PART 2

R&D and Global Technological Innovation

This section offers several perspectives on the effects that globalization and technological innovation have had on R&D budgets. By 1999, the global economy had broken through a period of malaise, due in large part to the sustained strength of the United States' economy. Credit for this growth has been given to the expansion of the service industry and the extraordinary innovations of the computing and high-technology sectors. The rapid growth, coupled with forecasts of long-term budget surpluses, has provided policymakers with the freedom to increase R&D spending and promote new initiatives in science and technology.

In Chapter 2, Barry Bosworth, senior fellow at the Brookings Institute, discusses the sources of the economic expansion. He credits the expansion to a recovery in the level of U.S. business investment and an increasing rate of consumption. This level of consumption is fed by global investment, in part because the "U.S. is the cheapest place in the world to buy anything." Bosworth finds that this vigorous growth has led to long-term forecasts of budget surpluses in the U.S., which is influencing budgets on the local, state and federal levels, and affecting available funding for private-sector R&D. He concludes with a warning that not everything is as rosy as it appears. The expansion is unfortunately not benefiting all sectors of society, and income disparities still remain. "There is a surplus of people with limited education, and there is a shortage of people with high levels of education" at a time when education is becoming a greater factor in determining the distribution of wealth in our society.

Neal Lane outlines the Clinton Administration's FY 2000 budget for R&D in Chapter 3, and highlights specific ways in which increases in the budget for R&D will impact the path that the science and technology community follows in the new century. These proposals include increases in funding for the 21st Century Research Fund and increasing R&D funding for all agencies. Lane also outlines Vice President Gore's "New Compact" between the scientific community and government. The Vice President's Compact proposes the creation of the Information Technology for the 21st Century (IT2) initiative, which would promote research into advanced information technology (IT), and address societal problems arising from the increased prevalence of IT. The Compact would additionally "address the needs of the science and technology workforce of the 21st century," and also provide guidance on issues raised by biomedical research.

Robert Shapiro, under secretary for economic affairs at the U.S Department of Commerce, focuses on the relationships between technology, trade, and the global economy in Chapter 4. He lists global unevenness in growth, and worldwide "disinflation," as key factors that influence a government's policy regarding the interactions between technology and economic growth. American businesses are becoming increasingly focused on information technologies, which he says, "have accounted for more than one-third of U.S. growth over the last five years." According to Shapiro, "Technological advances affect trade as well as growth." In a global system, borders are permeable, and technological advantages will eventually minimize a country's comparative advantage. Additionally, he finds that technological innovation has influenced R&D budgets globally, with all of the major industrial countries sharing comparable ratios of R&D to gross domestic product.

In Chapter 5, Donald Dalton and Manuel Serapio, Jr., provide another view from the U.S. Department of Commerce. In an excerpt from their Commerce Department study, they show the "magnitude, nature, and scope" of R&D spending by foreign-owned companies in the United States. They provide their key findings concerning foreign investment in the United States, and in U.S. R&D investments abroad. They find that foreign R&D in the U.S. had tripled in a single decade to $19.7 billion in 1997. Their report also states that although industrial R&D has become increasingly globalized, the U.S. "retains a clear technological advantage in most sectors."

The section concludes with Chapter 6, which Kenneth Flamm of the Lyndon B. Johnson School of Public Affairs at the University of Texas begins with the following question: "Are new rules for high-technology trade needed?" In attempting to answer this question, Flamm looks to the current rules regarding trade as defined by the General Agreement on Tariffs and Trade (GATT). He finds that GATT has fallen short in the areas of antitrust, antidumping, and intellectual property, primarily because the agreement pre-dates the birth of the modern high-tech economy. A new system of international rules is needed, and he suggests that governments look first towards redefining the rules for subsidies and the roles of governments in strategic trade policy and R&D funding. He concludes by conceding that there is no clear solution, and suggests that an answer may be "to negotiate reciprocal access to national technology programs."

2 Outlook for the National Economy

Barry Bosworth

I want to discuss the background of our current economic situation because it has an enormous influence on the federal budget, on state and local government budgets, and on the private sector in terms of the funding that is available for research and development. One of the biggest lessons we are learning about our economy is that we presently operate in a global system rather than a national system. To understand what is happening in this country and the role it plays, we have to look at the United States within a global context.

