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Promoting Research and Development: The Government's Role

Remarks by

Ben S. Bernanke

Chairman

Board of Governors of the Federal Reserve System

at the conference

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I am pleased to speak at this conference on new building blocks for jobs and economic growth. The conference organizers have gathered an outstanding group of participants and have set an ambitious agenda. The topics you will address today and tomorrow, bearing on innovation and intangible capital, are central to understanding how we can best promote robust economic growth in the long run.

I won't have to spend much time convincing this audience of the importance of long-run economic growth. The Nobel Prize-winning economist Robert E. Lucas, Jr., wrote that once one starts thinking about long-run growth and economic development, "it is hard to think about anything else."[1] Although I don't think I would go quite that far, it is certainly true that relatively small differences in rates of economic growth, maintained over a sustained period, can have enormous implications for material living standards. A growth rate of output per person of 2-1/2 percent per year doubles average living standards in 28 years--about one generation--whereas output per person growing at what seems a modestly slower rate of 1-1/2 percent a year leads to a doubling in average living standards in about 47 years--roughly two generations. Compound interest is powerful! Of course, factors other than aggregate economic growth contribute to changes in living standards for different segments of the population, including shifts in relative wages and in rates of labor market participation. Nonetheless, if output per person increases more rapidly, the prospects for greater and more broad-based prosperity are significantly enhanced.

Over long spans of time, economic growth and the associated improvements in living standards reflect a number of determinants, including increases in workers' skills, rates of saving and capital accumulation, and institutional factors ranging from the

[1] Lucas (1988), p. 5.

flexibility of markets to the quality of the legal and regulatory frameworks. However, innovation and technological change are undoubtedly central to the growth process; over the past 200 years or so, innovation, technical advances, and investment in capital goods embodying new technologies have transformed economies around the world. In recent decades, as this audience well knows, advances in semiconductor technology have radically changed many aspects of our lives, from communication to health care. Technological developments further in the past, such as electrification or the internal combustion engine, were equally revolutionary, if not more so. In addition, recent research has highlighted the important role played by intangible capital, such as the knowledge embodied in the workforce, business plans and practices, and brand names. This research suggests that technological progress and the accumulation of intangible capital have together accounted for well over half of the increase in output per hour in the United States during the past several decades.[2]

Innovation has not only led to new products and more-efficient production methods, but it has also induced dramatic changes in how businesses are organized and managed, highlighting the connections between new ideas and methods and the organizational structure needed to implement them. For example, in the 19th century, the development of the railroad and telegraph, along with a host of other technologies, were associated with the rise of large businesses with national reach. And, as transportation and communication technologies developed further in the 20th century, multinational corporations became more feasible and prevalent.

Economic policy affects innovation and long-run economic growth in many ways. A stable macroeconomic environment; sound public finances; and well-functioning

[2] See Corrado, Hulten, and Sichel (2009) and Corrado and Hulten (2010).

financial, labor, and product markets all support innovation, entrepreneurship, and growth, as do effective tax, trade, and regulatory policies. Policies directed at objectives such as the protection of intellectual property rights and the promotion of research and development, or R&D, promote innovation and technological change more directly.

In the remainder of my remarks, I will focus on one important component of innovation policy--namely, government support for R&D. As I have already suggested, the effective commercial application of new ideas involves much more than just pure research. Many other factors are relevant, including the extent of market competition, the intellectual property regime, and the availability of financing for innovative enterprises. That said, the tendency of the market to supply too little of certain types of R&D provides a rationale for government intervention; and no matter how good the policy environment, ultimately, big new ideas are often rooted in well-executed R&D.

The Rationale for a Government Role in Research and Development

Governments in many countries directly support scientific and technical research, for example, through grant-providing agencies (like the National Science Foundation in the United States) or through tax incentives (like the R&D tax credit). In addition, the governments of the United States and many other countries run their own research facilities, including facilities focused on nonmilitary applications such as health. The primary economic rationale for a government role in R&D is that, absent such intervention, the private market would not adequately supply certain types of research.[3] The argument, which applies particularly strongly to basic or fundamental research, is that the full economic value of a scientific advance is unlikely to accrue to its discoverer,

[3] For an early version of this argument see Arrow (1962).

especially if the new knowledge can be replicated or disseminated at low cost. For example, James Watson and Francis Crick received a minute fraction of the economic benefits that have flowed from their discovery of the structure of DNA. If many people are able to exploit, or otherwise benefit from, research done by others, then the total or social return to research may be higher on average than the private return to those who bear the costs and risks of innovation. As a result, market forces will lead to underinvestment in R&D from society's perspective, providing a rationale for government intervention.

