# Technological Change: Connecting Innovation to Performance –

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No matter how you look at it, coming to supportable conclusions about the impact of science and technology policy upon economic performance is remarkably difficult. For one thing, even coming to an agreement about what we mean by "technology policy" is far from straightforward. Does it include, for example, the regulatory activities of the Food and Drug Administration (FDA) or the Environmental Protection Agency (EPA)? There can be no doubt that the FDA's regulatory actions have a very powerful effect on the development of new technologies by pharmaceutical firms and medical device firms.

Similarly, many governmental activities exercise a powerful influence over the development and exploitation of new technologies, even though the primary purpose of those activities may have little or nothing to do explicitly with technology development. Technology policy may be primarily a matter of unintended consequences.

To make matters worse, economists are far from agreeing on the quantitative importance of technological change to American economic growth. Beginning in the mid-1950s there was a huge increase in interest in the subject and it would be fair to say that economists now set the contribution of technological change to economic growth higher than they once did. There has also been a growing awareness that the contribution can not be represented by some single abstract number because the impact of technological change on the economy is going to depend on what is going on simultaneously in other sectors of the economy – the rate of accumulation of tangible capital, the acquisition of skills on the part of the labor force, demographic changes, etc. In order to simplify and narrow my focus, I will confine my attention to federal R&D spending.

A budget is clearly a statement of policy. I'd like to make three observations concerning distinctive features of the post-World War II period that have been very important for their eventual economic impact.

First of all, the government became the dominant purchaser of R&D, but without at the same time becoming the primary performer. The unique institutional development has been the manner in which the federal government has accepted a vastly broadened financial responsibility for R&D without at the same time arranging for the in-house performance of R&D, with the exception of the federal labs.

Second, private industry has become the main performer of all R&D. And third, the university community has become the main performer of the basic research component of R&D, as Bush had advocated. In the post-war years, somewhere around two-thirds of basic research has been financed by the federal government but more than half of all basic research has been performed by universities. These observations help to clarify why it is easier to discuss the government's science policy than its technology policy. The government has emerged as the main source of financial support for science.

Technology, however, is a far different and much more complex matter, and yet technology, not science, directly affects the course of economic activity. And since technology is primarily incorporated in goods and services that eventually are sold in the marketplace, the ultimate responsibility for technology is in the hands of profit-maximizing firms in the private sector. So that, as I see it, technology policy presumably must refer to the actions of government that influence the decisions of firms as they consider the wisdom, or "unwisdom," of investing in new technologies.

In this sense, decisions to improve technology or purchase new technology are investment decisions. And investment decisions may be influenced by various activities of government, many of which are conducted with other criteria or goals in mind – such as regulation, taxation, and matters of national security. Or perhaps even more important, success or failure in the exploitation of new technology, in a certain sense the bottom line, goes far beyond the activities that are directly subject to government influence.

Success involves commercial skills; it involves and intimates understanding of the trade-offs between costs and performance, and the design of new technologies; and it involves the development of effective feedback mechanisms that permit quick adjustments and

adaptations in response to new information from the marketplace about consumer preferences.

In addition, America's leadership in the high-tech sectors in the post World War II years has been vastly assisted by the easy entry of new small firms that frequently have served as the early carriers of new technology. This role was facilitated by the venture capital industry, an almost uniquely American institution. The venture-capital industry has been vital to the early American lead in new industries of precisely the kind that have tended to be spawned by university research – electronics, biotechnology, medical devices, etc.

It should be added that creativeness of the interface between university research and industrial research has been one of the most decisive determinants of American success in the high-tech world. Having said that, I'd also suggest that in the post-war years, American society has become excessively absorbed with the up-stream forces shaping the course of technological change, to the neglect of downstream forces that are much closer to the marketplace.

By any measure, we have done remarkably well at the research activities that occasionally win Nobel Prizes, but we've been a great deal weaker, especially in recent years, at the skills that are nourished by continuous information feedback from the market, and that involve improvements in efficiency in the manufacturing process. One relevant piece of evidence on this score is that American high-tech firms report that they devote about two-thirds of their R&D expenditures to product innovation, and only one-third to process innovation, whereas their Japanese counterparts do exactly the opposite – two-thirds to process improvement, and one-third to product innovation.

So the federal government's post-war largesse and support of research may have had one entirely unintended consequence. This nation has developed a strong comparative advantage in the early research-intensive stages of the innovation process – the kinds of research activities at which universities excel. But at the same time, we have neglected the later stages of the innovation process that become more important as an innovation moves closer to the marketplace, where sustained attention to incremental improvement, rapid

response to information concerning consumer tastes, and the refining of process technologies come to determine commercial success. This neglect was reinforced during the first half of the post-war period by the sheer absence of credible competitors to American firms across a wide swath of high-tech product markets.

