8 Science and the Economy

William B. Bonvillian

For 60 years the story of science largely has been the story of the relationship between science and national defense. Science began coming into its own at the middle of the 19th century. Initially science thought it could stand alone as a separate and higher discipline in society, almost a separate religion, with an identity all its own. While science was grappling with this separatist ideology, the dominant story of the 20th century was the shift in conflict from nation state against nation state to conflict between competing supranational ideologies. Science, for all its earnest hopes at the outset of the century to remain aloof and above the fray, was instead swept into it, becoming a critical tool in supranational conflict. Now that kind of conflict, too, has been swept away. We are now confronting the problem of identifying the next great underlying force science will attach itself to for nurture and support. The answer, I think, is obvious—the economy.

The 19th century romantic view of science would have it return to aloofness, to its own separate, religious base. This is unrealistic. Science and society are in a symbiotic relationship, feeding on each other. We might think it nice if science could return to the ideal of the isolated medieval university (which in turn descended from the isolated monastery). But just as the academy is increasingly a center of the economy's well being, science will also be attached to the great forces that affect the well being of society. Indeed, it is part of those forces.

William B. Bonvillian is legislative director for Senator Joseph Lieberman (D-CT). This article is based on remarks delivered at the 25th Anniversary AAAS Colloquium on Science and Technology Policy, held April 11–13, 2000, in Washington, DC.

The New Direction of the Economy Means a New Direction for Science

If science is going to be ever more intimately attached to the economy, we need to examine the forces that are moving the economy. Our whole economic policy agenda is shifting. We see a move from current productivity dominating economic analysis to innovation now dominating economic policy.

If innovation drives business organization, then science, the innovation force, will have to be more closely integrated with business for the well being of both. "Science trickle-down," the theory at the heart of Vannevar Bush's 1940s pipeline model of separate, disconnected steps of innovation, will increasingly be replaced by "connected science," where science is integrated into an innovation continuum.

R&D Investment Levels by Government and Industry

If innovation is king of the economy, research and development (R&D) investment levels become critical. Overall R&D investment levels look excellent. The National Science Foundation (NSF) tells us that:

> As a percent of Gross Domestic Product (GDP), R&D last year was at 2.8 percent (up from 2.67 percent in 1998), the highest level since that great heyday, the mid-1960s (when we had a hot war, a cold war, and a space race to sponsor R&D).[1]

NSF data also tell us that business has been stepping up to the R&D plate:

> U.S. R&D expenditures have steadily increased. Between 1995 and 1999, the average yearly growth rate was 6.1 percent, about triple the inflation rate. For 1999, the R&D growth number looks like eight percent. The growth in our R&D rate is due to the private sector. Business is now outspending government on R&D by more than two-to-one. This is an historic reversal of roles. In the 1960s and 1970s the federal government completely dominated R&D, outspending the private sector two-to-one.[2]

Fixing the Problems of the 1970s and 1980s

These numbers show us something about the private-sector role in science. First, they show us that the business role in R&D is growing by leaps and bounds. This underscores my point about science being allied to the economy in the next half century.

Second, they suggest that business is pursuing the problem we had in the 1970s and 1980s. That was a period of the lowest economic growth in U.S. history. Growth was locked in the two percent range and productivity gains were alarmingly dismal. This meant a constant risk of inflation every time growth inched up, which in turn forced caps on growth through interest rates that set the cost of capital. Literature from that era speaks about our failure to capitalize on our research base and create new products.

We saw a disconnect known as the "Valley of Death" between research and development in the economic sector in the 1970s–80s. There was a great connection between research and development in the defense sector, because so much of science, especially physical science, was funded by defense. (This intimate connection between research and defense was exposed to the world in the lightning campaign of Desert Storm in Kuwait and Iraq, for example.) The federal investment level in research was high through the 1970s as measured by percent of GDP. But the connection in the private sector between research and development was a serious problem. Put another way, we had R and D (Research and Defense) but not R and E (Research and the Economy).