One possible policy response to the market underprovision problem would be to substantially strengthen the intellectual property rights regime, for example, by granting the developers of new ideas strong and long-lasting claims to the economic benefits of their discoveries--perhaps by extending and expanding patent rights. This approach has significant drawbacks of its own, however, in that strict limitations on the free use of new ideas would inhibit both further research and the development of valuable commercial applications. Thus, although patent protections and similar rules remain an important part of innovation policy, governments have also turned to direct support of R&D activities.

Of course, the rationale for government support of R&D would be weakened if governments had consistently performed poorly in this sphere. Certainly, there have been disappointments; for example, the surge in federal investment in energy technology research in the 1970s, a response to the energy crisis of that decade, achieved less than its initiators hoped. In the United States, however, we have seen many examples--in some cases extending back to the late 19th and early 20th centuries--of federal research initiatives and government support enabling the emergence of new technologies in areas that include agriculture, chemicals, health care, and information technology. A case that has been particularly well documented and closely studied is the development of hybrid seed corn in the United States during the first half of the 20th century.[4] Two other examples of innovations that received critical federal support are gene splicing--federal R&D underwrote the techniques that opened up the field of genetic engineering--and the lithium-ion battery, which was developed by federally sponsored materials research in the 1980s. And recent research on the government's so-called war on cancer, initiated by President Nixon in 1971, finds that the effort has produced a very high social rate of return, notwithstanding its failure to achieve its original, ambitious goal of eradicating the disease.[5]

What about the present? Is government support of R&D today at the "right" level? This question is not easily answered; it involves not only difficult technical assessments, but also a number of value judgments about public priorities. As background, however, a consideration of recent trends in expenditures on R&D in the United States and the rest of the world should be instructive. In the United States, total R&D spending (both public and private) has been relatively stable over the past three decades, at roughly 2-1/2 percent of gross domestic product (GDP).[6] However, this apparent stability masks some important underlying trends. First, since the 1970s, R&D spending by the federal government has trended down as a share of GDP, while the share

[4] See Griliches (1958).
[5] See Lakdawalla et al. (2010).
[6] In 2010, total U.S. R&D spending as a share of GDP was estimated to be 2.8 percent (Battelle and *R&D Magazine*, 2010). For earlier data, see National Science Foundation (2010), table 13.

of R&D done by the private sector has correspondingly increased.[7] Second, the share of R&D spending targeted to basic research, as opposed to more applied R&D activities, has also been declining.[8] These two trends--the declines in the share of basic research and in the federal share of R&D spending--are related, as government R&D spending tends to be more heavily weighted toward basic research and science. The declining emphasis on basic research is somewhat concerning because fundamental research is ultimately the source of most innovation, albeit often with long lags. Indeed, some economists have argued that, because of the potentially high social return to basic research, expanded government support for R&D could, over time, significantly boost economic growth.[9] That said, in a time of fiscal stringency, the Congress and the Administration will clearly need to carefully weigh competing priorities in their budgetary decisions.

Another argument sometimes made for expanding government support for R&D is the need to keep pace with technological advances in other countries. R&D has become increasingly international, thanks to improved communication and dissemination of research results, the spread of scientific and engineering talent around the world, and the transfer of technologies through trade, foreign direct investment, and the activities of multinational corporations. To be sure, R&D spending remains concentrated in the most-

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[7] The federal share of total U.S. R&D spending was 26 percent in 2008, while the private-sector share was 67 percent. The remaining funding comes from universities and colleges, private foundations, and other nonprofits. Three decades prior, the federal and private-sector shares were 50 percent and 46 percent respectively. See table 5 in National Science Foundation (2010).

