R&D Priorities and Human Resources for Science and Technology Implications of U.S. Experience for Japan

Christopher T. Hill
George Mason University
and
Technology Policy International

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General Theory of this Presentation

Despite their great differences in history, culture, institutions and other factors, the science and technology systems of advanced countries have been converging for a number of decades. In keeping with the practice of "benchmarking" made popular in industry, countries look to other countries for ideas and to assess their policies, practices and outcomes in light of the achievements of other countries. Owing to its dominance of world science and technology throughout the past half century, the United States has often been the "reference nation" against which others benchmark their own systems. Many aspects of the American system have, as a result, been adopted by a variety of countries.

Japan has long made a practice of examining other countries for ideas about how to improve its own society, so it should be no surprise that for the present symposium, science policy experts from a number of other countries, including but not limited to the United States, were invited to contribute to its deliberations.

At the same time, two key principles must be kept in mind. The first principle is that features of any one country's science and technology system may reflect profound yet obscure developments in the country; developments that are not immediately apparent to even seasoned observers and that may not be at all relevant to other countries' needs. So, in making international comparisons it is important to try to understand not only WHAT another country does but WHY it does it.

The second principle mirrors the first. Essentially it reminds us that countries do, in fact, differ in important ways that make elements of the sytems of other countries less relevant than might be thought at first glance. Furthermore, each country must manage a range of internal political, regional, and historical aspects of its situation that may constrain its ability to adopt and/or use policies and practices that may seem manifestly superior in the eyes of external observers.

Keeping in mind these two principles, analysts of comparative science and technology policies should proceed with a great deal of humility—they don't always understand their own system as well as they think they do, and they are often blissfully unaware of how another country's circumstances mean that their observations not be as relevant as the analyst would claim.

In this spirit, I offer some observations on the central issues of this paper. They are, first, how does the United States seek to match the availability of people ("human resources") trained in specific areas of science and technology to the R&D priorities of the nation? And, second, what implications does the U.S. approach have for the design of human resources policy for science and technology in Japan?

To approach these questions, I have divided this paper into three parts. The first part presents some key characteristics of the U.S. science and technology approach to preparing science and engineering human resources that may be of particular interest to Japan. The second part addresses how the U.S. science and engineering system responds to forces acting upon it from other parts of American society. The third part offers some observations on the comparisons of the U.S. and Japanese science and technology systems that are offered in the evaluation of the Basic Plan for Science and Technology in Japan.

Key Characteristics of the U.S. Science and Technology System

Five characteristics of the U.S. science and technology system (hereinafter the U.S. "S&T" system) are of particular importance and relevance not only to the United States but also to Japan and other nations. They are:

- Flexibility
- Diversity
- Openness
- Mobility
- Competition

These five characteristics are key to understanding how and why the U.S. S&T system is so highly responsive to changing societal and political expectations regarding the contributions of science and technology to achieving national goals. As will become apparent, each of these characteristics has features of market or market-like behavior in which competitive, open processes are highly favored over centrally planned or administered processes of decision making.

Flexibility

A hallmark of the American S&T system is its great flexibility. This flexibility enables the system to adapt to changing needs and opportunities very rapidly, if not always efficiently. The work of most academic researchers in S&T is funded through the project grant and contract system, with funds flowing from federal agencies, foundations and industry to support each project as a separate activity. As new funds become available, researchers change their agendas to make their work more attractive to potential new funders. Nearly every academic faculty member who is active in research has full authority and responsibility to seek his or her own funds, and he is not dependent on funds flowing to senior professors to support his research. (Of course, he also does not enjoy the comfort of being supported by senior professors.)

Because researchers in academia, as well as in most government laboratories and many companies, do not have guaranteed funding for their research programs, they must continually be on the lookout for potential funding sources and seek to interest potential funders in their work. Researchers who fail to keep up with new needs expressed through new program funding will typically not succeed in the system.

In addition, because R&D agency funding levels are revisited each year by Congress and the Administration through the annual budget and appropriations processes, there are several opportunities for new public needs to be articulated through changes in agency R&D budgets. In addition, if agencies have not sought funds for new programs in areas that are rapidly emerging, Congress can use the system of "ear marking" funds to specific projects to react more rapidly to changing needs. For example, in the late 1990s and before the events of September 11, 2001, the federal R&D agencies had very limited funds to commit to support research in such emerging areas as information security, biodefense, and critical infrastructure protection. Fortunately, certain influential members of Congress recognized the importance of these problems and arranged for earmarked funds to go to several universities, including my own, to support such research. When national tragedy focused new concern on these problem areas, the groups that had received earmarked funds were in a position to provide results of interest to federal agencies which had not previously supported such research.