We are in the midst of an extraordinarily strong economic recovery here in the United States, which has been going on for about a decade. I think it is almost insured that this will be the longest economic expansion that the United States has in its recorded history. It is a period of very strong growth driven primarily on the demand side.

There are two reasons that the U.S. economy is so strong. First of all, business investment has recovered from the startlingly low levels of the early 1990s, when it had collapsed in the recession of 1990 and 1991. In 1990, private investment in the United States was down to just a couple percent of GDP. Since that time there has been a steady, eight-year recovery—we are nearly back to some of the historical peaks. Much of the present expansion of the U.S. economy has been investment-led.

The second—and probably even more dramatic—aspect of the U.S. economy is that we are in the midst of another consumption binge. This country has an incredible desire to consume. In fact, the private savings rate in the United States collapsed during the 1990s. It has not, however, hurt anything for purposes of American investing. You might ask how investment can increase while savings—which you would think

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Barry Bosworth is a senior fellow in the Economic Studies Program at the Brookings Institution. *This article is based on remarks delivered at the 24th Annual AAAS Colloquium on Science and Technology Policy, held April 14–16, 1999, in Washington, DC.*

would be needed to finance investment—decrease. The answer is that there is another part of the story. The United States finances our investment by borrowing abroad, and we run a very large current account deficit with the rest of the world. At present, the United States is the major market for much of the global economy: it has been the primary engine of growth. Region after region in the 1990s has faltered seriously in growth prospects—most recently Asia—but the U.S. market continues to expand.

What keeps all of those economies going right now? It is the willingness of American consumers to go out and spend money. American spending gives these countries opportunities to sell goods here in the United States—and to our credit, we keep our borders open, despite complaints from some other countries about United States trade restrictions.

The U.S. is the cheapest place in the world to buy anything. We have the lowest barriers against imported goods and trade of any country in the world, which is reflected in the fact that prices are so low. Many Japanese goods are cheaper in the United States than they are in Japan, and the same is true for European products—because we have an extraordinarily open economy in the midst of a very strong economic boom and a willingness to let the rest of the world participate in that.

We benefit from that participation because we could not afford our consumption binge if we had to produce it all ourselves. The United States is basically at full employment; everybody is working. We do not have the capacity to produce all the goods and services that we are consuming at the present time, so the fact that there happens to be excess capacity in the rest of the world has been good for us.

There are a variety of reasons that demand is so strong here in the United States. Normally I would dismiss one that is frequently cited—the stock market. Historically, the stock market has gone up and down, and nothing happens to the economy. The stock market is just not that important—most people who invest in the stock market expect it to fluctuate, and fluctuations in stock market prices are discounted in terms of what it does to their wealth and what it does to their consumption.

I think that is still true. The impact of changes in stock market wealth on consumption is about half that of other types of wealth changes. But this stock market binge has been so huge that it has created enormous amounts of paper wealth—and many Americans are beginning to spend that wealth. That behavior can explain that the household savings rate in the United States is now zero, meaning that the average American household consumes everything earned in the form of money.

How could one possibly do that? It is financed by wealth—capital gains from the sale of stock wealth. There has not been a particularly large increase in debt in this expansion—we do not see people borrowing incredibly large amounts of money. But every time the interest rates go down, people rush out to refinance their mortgages. There is also an emerging tradition among Americans: When you refinance the mortgage, take out another ten percent and use it to pay off your credit cards so you can start over again. That has been important as interest rates and inflation have declined.

But the real key to a sustained expansion of the U.S. has been a continued low rate of inflation. We no longer have a regularity of business cycles in the United States, mainly because the production of goods is just not that important any more. The old durable good or inventory cycles are largely gone. We now have a primarily service-producing economy.

Instead, business cycles are largely a reflection of changes in government policy, which typically result from changes in inflation. The reason this expansion has been so long and drawn out is that despite an incredible decline in unemployment here in the United States, there has been absolutely no evidence of inflation. That is a major surprise to U.S. economists studying inflation behavior. We thought that a tightening of labor markets would give rise to pressures for nominal wage increases.

