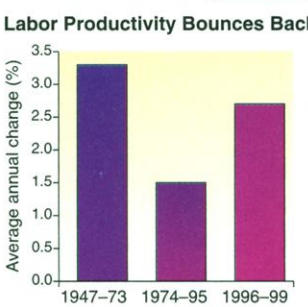
From the president on down, many are hailing science as the fuel for today's booming economy, and bigger research budgets are seen as essential to continued prosperity. But how strong is the evidence?

Does Science Drive The Productivity Train?

When President Bill Clinton unveiled a plan early this year to take the first step toward doubling the National Science Foundation's (NSF's) budget, his pitch rested on the promise of prosperity. Spending more on everything from biology to nanotechnology, he argued in a January speech, would help extend an unprecedented U.S. economic boom—a boom that was fueled by discoveries made decades ago in government-funded labs. In particular, Clinton spotlighted the economic contributions of taxpayer-funded information technologies (IT), such as supercomputers and the Internet, which he said are now "responsible for about 30% of our economic growth."

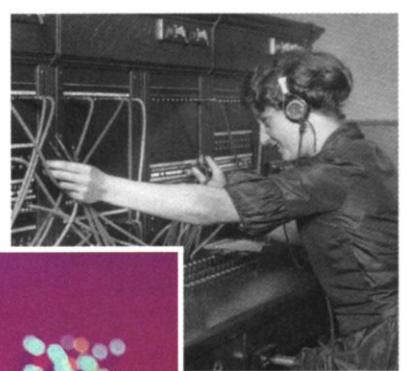
The statistic thrilled science supporters in the friendly crowd at the California Institute of Technology in Pasadena. For years, everyone from university presidents to science society lobbyists has been arguing that more government spending on a broad range of research could produce economic miracles. But the hard numbers needed to convince lawmakers proved scarce.

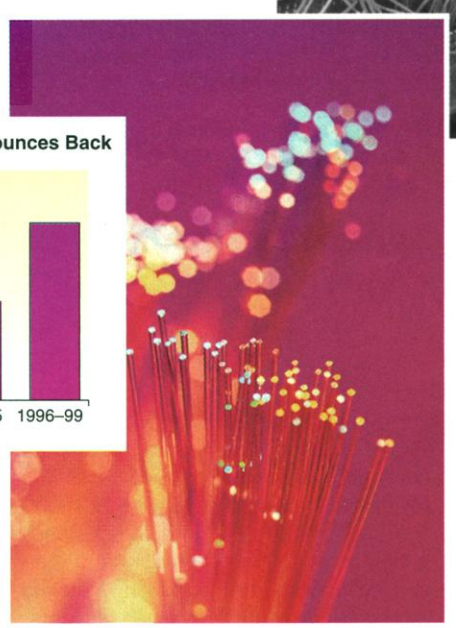
Now science advocates are awash in attention-grabbing statistics. This month, for instance, the Labor Department reported that productivity—worker output per hour—grew at 5.3% in the year prior to June, a 17-year high. And several recent studies conclude that up to 80% of the productivity jump is due to the "IT revolution." Even Alan Greenspan, the powerful head of the U.S. banking system, says past science investments that led to computers are paying off. "The U.S. is confronting what can best be described as another industrial revolution," he has told audiences.



Prominent science advocates—including NSF chief Rita Colwell and Democratic vice presidential nominee Joe Lieberman—have seized upon such statements to advance their agendas. And science lobbyists are holding up the computing-inspired economic boom as an example of how government investments in other areas, such as biology, could yield similar gold (see sidebar). But some economists are challenging the credibility of the statistics. One prominent skeptic, economist Robert Gordon of Northwestern University in Evanston, Illinois, says the IT revolution is overrated—a minor uprising compared to the truly society-shaking innovations of the past, such as electricity. Other economists are leery of efforts to isolate the exact percentage of economic growth that can be credited to new technologies, saying the data and models are weak.

Even some science lobbyists worry that hitching basic research's star too closely to economic arguments could backfire, prompting legislators to take a firmer hand in guiding cash toward less risky projects that they believe will pay off big. "For years, we've been saying that science is important to the economy, but everybody took it with a grain of salt," says Al Teich, head of the public policy program at the American Association for the Advancement of Science (AAAS, publisher of *Science*) in Washington, D.C. "Now people are starting to believe us, and it's a little scary."





New economy? Some economists say that new inventions, such as fiber optics *(above)*, are causing productivity to surge (graph) at rates unseen since the era of the telephone switchboard *(top)*.