Diversity

The United States is blessed with a very wide array of research institutions including some 200 significant research universities, more than 700 federal laboratories, and hundreds of firms that perform R&D, both large and small. Providing resources to these performers are half a dozen major federal R&D

agencies, each quite independent of the other; and numerous private foundations that support research in areas that are less favored by government funding.

Some might look at this system and see myriad opportunities for waste and duplication, among both funders and performers. Indeed, one of the perennial topics of U.S. science policy is how to improve coordination and avoid unnecessary duplication among R&D programs and projects.

However, there is another way to look at this array of funders and performers. Because it is highly diverse and not well coordinated, there are literally thousands of independent individuals and advisory groups making decisions about which topics, which projects, which performers, which methodologies, and which approaches should be used. This diversity of decision makers ensures that nearly every good idea will get an opportunity to be funded and that every good researcher will be able to get funding for his or her ideas somewhere. There is little chance that truly good projects or people will go unfunded. This is an especially important feature of the U.S. S&T system. Since any single decision on projects or performers is fraught with risk, decision making in this arena is highly uncertain, and highly centralized systems that seek to minimize the risk of making poor decisions are unlikely to be able to act in ways that optimize the rate of progress in science.

Thus, in the domain of S&T policy, as in other domains of life, we can perceive a trade-off between highly efficient and non-wasteful approaches on the one hand, and potentially wasteful but highly effective systems on the other. The United States has, deliberately or not, opted for an approach that favors progress over efficiency.

Openness

By “openness,” I mean that researchers and research institutions in the United States, with some important exceptions, are committed to relatively open exchange of problems, methods and results. Established institutions remain aware of and willing to move into new areas constantly. Close ties between academia and industry facilitate rapid commercialization of new understanding, regardless of whether formal technology transfer mechanisms are used. Increasingly, partnering among institutions in research is encouraged and engaged in.

The United States, at least until quite recently, has been open to students and visitors from around the world. Recent concerns about international terrorism have put new road blocks in the way of free movement of foreign students and scientists, and the scientific community has worked diligently to reduce those barriers or find ways to facilitate decision making in such a way as to keep out the tiny number of possible terrorists while admitting freely the much greater number of people with constructive motives.

Mobility

Personal mobility is highly valued in American society generally and in the fields of science and technology particularly. In fact, to the degree that American society can be characterized as a meritocracy, it is in the scientific and technical fields where the mechanisms of that meritocracy operate most effectively. These mechanisms include relatively objective assessment of an individual's capabilities and accomplishments, independent of his or her family connections or other personal attributes such as race, gender and age, and advancement based on personal merit as well.

Bright young people can move upward by demonstrating success at each prior level. For example, students who do well in undergraduate programs at marginal colleges are often highly sought after by leading research universities to be students in their graduate programs.

The U.S. has a long tradition of the "frontier mentality." The frontier, whidh is historically the westward edge of European settlement, is also a metaphor for seeking one's fortune in territory that may be unforgiving and harsh but that holds out promise of much greater riches than could be found at home. Another important aspect of the frontier is that it is a place where people who don't "fit in" can make a new life for themselves. And, the frontier was often accepting of people who had failed earlier in their lives and needed a second chance to build a good life for themselves. All of these attitudes characterize activity in the U.S. S&T system.

The United States was, of course, "settled" by foreigners who arrived from Europe, Africa and Asia throughout its long history. To be sure, there is also a long tradition of distrust and fear of foreigners in America, but compared with most other nations, the United States has been remarkably open to persons from other lands, and many of them go on to make a major mark on society, includingn in the scientific and technical fields. A significant fraction of all the Nobel Prize winners in America, for example, were born in other countries.

In the past two decades, the United States has adopted a series of public policies intended to make it easier and less expensive for employees to change jobs. Rules requiring that corporate pension contributions "vest" in the employee after a brief period of time help workers avoid big financial losses if they change jobs. Similar rules give employees rights to access to medical insurance when they are between jobs or temporarily out of work.