Unemployment is now down to 4.5 percent, where we once thought the level of full employment was six percent. And there is still no evidence of accelerating inflation. That is probably the biggest puzzle of the economic expansion. In such a tight labor market, why have American workers not pressed for wage increases?

One possible reason is that Americans feel more subject to global competition and are more uncertain about what is going on—therefore, they are reluctant to push for wage increases because they are more afraid of losing their jobs. There also has been a lot of deregulation in the sectors of the economy that were dominated by strong worker groups—the transportation industry and the communications industry often led the way in past inflation cycles. Those are very open, competitive sectors in which it is difficult for workers to push up wages.

In general, there has been a decline in unions, which used to play a role in the process. Most Americans seem to have decided that instead of joining a union, it is a much better to threaten to join a union. Then you get everything you want. So now union membership in the United

States is at an extremely low level, and therefore not an important force in wage determination.

The trouble with such explanations is that they have been going on now for several decades, starting in the late 1970s and early 1980s. Yet in 1988–89, when unemployment in the United States declined about 5.5 percent, inflation took off. And the Federal Reserve, trying to curb that inflation, put the United States back into a recession. Why is it that when unemployment crossed six percent in 1995 and then stayed below that every year, it did not go down? What has happened since 1989? That is much harder to explain.

Part of the explanation may be that labor markets are not as tight as they seem. Years ago, women typically had relatively high rates of unemployment compared to men—with a relatively loose attachment to the workforce—and they tended to experience higher unemployment rates. That is no longer true. If they lose a job, women are just as aggressive as finding another one, and their unemployment rate is now actually below that of men in the same age groups. So there has been a shift in the composition of unemployment. However, if you focus on male unemployment rates rather than the overall unemployment rate, the market is not quite as tight as it would appear to be.

There also has been some improvement in productivity in the last few years, so we were able to offset some of those wage increases in the last three years by increasing American productivity. That is very encouraging for the future—maybe we are beginning to realize some benefits of all those computers we all bought.

Another reason that inflation remains low may be luck: a fortunate set of external circumstances. Take, for example, the 1970s. We had many shocks to the economy that tended to be inflationary, such as the driving up of oil and agricultural prices. In contrast, the shocks of the 1990s have had favorable effects on inflation.

In 1995, oil prices collapsed, providing real income gains to workers without the need for large wage increases. More recently, the Asian financial crisis contributed to low prices for other commodities and electronic parts.

Given this very strong economy, the United States is now forecasting a budget surplus, which we have not had since 1969. Most of the budget surplus is actually a surplus in the social security accounts, and it is occurring because all the baby boomers are working now and they are pumping a lot of tax revenues into the social security fund. That will continue for about another 15 years.

But there is also a large improvement in the other parts of the budget. How did that happen? The President and Congress did not agree to a tax increase and they did not agree to an expenditure cut. Part of the surprise is on the expenditure side—Medicare is increasing less than we expected it to. But the major surplus is on the revenue side. In effect, money has been pouring into the treasury, and we cannot fully figure out where it is coming from. One thing we do know is that it is in the personal income tax—not in social security tax payments or component taxes.

How can we possibly be getting that much money? One explanation is that the national income accounts of the Commerce Department are way off target, and the economy is growing a lot faster than we think it is. I believe we can largely discount that explanation, because if that were true, one would expect to see a surge in the employment taxes, as well as income taxes.

The other two explanations are that a large proportion of the income gains in the 1990s have gone to people at the very top of the income distribution, and they pay higher marginal tax rates than people at the bottom; and there has been a large increase in income from realized capital gains, which are not reported in the national accounts. That appears to be happening with consumption—people are spending some of their capital gains, so some part of the tax increase is coming from capital gains.

The reason we do not know for sure is because the information about individual returns comes from IRS records, and IRS is still processing 1996 tax returns. We know the total tax payment, but we cannot yet allocate it among individuals to figure out who paid. A little bit later this year we will begin to get information that will resolve some of the debate about the origins of the surplus. If you thought it was due to the redistribution of income, then I guess you would maybe argue that it might go on for some period of time yet, because I do not think the redistribution of income will reverse. But if it is due to capital gains, the budget surplus may turn out to be a little ephemeral.