Pins and productivity

The current debate over the economic impact of science and technology isn't new. In the late 1700s, economics pioneer Adam Smith observed in his seminal treatise, *The Wealth of Nations*, that new inventions had helped English pin factory workers produce nearly 5000 pins per day, many times what could be done by hand. Today, according to economists, that total has risen to 800,000 pins per day. But economists disagree over how much of such productivity gains should be credited to new technologies and how much to other factors, such as better trained workers.

The most influential answer came in 1957, when economist Robert Solow of the Massachusetts Institute of Technology published a formula for breaking down the causes of productivity gains into several categories. They included various forms of capital investment and a so-called "residual," which he dubbed "technical change." The paper, which helped Solow win a Nobel Prize in 1987, "was a shot heard 'round the world. It transformed the study of technical change into something more than an obscure sideshow," says economist Frederic M. Scherer of Harvard University. It also began an arms race of predictions. A new generation of growth accountants, for instance, used Solow's equations to estimate that up to half of all past economic growth could be attributed to the introduction of new technologies, from electricity and the internal combustion engine in the late 19th century to radio and modern chem-

CREDITS: (LEFT TO RIGHT) BUREAU OF LABOR STATISTICS; DIGITALVISION LTD.; MINNESOTA HISTORICAL SOCIETY/CORBIS

'To Your Health' Is More Than A Toast to Economists

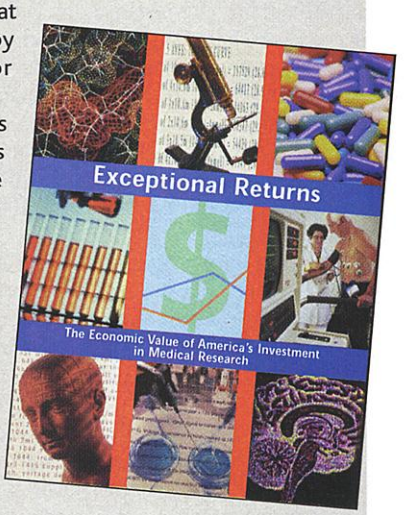
The debate over the role of innovation in the country's current economic boom has focused mainly on information technology (IT), a fast-growing and seemingly ubiquitous part of today's society. But there's another pervasive activity that's become a battleground for economists and policy analysts: biomedical research. Here, even the terms of measurement are debated. Whereas growth accountants use standard monetary measures of return on investment to estimate IT's impact on productivity, those who study the country's $45 billion annual investment in biomedicine tend to talk instead about "the social rate of return." In health, they argue, the coin of the realm is having a longer, more comfortable life.

Two reports released last May conclude that this return is huge—in some cases, more than $20 for every dollar invested. One even claims that "medical research surpasses every other source of rising living standards in our time." But some economists question the usefulness of such studies. The dozens of rate-of-return studies completed over the last 40 years have "questionable validity," says economist Steven Payson, an academic currently working at the National Science Foundation. Not only have the results varied wildly, he says, but none provides data on what policy-makers really want to know: Will extra spending produce substantially greater results? "The question is whether the second billion buys you as much as the first one did," says Payson.

One of the new studies—*Exceptional Returns*, from Funding First, an initiative of the Mary Woodard Lasker Charitable Trust in New York City (laskerfoundation.org)—concedes that translating biomedical research benefits into dollars and cents is "difficult." But in a series of papers, the nine authors, all economists, make the case that the healthier, longer lives made possible by modern medical treatments are worth trillions of dollars to the economy. Kevin Murphy and Robert Topel of the University of Chicago, for instance, estimate that the few extra years of life the average American gained between 1970 and 1990 added $57 trillion to U.S. coffers. By their reckoning, extending life during prime working years (ages 35 to 44) was worth up to $171,000 per year for a man and $120,000 for a woman.

There's a problem with these raw numbers, however: They may also reflect benefits from such low-tech factors as better nutrition, more exercise, or safer workplaces. In an attempt to isolate the contribution of biomedical research, David Cutler of Harvard University and Srikanth Kadiyala of the National Bureau of Economic Research in Washington, D.C., looked at one major area—efforts to reduce premature deaths from heart disease. They concluded that about one-third of the fall in mortality rates over 40 years, from 400 to 200 per 100,000, could be credited to new technologies and drugs. The new technologies, such as ventilators that help victims survive the critical first few hours after a heart attack or stroke, accounted for at least 20% of the reduction, they argue. Another 13% of the drop was linked to new drugs that reduce the risk of problems by lowering blood pressure or cholesterol.

Using Murphy and Topel's numbers, the report concludes that better treatments were worth about $500 billion per year between 1970 and 1990—a figure that is about 20 times greater than the country's annual spending on medical research during that period. "By any benchmark," the report concludes, it was "an astonishing return for the investment."