The painful structural adjustments that many American industries have been making in the past 15 or 20 years are part of the process of adjustment to a more competitive world economy after other industrial powers recovered from the devastation of the second World War and largely completed the process of technological catch-up with America.

This leaves us still with some fundamental unanswered questions. The widespread public impression is that we live in a world of unprecedentedly rapid technological change. If the purpose of science and technology policy is to accelerate technological change, it would appear to have been a spectacular success. We talk routinely about information superhighways, the internet, a remarkable assortment of new medical technologies, and Gordon Moore's law, which states that the memory capacity of a chip doubles every 18 months. Computers are everywhere.

At the same time, the rapid technological progress of the last 20 years also coincides closely with a rather abysmal slowing down of American productivity growth. The question that must be posed is: what's going on? In Robert Solow's succinct formulation, we see computers everywhere except in the productivity statistics, and that is really surprising.

If one wanted to be even more paradoxical, one could point out that the U.S. was the leader in productivity growth among industrial countries before the second World War, when she was far from the frontier, in most cases, of scientific leadership; and that she lost the leadership and productivity growth in the post-war years, at precisely the time that she came to a position of undisputed scientific leadership. One might add that America pre-World War II looks, in some rather striking respects, like Japan post-World War II. The similarity is precisely the lack of correspondence in both cases between scientific leadership and leadership in productivity growth.

I'm not going to unravel all of this, but I think I can make a couple of useful suggestions. Deeper insight can be gained by even a crude sectoral breakdown of the economy. Although the rate of growth of GNP per capita has indeed slowed down, not all sectors have been performing equally poorly. Indeed, our earlier investments in agriculture have paid off so handsomely that only about 3 percent of the labor force is now in that sector, and yet it still manages to produce far more food than the American public is prepared to consume. In 1940, federal R&D for agriculture substantially exceeded federal R&D for all sectors of our military establishment. That is worlds away in time.

Manufacturing productivity has also been growing at a very significant rate. There does not seem to be a complete awareness of this. That is precisely the issue at hand when we express concern over downsizing in the manufacturing sector. Downsizing is productivity growth – it is simply the flip side of the coin. The slowdown in the overall rate of growth seems to owe a great deal to the fact that the American economy has been transformed in the post-war years into a service economy.

Currently more than 40 percent of the American labor force is in services, and we may be understating that growth. Although it is certainly true that there are huge difficulties in measuring the productivity of service workers – how do you measure the productivity of doctors, college professors, policemen? – I think there is a deeper problem.

There appear to be enormous difficulties in turning our technological sophistication toward raising productivity in the service sectors. An important part of the problem is that it seems to be inherently difficult to raise productivity in the service sectors without at the same time bringing about unacceptable reductions in quality. Doctors can see far more patients per day – in other countries, they do. Elementary school teachers can teach much larger classes. But most people would not regard these measures as productivity-increasing.

The quality issue raises another subtle but crucial point. Along with our growing technological sophistication, there has been a collective increase in standards and expectations. Much of this increase takes the form of a higher trade-off, for example, between risk and safety – that is, a willingness to incur cost increases in order to reduce

certain risks. This seems to be the common denominator underlying an expanding swath of government regulations, including the National Environmental Policy Act, the Occupational Safety and Health Act, food and drug regulations of all kinds, the Toxic Substances Control Act, increasing safety controls over nuclear power, and so on.

The growth in expectations emerged with particular force in health-reform discussions. Achieving agreement on some basic package that would be available to all proved to be impossible because such packages necessarily involved excluding significant segments of the population from access to highly expensive technologies that are now part of the medical armamentarium.

Massive federal investments in medical research have yielded massive improvements in medical technology. But unlike investments in agricultural research earlier in the century, they have proven to be cost-increasing rather than cost-reducing. It would be easy to reduce medical costs if we were satisfied to take what is sometimes called the Sears Roebuck catalog approach.

Suppose we go back to 1960. If everyone today would be satisfied to receive only the services that were available in 1960, we could achieve a considerable reduction in medical-care costs. But I suspect that there are few people who would want to go back to a period where there was no kidney dialysis, no bypass surgery, no angioplasty, no hip replacements, no laparoscopic surgery.

I trust that it is clear that I am not advocating a sweeping away of CAT scanners and magnetic-resonance imaging devices. I'm not advocating 1960, I'm simply observing that a rapid advance in the endless frontier of which Bush spoke 50 years ago has brought with it an escalation of standards and expectations that he probably did not anticipate.