Employers also recognize that hiring staff from their competitors is a good form of corporate intelligence and a good way to obtain highly trained employees at a "discount." Some object to high worker mobility for these reasons, but on balance the social bargain is that the country gains more than it loses from high employee mobility.

It should be noted in fairness, that American society still has many important barriers to full worker mobility. For professionals, "non-compete" clauses in employment contracts can inhibit workers from moving to new employers. There are still important race, class and gender barriers to full mobility for minorities, women and economically disadvantaged people. Nevertheless, for S&T human resources particularly, mobility across employers, job roles, and even fields of science is an important characteristic of our system.

Competition

Another hallmark of the American S&T system is a strong preference for competitive processes for selection of research projects, performers, and, even, topics. To be considered competitive, processes must typically be open to all, or to all who meet some minimum and reasonable standards of eligibility; must be made available fairly and with reasonable time to respond; must use processes of selection that are free of institutional or personal bias; and must be transparent and accountable to higher authority if challenged. Of course, in practice actual competitive processes approach these ideal qualities to greater or lesser degrees.

Americans generally love competitive games, whether they be baseball, chess, poker, or mathematics Olympiads. We hold in highest regards games whose outcome is dependent on the skills, abilities and performance of the players, and, for games in which skill plays little role, we still sometimes attribute skills even to those who are successful in games through no special qualities of their own, such as lotteries. So long as the game is played "fairly," we accept the outcomes as just and right. Winners receive adulation. Losers receive condolences and admonitions to try harder, but winners feel no obligation to ameliorate the feelings or the real losses of the losers.

As a rule, Americans prefer not to worry too much about whether differing natural endowments of abilities give some people an inherent advantage in a game – even the game of "life." John Rawls' theory of justice has not found many strong adherents in America. Consistent with this, we are relatively comfortable with our meritocratic system under which people with superior mental or personal capabilities rise to the top and enjoy generally better life than those with less. Thus, we view as fair and just competitions whose outcome depends in part on natural endowments that are enjoyed by some and not by others.

One should not overemphasize the notion that American is a country comfortable with the results of unbridled competitive processes. For example, we have policies that seek to develop the abilities of those less favorably positioned so that they can compete more effectively with favored persons. In the field of S&T, the EPSCOR (Experimental Program to Stimulate Competitiveness in Research) programs of NSF and other agencies are intended to help improve the capabilities of states that are less successful in garnering competitive federal research funds to compete more successfully. And, we engage in a continual national debate about the degree to which society as a whole should provide for a "social safety net" to help those who can't or won't succeed in broadly competitive American life. Finally, we also have laws that seek to reign in economic monopolies whose success is based on winning the competitive race, in part on the theory that if one competitor succeeds in driving out all the others, then the benefits of competition to society would be lost.

Summary Observations on Characteristics of the U.S. S&T System

The United States uses many market-like, competitive mechanisms to achieve flexibility, mobility, openness and diversity in its S&T system, in order to maximum the effectiveness of that system in generating new understanding and new technological capabilities.

The competitive American system has proven to be highly responsive to changing societal needs by moving quickly to take advantage of new opportunities and to address new problems.

However, the American system achieves a high degree of responsiveness in part by tolerating a certain amount of waste and duplication of effort. And, it accepts as not only inevitable but also fair and just that winners of such competitions will be better off than losers. Only modest efforts are made to offset the occasional harsh consequences of competitive processes for those who lose.

Articulation of Changing Societal Needs and Opportunities

The previous section of this paper discusses the "supply-side" aspects of the responsiveness of the U.S. S&T system. Left for discussion here is how the demand for S&T activity is articulated in the American system.

If the supply side acts as a market for S&T services, so does the demand side have many market-like attributes. In the private sector, demand for new technology is articulated not only by consumers but also by a myriad experts in market analysis and prediction of consumer preferences. Radical new technologies have no recognized source of demand, of course, so consumers acting directly on R&D are not effective. For example, consumers did not know that they "needed" high-definition television or personal digital assistants until those technologies became available.

Demand for exotic and advanced activity in the sciences and technology is often articulated, not by end users and consumers, but by organized groups of scientists and engineers themselves, who can foresee the potential uses of new knowledge, even it is not yet perfected into useful products, and who seek support for further research or development from government agencies. If the new ideas are so radical as to have no identifiable source of likely support in government, the advocates may go to Congress for support, either through earmarking or through advocacy of new programs and new agencies, as happened over the past half dozen years with Nanotechnology. In addition, certain highly influential individuals can serve as effective spokespersons for new programs of research support, as happened when Edward Teller convinced President Reagan personally of the importance of investing in ballistic missile defense technology.