Making the case. New reports, including this one, argue that biomedical research produces big payoffs.

The other report, issued by the Senate's Joint Economic Committee (www.senate.gov/~jec), cites similar gains in arguing for a bigger National Institutes of Health budget. In general, it notes, taxpayer-funded research "generates high rates of return to the economy, averaging 25% to 40% a year."

These high average numbers mask the fact that individual estimates vary wildly from one area of science to another, Payson notes in his recent book, *Economics, Science and Technology*. "When one study comes up with a 0% return, and the other with a 100% return, it is surely unscientific to conclude that the return is somewhere around 50%," he says. That variability also poses a problem for legislators trying to decide which areas should receive scarce federal dollars. Given those limitations, as Payson writes, claims of a 20-fold payoff for research investments deserve "greater scrutiny." **–D.M.**

CREDIT: FUNDING FIRST

istry in the early 20th.

In the 1980s, however, growth accountants grew perplexed when they tried to measure the impact that computers were having on productivity: It wasn't there. In a famous 1987 quip, Solow characterized the puzzle—which came to be known as Solow's Paradox—this way: "The computer age is everywhere, except in the productivity statistics."

That changed in 1996, however, when U.S. productivity in nonfarm businesses shot up by a percentage point, to more than 2.5% per year, a huge increase (see chart). Among those who tried to explain the boom were Stephen Oliner and Daniel Sichel of the Federal Reserve Board in Washington, D.C., which steers U.S. monetary policy. In a 1994 study, the pair had used government labor data to argue that Solow's paradox was no paradox at all. "There was no puzzle, just unrealistic explanations," they recall in a recent paper (federalreserve.gov/pubs/feds). Computers did not contribute much to growth in the early 1990s, they say, because they were still a relatively small part of the machinery purchased by U.S. businesses. By 1995, however, computers and related communications equipment had reached critical mass, "boosting their contribution to growth." Overall, Oliner and Sichel attribute about two-thirds of the one-point increase in annual productivity growth over the past 5 years to the manufacture and use of new IT equipment. "Information technology largely is the story," they conclude.

Their interpretation has attracted both supporters and detractors. "It's a very serious effort," says Solow. And Roger Ferguson, vice chair of the Federal Reserve Board, has cited this study as "evidence that fundamental changes are under way in our economy."

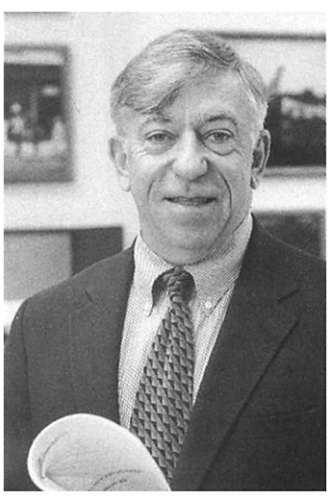
But even those economists who agree that computers are boosting productivity quibble over how much. Karl Whelan, another Fed economist, attributes nearly 80% of recent productivity gains to computerization. But Dale Jorgenson of Harvard and Kevin Stiroh of the Brookings Institution, a think tank in Washington, D.C., are stingier. In a forthcoming article in *Brookings Papers on Economic Growth*, they give

computers credit for just about half of the productivity increase since 1995.

Not-so-new economy

Others, however, doubt that computers are having such major impacts and attribute the productivity rise to other factors, from the ordinary dip and fall of the business cycle to changes in the way the government collects labor statistics. In a discussion paper published last July, for instance, the Federal Reserve Board's Richard Kiley concluded that companies are still having trouble integrating new computers into their businesses. These "adjustment costs" have pulled productivity down by about a quarter-point a year since 1995, he figures, and the trend won't reverse until firms fully digest the new technology.

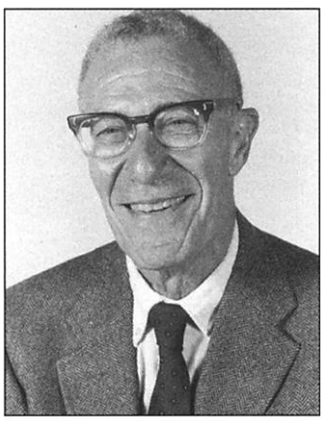
Perhaps the strongest attack comes from Northwestern's Gordon. In a widely cited critique (faculty-web.at.northwestern.edu/economics/gordon) soon to appear in the *Journal of Economic Perspectives*, Gordon assails the claims that computers and the Internet represent an industrial revolution equal to that which produced the "golden age" of 1913 to 1972, when U.S. productivity rose at more than 3% per year. In particular, Gordon argues that computer-driven productivity gains—while significant—are confined to a handful of industries, such as computer manufacture and telecommunications, that constitute just 12% of the nonfarm economy. "There is no revival of productivity growth in the 88% of the private economy lying outside" those industries, he writes. Economists have mistaken a short-term uptick in the business cycle for a longer term rise in productivity, he asserts.



