gap between themselves and the U.S., especially if they are able to encourage their own overseas students who have enrolled in science programs at U.S. universities to return to their homelands.[9]

Serious competition arising from abroad does not necessarily mean American science is in decline. It may only mean that science today is becoming more globalized. In an age when other countries are catching up, American science will inevitably become less dominant, even when it is *not* in decline relative to its own past. As more scientists in countries outside the U.S. and Europe begin to participate in scientific research, the world of science is becoming globalized not only in terms of connectedness but also in terms of active participation in the practice of science. In light of this new world order, American science will surely have difficulty maintaining its historically unchallenged dominance, but this does not mean that science will ultimately be worse off in America because of it.

At a fundamental level, globalization of science is beneficial to science, and thus to the whole of humanity. Fuller participation in science by more nations means much greater government investment in research and a much larger science labor force worldwide. Because a scientific discovery only needs to be made once but often benefits all, globalization is certain to speed up scientific advances, for two reasons. First, science as a whole may gain efficiency via complementarity, as scientists in different parts of the world may hold distinct advantages due either to unique natural resources (for example, access to unusual

[9] Such concerns are expressed by Cole (2009) and the National Academy of Sciences (2007).

weather or unusual plants) or to unique intellectual traditions.[10] Second, the sheer expansion of the scientific labor force means more opportunities to produce fruitful scientific results. Hence, globalization of science has the potential to benefit American science as well as American society as a whole.

Of course, globalization of science also presents challenges to American science. One of them is a heightened intensity of competition. With more contenders worldwide competing for recognition, individual American scientists will find it harder in the future to attain top positions in world science. Scientists motivated by the possibility of making path-breaking discoveries may become particularly discouraged, knowing that more scientists around the world, similarly trained and equipped, are now pursuing the same dream.

A call for better science education and more investment in science in the U.S., as represented in the 2007 NAS report, *Rising Above the Gathering Storm*, may lead to policy changes that help American science maintain its competiveness and world leadership, which in turn will contribute to the American economy. This call does not need, however, to be based on an alarmist assessment of American science today, although it is often made this way in practice, possibly because federal support for science grew out of past war efforts, including those made during the Cold War after the Sputnik launching.[11] Perhaps due to this unique history, public support for and commitment to science in the U.S. are strong when the impact of science is couched in terms of national interests.

While most results in basic science are in the public domain and available to all, some scientific knowledge is kept confidential for reasons of either national security or corporate profit, especially in applied science and technology. Thus, if the U.S. loses its leadership role in basic science and consequently in technological advances, this may, in a knowledge-based economy, have negative effects on our whole society, justifying concerns based on national interests about American science. In the future, competitive countries such as China seem likely to rival -- or even surpass -- the U.S. in two areas:

---

[10] See Page (2007) for efficiency gains due to intellectual diversity.

[11] Most notably, the Bush (1945) report for the establishment of the National Science Foundation. Also see Kevles (1977b).

adequately equipped scientific laboratories and well-educated scientific personnel. Given the current reliance on the Internet for communication and widespread availability of inexpensive air transportation, physical proximity to existing centers of scientific excellence is becoming less and less crucial. What special assets of American science, then, may still put it at an advantage relative to its foreign competitors? We will answer this question in the next section.

American **Science**

Science is a social institution. As such, it is interrelated with many other social arenas, such as politics, economics, education, and culture, and must be understood within its social contexts. American science has always been fundamental to American society. In order to understand why, we first need to recognize three defining characteristics of science as a unique social institution: (1) universalism, (2) emphasis on innovation, and (3) devotion to the public good.[12] We believe that these three special features of science fit exceptionally well with certain unique aspects of American traditional culture.

First, universalism has always been a strong norm in America, which was founded as a land of equal opportunity for all.[13] In the absence of a privileged, ruling noble class, such as that in Europe, American society has traditionally valued achieved attributes over ascribed characteristics.[14] This cultural emphasis is also known as “individualism.” One indication of American individualism is the strong emphasis American culture places on individuals doing their own thinking rather than following that of conventional authorities.[15] For example, America’s individualism is manifested in its continual acceptance of immigrants, who gradually assimilate to become full members of American society, both culturally and economically.[16] In terms of cultural norms, no American's achievements or contributions

---

[12] The three features we list here are similar to the set of four “institutional imperatives” described by Merton (1942): universalism, communism, disinterestedness, and organized skepticism.