[8] See tables 6 through 8 in National Science Foundation (2010).

[9] For example, see Jones and Williams (1998). Griliches (1992) reports estimates of the average social return that cluster in the range of 20 to 60 percent a year. See also Hall, Mairesse, and Mohnen (2009). The estimates in the literature are typically for average social returns; the return to an additional dollar of R&D spending, which is the relevant variable for determining whether further spending is warranted, may be lower than the average return.

developed countries, with the United States still the leader in overall R&D spending.[10] However, in recent years, spending on R&D has increased sharply in some emerging market economies, most notably in China and India. In particular, spending for R&D by China has increased rapidly in absolute terms, although recent estimates still show its R&D spending to be smaller relative to GDP than in the United States.[11] Reflecting the increased research activity in emerging market economies, the share of world R&D expenditures by member nations of the Organisation for Economic Co-Operation and Development, which mostly comprises advanced economies, has fallen relative to non-member nations, which tend to be less developed. A similar trend is evident, by the way, with respect to science and engineering workforces.[12]

How should policymakers think about the increasing globalization of R&D spending? On the one hand, the diffusion of scientific and technological research throughout the world potentially benefits everyone by increasing the pace of innovation globally. For example, the development of the polio vaccine in the United States in the 1950s provided enormous benefits to people globally, not just Americans. Moreover, in a globalized economy, product and process innovations in one country can lead to employment opportunities and improved goods and services around the world.

On the other hand, in some circumstances, the location of R&D activity can matter. For example, technological prowess may help a country reap the financial and

[10] Among Organisation for Economic Co-operation and Development (OECD) nations, the United States is estimated to have spent the most on R&D in 2010, followed by Japan, Germany, South Korea, France, and the United Kingdom (Battelle and *R&D Magazine*, 2010). As a percentage of GDP, Israel ranked first among OECD nations in R&D spending, followed by Finland, Sweden, Japan, and South Korea (OECD, 2010).
[11] China's gross R&D expenditures are estimated to have increased more than five-fold between 1997 and 2007 and, by 2010, are estimated to have been roughly on par with expenditures in Japan, the world's second-largest spender on R&D, although they were still about one-third the expenditures in the United States. See National Science Foundation (2010) and Battelle and *R&D Magazine* (2010).
[12] See OECD (2010).

employment benefits of leadership in a strategic industry. A cutting-edge scientific or technological center can create a variety of spillovers that promote innovation, quality, skills acquisition, and productivity in industries located nearby; such spillovers are the reason that high-tech firms often locate in clusters or near leading universities.[13] To the extent that countries gain from leadership in technologically vibrant industries or from local spillovers arising from inventive activity, the case for government support of R&D within a given country is stronger.[14]

How Should Governments Provide Support for Research and Development?

The economic arguments for government support of innovation generally imply that governments should focus particularly on fostering basic, or foundational, research. The most applied and commercially relevant research is likely to be done in any case by the private sector, as private firms have strong incentives to determine what the market demands and to meet those needs.[15]

If the government decides to foster R&D, what policy instruments should it use? A number of potential tools exist, including direct funding of government research facilities, grants to university or private-sector researchers, contracts for specific projects, and tax incentives. Moreover, within each of these categories, many choices must be made about how to structure specific programs. Unfortunately, economists know less about how best to channel public support for research and development than we would like; it is good news, therefore, that considerable new work is being done on this topic, including recent initiatives on science policy by the National Science Foundation.[16]

[13] See Jaffe (1989).
[14] Another argument for fostering domestic innovation is that it may have national security implications.
[15] For example, see David, Hall, and Toole (2000) and Hall and van Reenen (2001).
[16] See Lane (2009).

Certainly, the characteristics of the research to be supported are important for the choice of the policy tool. Direct government support or conduct of the research may make the most sense if the project is highly focused and large-scale, possibly involving the need for coordination of the work of many researchers and subject to relatively tight time frames. Examples of large-scale, government-funded research include the space program and the construction and operation of "atom-smashing" facilities for experiments in high-energy physics. Outside of such cases, which often are linked to national defense, a more decentralized model that relies on the ideas and initiative of individual researchers or small research groups may be most effective. Grants to, or contracts with, researchers are the typical vehicle for such an approach.