Skeptic. Northwestern's Robert Gordon says computers haven't yet revolutionized the U.S. economy.

Solow, for one, says that Gordon's idea that the business cycle is inflating computing's contribution to productivity is "worth thinking about. Making corrections for [the cycle] is very difficult."

The debate is unlikely to be settled anytime soon. "The game of growth accounting is very much like trying to explain how much of a cake's good taste is due to the sugar and how much to the cream," says Richard Nelson, an economist at Columbia University in New York City. "There are enormous measurement problems" that muddle growth analyses, adds Steven Payson, an economist with the NSF and author of *Economics, Science and Technology* (Elgar Publishing, 2000). Government statistics, for instance, often misclassify spending or obscure a company's real operations. And mathematical models typically lag behind what's happening in the real world.



Productive. MIT's Robert Solow figured out a way to account for technology.

To aid policy debates, "economists can, and should, do much better," Payson says. For one, he'd like to see them use measures that more accurately reflect a new technology's capabilities. Computers, for instance, could be measured in terms of calculations per second. In the meantime, Payson says, "people need to be very cautious about how they use" the productivity statistics in making the case for greater R&D investments.

Political economics

But science advocates aren't waiting for any fine-tuning. Lobbyists from virtually every discipline—from physics to biomedicine—argue that, given the potential rewards of boosting public investment in fundamental research, their field is vastly underfunded. "We even cite the statistics to support our call for greater investment in science education," says David Schutt, a lead lobbyist for the American Chemical Society in Washington, D.C. "Are they our whole story? Certainly not. But it doesn't hurt" in making the pitch for improving education.

Greenspan's vocal recognition of technology's role in the boom has also lent credibility to the science community's economic case, says Kathleen Kingscott, a science policy specialist in IBM's Washington office. "What he is saying has changed the debate," she says. "It's no longer: 'Should government invest in science?,' but 'How much can we do?' " The changing mood has also pushed leading politicians from both parties—not just Lieberman but also Senate Majority Leader Trent Lott (R–MS)—to highlight science's economic impact in their policy statements. Under Lieberman's leadership, for instance, the centrist New Democrats last month released a legislative blueprint that calls for major spending increases for basic research. "Science and technology form the core of a new economic policy paradigm," says Rob Atkinson of the Progressive Policy Institute in Washington, D.C., which organized the exercise. Still, Atkinson thinks it may be a while before lawmakers from other camps sign on. "We have a long, uphill fight to make it clear that science policy *is* economic policy," he says.

Although most economists might not go that far, there is a broad consensus among them that more R&D investment wouldn't hurt—even if the numbers are debatable. But that general agreement doesn't necessary help lawmakers, who still face tough decisions, says AAAS's Teich. "Policymakers are presented with the same dilemmas as before," he says. "Productivity statistics don't tell you the right amount to put into different areas of research." The result, he worries, is that science funding "could become even more political," as lawmakers vie to steer dollars into their districts. Solow sums up the problem another way: "There is no way that anybody can tell you what an extra billion dollars added to NSF's budget will get you in terms of productivity."

Still, science lobbyists are hoping that economic arguments will pay off in hard cash, starting next month when Congress returns to finish work on the 2001 budget. And they are counting on the economic boom—which is expected to produce record budget surpluses—to tilt the negotiating table in their favor.

But it's not clear if they'll be able to use the boom to their advantage in the future. Solow, for instance, "is not prepared to bet any part of the farm" that the economic surge will continue. And some science lobbyists don't relish the prospect of trying to argue that science is good for the economy during a downturn. That, says Schutt, "is an experiment I don't want to run."

—DAVID MALAKOFF

COMPUTING'S ROLE IN PRODUCTIVITY GAINS

Author	Year	% annual growth
Whelan	1996–98	+0.82
Oliner and Sichel	1996–99	+0.63
Jorgenson and Stiroh	1996–99	+0.49
Gordon	1995–99	Negligible
Kiley	1985–98	–0.27

Pick a number. Economists differ over information technology's impact on overall productivity.

CREDITS: (LEFT TO RIGHT) JIM ZIV PHOTOGRAPHY; D. COVENEY/MIT