[13] Lipset (1963); McElroy (1999); Nye (1960); Tocqueville (1904).

[14] This is true despite a history of racial conflicts and gender inequality. Blau and Duncan (1967); Hout, Michael (1988); Lipset (1963); Xie and Goyette (2003).

[15] Lipset (1963, pp.121-2).

[16] Alba and (2003); Zeng and Xie (2004).

are predetermined by his or her place of birth. Instead, all Americans are supposed to be judged solely on the basis of what they accomplish. This is universalism at work, the same norm that is essential to science.

Of course, American practice falls far short of the American ideal. The processes of educational and occupational attainment are not fully universalistic, either generally or within science.[17] For example, our own analyses in Chapter 8 indicate that, net of their academic performance, the social origins of high school students play a part in determining whether or not they will receive a bachelor's degree. Within science, too, universalism may be espoused but not fully implemented.[18]

Social norms are nothing but social influences and constraints on individuals' behaviors and beliefs. As such, they are not always followed in practice. However, violations of social norms themselves do not constitute the proof that these norms do not exist. In fact, frequent public outcries against such violations when they occur only serve as indications that social norms do exist, and that they do influence and constrain individuals' behaviors and beliefs.[19] The presence of the universalistic norm in America, even if it is not fully implemented, may encourage Americans to pursue science, as it influences the perceptions of young people considering various careers and, thus, affects their career choices. The universalism norm in general may also explain why public confidence in the leadership of science and the prestige of scientists have remained high in recent decades, during which the American scientific labor force became increasingly composed of women, non-whites, and immigrants.

Second, American culture strongly emphasizes innovation. From the beginning, the United States was unique not for its appreciation of innovation, which had existed earlier in Europe, but its "belief in the creativity . . . of the ordinary people."[20] In Tocqueville's words, Americans "have swept away the privileges of some of their fellow-creatures which stood in their way, but they have opened the

[17] Fischer et al. (2006); Hodgson (2009); Glazer (2003).

[18] Long and Fox (1995); Long, Allison, and McGinnis (1979).

[19] Merton (1942).

[20] Lipset (1963, p.68).

door to universal competition."[21] Indeed, given the universalism discussed above, Lipset proposes that this pressure to innovate may be higher for otherwise disadvantaged social groups:

> Since the emphasis is on individual success in the United States, those individuals or groups who feel themselves handicapped and who seek to resolve their consequent doubts about their personal worth are under strong pressure to "innovate," that is, to use whatever means they can find to gain recognition.[22]

The pressure to be creative is good for science, because science thrives on, and rewards, innovation. As we described in Chapter 2, American history has been marked by notable technological innovations throughout.

Third, Americans tend to view high levels of achievement as contributing to the public good. One of their most unique social beliefs is that "Every Person's Success Improves Society."[23] Note that inequality has been and is a social reality in America, as it is in many other countries.[24] However, Americans have shown relatively little resentment or envy toward that small number of their fellow citizens who enjoy disproportionately large shares of fame and fortune.[25] This tolerance for inequality may be criticized if it contributes to the low degree of income redistribution in the United States and thus exacerbates income inequality. Compared to citizens of other Western countries, Americans are less likely to believe both that it is the responsibility of the government to reduce income inequality and that it is the responsibility of the government to provide a basic income for its members.[26]

One result of the American tolerance for inequality, however, is that instead of the deep class divisions found in European countries, American society is characterized by mass celebration and popular

---

[21] Tocqueville (1904. p.624).

[22] Lipset (1963, pp.175-6).

[23] McElroy (1999, p.148).

[24] See, for example, the classic book by Jencks et al. (1972).

[25] McElroy (1999, p.155).