Of course, the success of decentralized models for government support depends on the quality of execution. Some critics believe that funding agencies have been too cautious, focusing on a limited number of low-risk projects and targeting funding to more-established scientists at the expense of researchers who are less established or less conventional in their approaches. Supporting multiple approaches to a given problem at the same time increases the chance of finding a solution; it also increases opportunities for cooperation or constructive competition.[17] The challenge to policymakers is to encourage experimentation and a greater diversity of approaches while simultaneously ensuring that an effective peer-review process is in place to guide funding toward high-quality science.[18]

However it is channeled, government support for innovation and R&D will be more effective if it is thought of as a long-run investment. Gestation lags from basic

[17] For early work in this area, see Nelson (1959, 1961).
[18] See Greenstein (2007), Huang and Murray (2010), and Freeman and van Reenen (2009).

research to commercial application to the ultimate economic benefits can be very long. The Internet revolution of the 1990s was based on scientific investments made in the 1970s and 1980s. And today's widespread commercialization of biotechnology was based, in part, on key research findings developed in the 1950s. Thus, governments that choose to provide support for R&D are likely to get better results if that support is stable, avoiding a pattern of feast or famine.[19]

Government support for R&D presumes sufficient national capacity to engage in effective research at the desired scale. That capacity, in turn, depends importantly on the supply of qualified scientists, engineers, and other technical workers. Although the system of higher education in the United States remains among the finest in the world, numerous concerns have been raised about this country's ability to ensure adequate supplies of highly skilled workers. For example, some observers have suggested that bottlenecks in the system limit the number of students receiving undergraduate degrees in science and engineering: Surveys of student intentions in the United States consistently show that the number of students who seek to major in science and engineering exceeds the number accommodated by a wide margin, and waitlists to enroll in technical courses have trended up relative to those in other fields, as has the time required to graduate with a science and engineering degree.[20] Moreover, although the relative wages of science and engineering graduates have increased significantly over the past few decades, the share of undergraduate degrees awarded in science and engineering has been roughly stable.[21] At the same time, critics of K-12 education in the United States have long argued that not enough is being done to encourage and support student interest in science

[19] See Freeman and van Reenen (2009).
[20] For a discussion of why these bottlenecks persist, see Romer (2000) and Noll (2003).
[21] See National Science Board (2010), tables 2-6 and 2-12.

and mathematics. Taken together, these trends suggest that more could be done to increase the number of U.S. students entering scientific and engineering professions.

At least when viewed from the perspective of a single nation, immigration is another path for increasing the supply of highly skilled scientists and researchers. The technological leadership of the United States was and continues to be built in substantial part on the contributions of foreign-born scientists and engineers, both permanent immigrants and those staying in the country only for a time. And, contrary to the notion that highly trained and talented immigrants displace native-born workers in the labor market, scientists and other highly trained professionals who come to the United States tend to enhance the productivity and employment opportunities of those already here, reflecting gains from interaction and cooperation and from the development of critical masses of researchers in technical areas. More generally, technological progress and innovation around the world would be enhanced by lowering national barriers to international scientific cooperation and collaboration.

Conclusion

In the abstract, economists have identified some persuasive justifications for government policies to promote R&D activities, especially those related to basic research. In practice, we know less than we would like about which policies work best. A reasonable strategy for now may be to continue to use a mix of policies to support R&D while taking pains to encourage diverse and even competing approaches by the scientists and engineers receiving support.

We should also keep in mind that funding R&D activity is only part of what the government can do to foster innovation. As I noted, ensuring a sufficient supply of individuals with science and engineering skills is important for promoting innovation, and this need raises questions about education policy as well as immigration policy. Other key policy issues include the definition and enforcement of intellectual property rights and the setting of technical standards. Finally, as someone who spends a lot of time monitoring the economy, let me put in a plug for more work on finding better ways to measure innovation, R&D activity, and intangible capital. We will be more likely to promote innovative activity if we are able to measure it more effectively and document its role in economic growth.

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