Some federal agencies actively seek out the opinions of the scientific community about possible future research programs and projects, through advisory committees and, sometimes, by encouraging submission of white papers describing entirely new opportunities, as has been done by DARPA and by the NIST Advanced Technology Program.

In the processes of demand articulation, it is tempting to look to specific agencies or the White House for leadership, through its agencies like OMB and the NSTC. However, even these high level bodies typically act in reaction to expressions of need or opportunity imposed from outside the government.

Implications of the U.S. S&T System for Japan's Five-Year Basic Plan

R&D Priority Setting

The diverse nature of the U.S. S&T system makes it quite difficult to set meaningful priorities for R&D in all but the most cursory or highly focused manner. Many proposals have been offered over the years for setting priorities for federal research funding, but with only limited success.

Japan, on the other hand, seems much more able to set priorities for research funding owing to its embrace of both systematic planning functions and the powerful role played by the political parties, the agency staffs, and senior officials in governing S&T spending. However, from an American perspective, it is not clear that "success" in setting R&D priorities is necessarily a desirable outcome. If one believes that part of America's strength lies in its diverse approaches, then one must suggest caution concerning Japan working too hard to do what American tends not to find successful.

It is especially important for Japan to consider whether its R&D support system is sufficiently responsive to "new entrants," whether these be young scientists with radical new ideas, new companies with new capabilities to offer, new universities and other institutions, or new problems needing to be addressed. A key issue for the five-year plans, I would suggest, is finding ways to ensure that "the new" gets sufficient attention in light of the prior calls on resources by established institutions and problems.

R&D Funding Systems

As noted above, the U.S. features diverse sources of funding for R&D in both the public and private sectors. This helps ensure responsiveness of the system as a whole and, especially, helps to avoid errors of omission in funding research. It does, however, lead to inefficiencies and to what can appear, *ex post*, as overlap and waste in funding R&D. The U.S. has opted for a system that tolerates a certain amount of waste and overlap as a natural accompaniment of flexibility and responsiveness.

The Japanese system for funding R&D has become increasingly diverse in recent years, with the emergence of METI as a strong supporter of fundamental and applied research, supplementing the efforts of MEXT. As Japan's agencies become more balanced and more likely to support similar activities, Japan can expect more waste and duplication, but, if the U.S. experience is a useful guide, will also experience a more rapid rate of progress.

S&T Worker Mobility

The high mobility of S&T workers in the United States is an important source of strength, but it comes with costs as well. Among those weaknesses are the greater chance that trade secrets and tacit know-how important to succeed in new technology will "leak" from one firm to another through workers who change jobs. In addition, since the other side of worker mobility is limited commitment to workers' jobs by companies, high mobility can be accompanied by relatively high worker anxiety. In turn, S&T workers in the United States often seem to be more loyal to their fields of inquiry than to their employers. Workers who change jobs may represent a loss of expertise to the firm from which they left. Openness to foreign S&T workers can become a liability as they begin to return to their countries of origin in increasing numbers.

The University System

In the United States, faculty, students and administrators move with relative ease among universities throughout their careers. Similarly, it is possible for working scientists and engineers to move from positions in government, industry or academia to positions in other sectors. To be sure, most moves into academic in mid-career are made by persons who have continued to publish and conduct relatively fundamental studies while they worked in industry or government laboratories. And, industry sometimes recruits leading academics to become senior officers in companies, such as vice president for research.

Japan has moved dramatically to enable such mobility in recent years via new personnel rules, through the recent university privatization action, through the privatization of the former AIST laboratories, and the "Japanese Bayh-Dole Act." To all appearances, Japan has made a major commitment to enhancing the mobility of science and engineering workers, at least at the formal level. It remains to be seen how frequently this new flexibility is actually used.

R&D Facilities

Federal funds to build new academic research facilities were quite plentiful in the 1960s and early 1970s. However, for the past several decades, a political dispute over construction worker contracts and wages on federally-funded facilities construction projects has brought such funding nearly to a complete halt. Not even congressional earmarks succeed if they are intended to fund facilities.