[26] Svallfors (1997).

recognition of a small group of highly accomplished citizens.[27] This phenomenon in America can be traced back to several causes.[28] First, in its inception America was a vast frontier land with apparently unlimited resources, and thus competition for success was never viewed as a zero-sum game, as it was in Europe. Second, early American settlers had to cooperate and rely on local communities for survival in a harsh environment, rendering the successes of some helpful to others. Third, high social status was achieved only through hard work in America, rather than through either birth or military conquests, as was the case of Europe. Finally, America has always been seen (accurately or inaccurately) as providing equal opportunities to all, whereas in other countries only a few have been selected for recruitment into the elite class.[29] For these reasons, intense competition for social status and recognition has been seen as socially beneficial.[30]

The cultural norm of recognizing individuals' achievements as socially beneficial has been important to the development of science in America, both for the interface between scientists and non-scientists and for dynamics within science. For the former, high social status and recognition have been bestowed on scientists in America with genuine appreciation and admiration.[31] For the latter, scientists have fostered a relatively healthy, but highly unequal, merit-based reward system that encourages scientific contributions.[32]

The tight fit, as described above, between American values on the one hand and the special features of science on the other has been instrumental in the creation of American science. Although we do not argue that America has a monopoly on the fit between individualistic values and science, we do

---

[27] Lipset (1963).

[28] The following points are drawn from Lipset (1963) and McElroy (1999).

[29] Also see Turner (1960).

[30] Lipset (1963, p.176) argued that Americans even forgive individuals who succeeded through illegal means.

[31] A notable example was that Einstein became a popular celebrity when he first visited America. Isaacson (2007).

[32] Cole and Cole (1973).

believe that it has found its fullest expression in this country. Indeed, science was fundamental to America's identity long before America became a world leader in science, as far back as the Colonial period, the experiments of Benjamin Franklin, and the earliest years of the American republic.[33] Thus, Samuel Cooper, in a sermon celebrating the commencement of the Constitution in 1780, cited scientific advancements as one happy result of political freedom:

> [Independence] opens to us a free communication with all the world, not only for the improvement of commerce, and the acquisition of wealth, but also for the cultivation of the most useful knowledge. It naturally unfetters and expands the human mind, and prepares it for the impression of the most exalted virtues, as well as the reception of the most important science.[34]

In the long run, a social and cultural environment that is conducive to science may prove to be American science's greatest asset in meeting the challenges of foreign competition. In America's highly competitive, but (at least in the ideal) open-to-all and beneficial-to-all, environment, science will continue to prosper, as it has in the past. An erosion of such an environment would mean the real decline of American science.

Policy Implications

A book that is motivated by a policy debate is customarily expected to deliver policy recommendations. Although we will do our best to fulfill these expectations, the reader may be disappointed to know that we will not be making any clear-cut recommendations. On a subject as complicated and difficult as science, we feel that any attempt to do so would be presumptuous and foolhardy, especially given the kind of information available to us.

In researching for our book, we have analyzed eighteen large, nationally representative statistical datasets, in addition to a large quantity of published materials and web-based information. These sources of information have been valuable and informative in uncovering certain social realities as we have done

---

[33] Nye (1960).

[34] Cooper (2010).

in this book, but they do not lend themselves directly to drawing causal conclusions.[35] In other words, our study suffers from data limitations unavoidable in all social science research of the kind we conducted for the book.

Some of the realities we have uncovered, however, do seem to have important ramifications for policy makers. In acknowledging these here, we offer them more as points for further attention in the science policy debate than as policy recommendations.

First, scientists' earnings have stagnated in the post-1960 decades against a generally increasing trend in earnings for the high-educated labor force during the same period. This decline has lowered the overall cost of conducting science in the United States, but it also makes science careers less attractive than they would otherwise have been. What to do about the situation is, however, less clear. Enhancing the demand for scientists by increasing government spending would boost the earnings of scientists overall but would also raise the cost of doing science.[36] Furthermore, if the increased spending is mainly in the form of research grants that would add to the budgets of existing research labs without leading to more permanent research positions, the increase may translate in practice to more temporary junior positions considered "glut" by some science observers.[37] Clearly, the solution is not just about spending more money: choices about how to spend it have real consequences. Spending in one area necessarily means reducing spending in other areas, or increasing debt. Thus, any decision to increase funding in science will come at the cost of other benefits that are also valued by the public, such as general education or health care – items that receive more support for increased funding than does science. However, inadequate spending in science would speed up the decline of America's dominance in world science.