The accelerating business investment in R&D in recent years is an attempt to tackle this problem. If one of the New Economy realities, as I mentioned above, is that innovation rules, R&D is crucial. Business, with major new R&D investment, may be tackling the connection between R and D, a most critical economic connection. The booming economy seems proof. We may never have had in our history the productivity growth we had during the first quarter of 2000: over six percent. Treasury Secretary Lawrence Summers suggested we focus on this level of six percent.[3] Economists in 1992 would have suggested this might be either the inflation level or the unemployment level, but they never would have suggested that six percent would be the sum of the inflation and unemployment rates. And 1992 economists could not conceive that six percent would be the productivity growth level.

But in the New Economy you have to get behind the macro numbers and get to the micro. The gross label "R&D" doesn't cover what business really does. Business does not do R, it does D. Because it was not doing D in the 1970s and 1980s, it was not able to move on the federal government's investment in R, so we had limited innovation and stunted growth. Now business appears to have woken up. It's spending on D in a way it never has before.

This spending is largely limited to three areas: computing, the Internet, and bio-pharmaceuticals. Our economy is working its way through these three interrelated technology revolutions. Each is at least as powerful to the economy as past technology shifts(for example, railroads, electricity, radio, and aircraft.) The current pattern appears to be that science contributes a breakthrough technology or batch of technologies and then the economy, over time, piles application after application on top of each. It is the accelerated pace of innovation and its acceptance that seems to be the most important characteristic of what economists are calling the New Economy.[4] (Perhaps it should really be called the Innovation Economy.) Accelerated R&D patterns are not the only innovation components of this economy. Venture capital and entrepreneurship are other elements in the emerging innovation system. But R&D is the crucial initial phase.

The gross private-sector numbers on investment in development indicate that we're making progress on the problems of the 1970s and 1980s. We can use the analogy of a seesaw. From the 1960s until the 1980s, the level of the federal investment on research was on the high end of the seesaw, but the level of the private-sector investment on development was on the low end. There was an imbalance and, in the emerging innovation economy with a focus on R&D, low development meant economic trouble. But change was on the way.

The R&D Seesaw Goes the Other Way

Amid the current economic euphoria, I am concerned that while we may have partly fixed one part of the seesaw (the D side), the seesaw is now tilting in the other direction. We're working on the D, but now we've got a problem with the R.

Total federal R&D (which means predominantly R, because the federal government funds the earlier stages of this equation) went down significantly in the mid-1980s through the mid-1990s.[5] This was in large part due to the post-Cold War decline in defense R&D.[6] This year, for a change, the prospects look somewhat better. The Administration, spurred in part by the Senate-passed R&D doubling bill (S.296), has submitted a budget with significant science increases. Although the Congressional Budget Resolution cuts that back significantly, there are reasonable prospects for the final numbers.[7]

We need to look at two trends. First, I believe that the real number to look at is the federal research share of GDP. This number shows in a way clearer than the annual numbers what the real investment level is, what the ongoing commitment to science is in the national economy. That number trend is continuing to stagnate or decline, and is far lower than it was in the 1960s or 1970s. While federal research was 1.8 percent of GDP in the mid-1960s, it is now 0.8 percent, despite the Innovation Economy's need for higher investment levels.[8]

Second, looking behind the appropriations totals for FY 2000, we see an imbalance within the federal research portfolio.[9] The life sciences have made their case for federal support and have assembled a very effective lobbying effort, which includes companies, medical schools, and grassroots patient groups. They are getting strong increases: 14 percent in FY 2000 and a comparable number anticipated this year. These increases are masking the cuts in the physical sciences, which largely result from declining defense research. Physics has had a 20 percent cut, electrical engineering a 30 percent cut, chemistry a ten percent cut, and mathematics a 20 percent cut, measured from 1993 to 1997.[10] Even President Clinton has decried this physical-life science imbalance.[11] The physical sciences have mounted no advocacy effort comparable with that of the life sciences.