The recent award of several major federal grants to build new biocontainment laboratories for research in biodefense is an exception to general practice that was made politically feasible only because funds were used that had not originally been appropriated for construction but rather for research support.

During this same period of time, Japan has built many new university facilities. The United States could take lessons from Japan in this regard.

Post-Doctoral Fellows

Large numbers of recent U.S. doctoral graduates have taken up formal post-doctoral positions. This phenomenon is especially prominent in the life sciences, where, according to NSF, almost three-quarters of new PhDs have taken up post-doctoral positions. While post-doctoral training deepens and sometimes broadens the preparation of new scientists, the trend toward post-doctoral training as the norm is not entirely a positive phenomenon. To some extent, it reflects the results of the very rapid rise in life sciences funding through NIH over the past decade. To “spend” this money, universities have enrolled many new graduate students, who have, when successful, completed their doctoral degrees. However, it appears to many observers that job opportunities have not kept pace with the rise in the number of new graduates, which has led to some grant monies being diverted into hiring new post-docs, who are available for much lower salaries and with lesser commitment over the long term than new junior faculty members. Post-docs typically receive low pay and few, if any employment benefits such as health insurance or retirement fund contributions. To some extent, the post-doctoral position is a “job of last resort” for new PhDs who cannot find appropriate professional employment elsewhere.

Thus, while Japan looks on the growth of the number of post docs in the United States with some envy, it should take care before adopting new programs to produce substantially more post-docs without a strong understanding of the merits of such positions as compared with other employment opportunities for new PhDs.

Graduate Student Support

Graduate education in the United States, even in public institutions, is quite expensive. Unless they receive individual financial aid, students are responsible for both tuition and living expenses. Fortunately, we have developed a wide-ranging set of policies and practices that eventuate in a significant proportion of all graduate students in science and engineering receiving financial assistance for their studies in the form of fellowships and research assistantships. (Some are also supported as graduate teaching assistants or, rarely, with “traineeships.”)

Over the past two decades, the trend in federal support has moved away from fellowships awarded to individual students and toward research assistantships funded through grant and contract funds awarded to faculty principal investigators. While this system has given faculty greater flexibility in determining the research topics their students pursue, it has also restricted the flexibility that students enjoyed under fellowship support. Because fellowships are typically awarded only to U.S. citizens and permanent residents but assistantships do not usually include such restrictions, the switch to assistantships has enabled universities to provide financial aid to top students from other countries, but at the expense, perhaps, of financing studies by some American students.

Thus, it can be seen that the details of financing schemes for graduate study can have far-reaching effects on the system as a whole.

Internships and Part-time Graduate Study

In the United States, the old model of full-time graduate studies imported originally from Europe, has begun to give way toward more flexible scheduling of doctoral work. Many people in the U.S. now pursue graduate degrees on a part-time basis while working full-time in industry or elsewhere. In fact, their graduate studies may be quite secondary to their full-time employment. Students who follow this route may be better prepared to accept responsible positions in industry, but they also take longer to complete their advanced studies. An advantage from the student's point of view is that part-time study enables students to work professionally and support not only themselves but a family as well.

Part-time study has other disadvantages for both students and faculty. Students burdened with study and work are unlikely to make the time for the informal exchange of ideas with fellow students and faculty that characterize the best of full-time graduate work. On occasion, students find themselves caught by intellectual property rules that may conflict between university and company. And, because such students are highly motivated to finish their studies, they may be less willing to take the risk of exploring uncertain but potentially far-reaching research projects and will seek instead relatively routine projects that can be planned and scheduled in a foreseeable way around work and family life.

One observes, by the by, that the emerging part-time focus of some U.S. graduate students in engineering science has a lot in common with the traditional industry doctorate practiced in Japan, with much the same sorts of limitations.

Concluding Remarks

The U.S. S&T system has many characteristics and attributes that other countries, including Japan, wish to learn from. The U.S. system is widely seen as successful and eminently worthy of emulation.

On the other hand, the U.S. system has its downsides as well, and not all aspects of should be considered as necessary to national success. Certainly, none of the characteristics of the U.S. system lead necessarily to success if adopted alone.

Thus, while comparative evaluation is a valuable tool for analyzing progress under the Five-Year plan for science and technology of Japan, it is important to avoid using such comparisons as the basis for recommending changes in the Japanese S&T system without deep analysis and understanding of the U.S. experience. END