Second, academic science may have cause for concern, but the solution is not clear. At the same time that the high risk associated with academic careers in science may deter risk-averse young people

[35] Drawing causal conclusions based on observational data always requires unverifiable assumptions. See Morgan and Winship (2006).

[36] In the 2007 Rand report (Galama and Hosek 2007), several economists discussed this recommendation to increase the demand for scientists (Freeman 2007; Stephan 2007; Teitelbaum 2007).

[37] Benderly (2010).

from pursuing this career, the funding process in science has been criticized for rewarding risk *too little*, stifling innovation. Despite the criticisms, the practice of the postdoc system will most likely continue into the future. As a 2005 National Research Council report already recommended, funding agencies such as the NIH should devise new guidelines and programs that would improve the lives of postdocs and encourage them to do independent research.[38] It would also be beneficial for these funding agencies to work closely with universities on some of the issues.

Third, international competition is real, as the science world is becoming progressively more globalized. However, it would be short-sighted for American science to be closed to outsiders, as science in the U.S. benefits from, indeed depends on, globalization. Scientific advances in other countries should help American science, as U.S. scientists will not only build on concrete contributions made by foreign scientists but also be stimulated by competition with them. Furthermore, much of the science that takes place today on American soil is practiced by scientists who have immigrated to the U.S. These immigrants make important contributions to American science, just as earlier generations of immigrant scientists did.[39] It is appropriate, however, to consider two possible risks for American science in over-relying on immigrant scientists: (1) the supply of immigrant scientists may decline or even stop altogether, perhaps unexpectedly, in the future; and (2) the supply of immigrant scientists may lower the overall earnings of scientists and thus reduce the attractiveness of science careers to native-born Americans.

Finally, as a policy matter, science education should not be detached from general education. The twentieth century was the American century mainly because America benefited from its huge investment in education -- human capital.[40] Indeed, there is an intrinsic, dynamic relationship between science and general education: Not only is an improvement in education a precondition for training scientists, technological advances made by scientists change the direction of the American economy, which, in turn,

---

[38] National Research Council (2005).

[39] See Cole (2009) for the history of the important role that immigrants have played in American science.

[40] This discussion draws from Goldin and Katz (2008).

demands better-educated workers. There are some signs that America's investment in higher education has slowed down in recent decades.[41] One piece of empirical evidence consistent with the underinvestment argument is a corresponding increase since the 1980s in earnings for highly educated workers.[42] To enhance general education, the U.S. would need to meet at least three sets of challenges ahead. First, it needs to narrow the gap in accessing education, especially in the early years, by race and family socioeconomic background.[43] Second, further investment in high-quality colleges and universities is needed to accommodate increasing demands.[44] Third, the academic mission for knowledge acquisition and training in American institutions of higher education needs to be strengthened.[45]

America is a great country, for both the gifted and the ordinary, native-born Americans and immigrants, scientists and non-scientists. In its relatively short history, America has faced serious challenges, such as the Revolutionary War, the Civil War, World War I, the Great Depression, World War II, and the Cold War, but it has surfaced each time from these periods of difficulty with greatly improved strengths. One of this nation's greatest assets has been the close affinity between American science and American society at large. In the long run, this invaluable asset will prove instrumental in keeping science strong in America, giving us good reason to remain optimistic about the future of American science. While America may not always remain dominant in a world that is becoming increasingly interconnected scientifically, this does not mean that science in America is doomed to mediocrity. Loss of dominance does not mean decline. All current signs indicate that American science can still remain a leader of world science for many years to come.

---

[41] Hout (2009).

[42] Fischer and Hout (2006); Goldin and Katz (2008); Heckman and Kruger (2003).

[43] Gamoran (2001); Heckman (2006); Kao and Thompson (2003). Note that James Heckman appropriately emphasizes the importance of education in early ages. See Heckman and Kruger (2003).

[44] Hout (2009).

[45] Arum and Roksa (2011).