So the seesaw is going out of balance in the other direction from the 1970s and 1980s: D is up and R, in the physical sciences, is down. This R imbalance is a problem science is going to have to address. A white paper from the Semiconductor Industry Association summarizes the seesaw problem well:

> A critical component of the foundation for the U.S. technology-based economy is our knowledge of the physical sciences and engineering. Our ability to produce the incredible advances of the 20th century, such as the transistor, the laser, the microchip, etc., rest on our understanding of the basic sciences of the material world. Basic research is primarily funded by the federal government. Therefore, as federal investment in the physical sciences and

> engineering declines, the future foundation for these disciplines is being weakened. What are the consequences of uneven funding? The attraction of these fields for university researchers declines, new discoveries in the more neglected fields shrink, and graduate students drift to other fields and departments.[12]

Industry Support for R *and* D in the Life and Physical Sciences

There is a fundamental difference between defense support for science (the story of the last 60 years) and private-sector support for science. The defense sector supported both Research *and* Development. Although I believe that the future ally of science will be the economy, only in the life sciences/bio-pharmaceutical areas does industry significantly support R as well as D. Support is not there yet for physical science research.

The life sciences provide an interesting model for the physical sciences. First, industry and academia are much more closely integrated in the life sciences than in the physical sciences. While academic medical research even a decade ago treated drug companies like "Upstairs/Downstairs," that attitude is gone. The biotech firms brought academics into business, and dual careers with frequent movement between business and the academy are now common. This integration has helped the life sciences obtain major increases in federal research support, as well as growing industry support.

Second, in the life sciences, capital has been available for research. Even though the U.S. venture capital industry historically refuses to finance research, and will fund development only if it is no more than three years from product manufacturing, biotech broke that rule and obtained financing for a wide range of research projects that were 10-to-15 years away from manufacturing. The race between public- and private-sector researchers over resolution of the human genome suggests how the line between fundamental and applied R&D is being erased in the life sciences. Part of that is accounted for by the power of intellectual property protection in the life sciences. A patent that ensures 17 years of monopoly rents, coupled with a certification from the Food and Drug Administration that ensures immediate market acceptance, can be compelling in commanding long-term capital. Perhaps because problems in the physical sciences have a wider variety of solutions, monopoly rents have been less accessible and patents have not been as powerful there yet.

So the "Valley of Death" between R and D remains very real in the physical sciences, even as it is being bridged in the life sciences. This means that the physical sciences will have to ride two horses. For research support they will continue to depend on government support; to tie to development, they will have to integrate more effectively with industry. These are the two major tasks confronting the physical sciences:

- rebuilding federal research support, including in the defense sector, and

- building new bridges to industry development support.

There will be no *deus ex machina* here to rescue physical science. No new force is likely to descend to fix the research imbalance. Physical science is going to have to make its own case, just as life science is now effectively making its case to the public and Congress.

Accommodation Between Business and Science

Let's suppose that physical science begins to catch up with life science and rebuilds federal support, and then it begins to create "connected science" with industry. The accommodation with industry, as recent experiences in the life sciences suggest, will not be easy.

As dependent on innovation as business is becoming, there is still a Tower of Babel language problem with science. While business speaks a language of trade secrets, science depends on open knowledge; while business seeks competitive advantage, science has a tradition of open inquiry. A recent polemic in *Atlantic Monthly* titled "The Kept University" (see chapter 26) illustrates the problem.[13]

We should remember that the accommodation between defense and science has always been uneasy, however profound the alliance was for science. Illustrative of this is J. Robert Oppenheimer's reaction to the initial atomic bomb explosions, that ". . . the physicists have known sin."

Science needs to be realistic, however. The isolated academy is simply not a likely prospect for this century. Science needs to go into its growing relationship with the economy with its eyes open, and develop rules and guidelines for research with industry. Many research universities are already working some of these issues out, and the life sciences, where integration with the private sector is already deep, will provide the initial tests. The science societies need to monitor these experiments and circulate results and models.

In a recent article, Professors Robert Rycroft of the George Washington University, and Donald Kash of George Mason University suggest there may be a positive ending to this story.[14] They argue that technologically complex products will increasingly dominate the world economy, which will require complex innovation. Innovation cannot be dominated by single firms in closed systems any more. Instead, groups of firms will have to collaborate across industries, as well as with research institutions. The speed of innovation will require self-assembled networks of researchers in industry and academia, across numerous fields, interacting, assembling, and reassembling. In other words, even as global competition in market economies increases, business will have to evolve a model of collaborative research that is inherently open. We already see the growth of such cooperation. It bodes well for a relationship between science and the economy if open inquiry also becomes an economic imperative.

Endnotes

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