In conclusion, I do not want to leave you with the impression that everything is great. There are problems in the changing income distribution: the failure of the expansion to benefit all groups throughout the income distribution. Between 1979 and 1996—in the midst of this long economic expansion and after adjusting for inflation—the income of men in the bottom 80 percent of the distribution declined. The only men who are experiencing income gains are at the top of that distribution.

For women, the picture is more positive—but that statement should be tempered with the fact that women started out earning only about 65 percent of what men did, and now they are up to about 75 percent. Even for women, the distribution of the gains is extremely skewed. They are much larger at the top of the distribution than they are at the bottom of the distribution. Finally, more than in the past, "likes" are marrying "likes" in the United States, meaning that men at the bottom of the distribution are marrying women at the bottom of the distribution, and men at the top of the distribution are marrying women at the top of the distribution. Thus, if you look at family incomes in the United States, there is a dramatic pulling apart of the income distribution.

I think the major reason for this is that because of technological changes, education is worth more in our society. There is a surplus of people with limited education, and there is a shortage of people with high levels of education. As a result, the price of unskilled labor is being driven down while the price of skilled labor is being driven up. That has some very serious social consequences for our country that we should be concerned about, and it is a big challenge to public policy.

The educational system plays a very important function in this whole process. We all should take pride, for example, in how well the American college and graduate system works—but no American should be proud of how well the American high school system works. We spend an amazing amount of money on people who go to college—but think about the 50 percent of Americans who stop at a high school diploma. We do not do anything for them, and the data are beginning to reflect some of the consequences of having ignored high schools for so long.

3 Ushering in a New Century of Progress Through Discovery

Neal Lane

In my remarks to this colloquium in May 1998, I spoke about the global imperative to make the fruits of science and engineering research available to all people, and I quoted Einstein's admonition: "From discord, find harmony. In the middle of difficulty lies opportunity." Personally, I have found these to be words to live by during my transition from National Science Foundation (NSF) to the Office of Science and Technology Policy over the past year. I like it when a speech has a take-away message, even if I'm the only one who takes it away!

This year, I would like to comment on some of the remarkable lessons I have learned in the White House about research and development (R&D) budgets. But I would also like to continue exploring the opportunities presented by the new millennium to unite the pursuit of world-class research with the pursuit of societal needs.

As we draw ever closer to the next millennium, I'm sure many of you have noticed the recent news stories offering various rankings of historic events. One such story reported on the results of a survey of leading journalists voting for the "biggest news stories" of the past 100 years. It was no surprise to those of us in the science and technology community that more than one-third of the top 100 stories concerned breakthroughs in science and technology. In fact, three of the top four were clearly science and technology news: the number one story was the United States' use of atomic bombs at the end of World War II; the number two story, astronaut Neil Armstrong's first steps on the moon in

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Neal Lane is the assistant to the President for science and technology and director of the White House Office of Science and Technology Policy. *This article is based on remarks delivered at the 24th Annual AAAS Colloquium on Science and Technology Policy, held April 14–16, 1999 in Washington, DC.*

1969; and the number four story was the flight of Wilbur and Orville Wright's powered airplane in 1903. In these examples, science and technology made headlines because they shaped—significantly and tangibly shaped—the daily lives of people all across the globe.

The decisions we make—in the Administration, in Congress, in the science and technology community—about future investments in science and technology will influence the headlines of the 21st century in ways both predictable and serendipitous. More importantly, they will affect the lives of our children, our grandchildren, and all of those who follow. Our political leaders' vision of where science and technology can take us is vital, then, to the success of the nation. President Clinton and Vice President Gore have used their time in office to promote a compelling vision of the future of science and technology. Many of you may have heard the President's address in 1998, at the AAAS sesquicentennial meeting, in which he presented the following view:

Your bicentennial meeting can convene in a world where climatic disruption has been halted; where wars on cancer and AIDS have long since been won; where humanity is safe from the destructive force of chemical and biological weapons, wielded by rogue states or conscienceless terrorists and drug runners; where our noble career of science is pursued and then advanced by children of every race and background; and where the benefits of science are broadly shared in countries both rich and poor.

That is what I pray it will be like 50 years from now, when my successors stand here before your successors and assess how well we did with our time.

In each budget cycle, this Administration has made steady improvements in the science and technology investment portfolio to move us closer to the President's vision. This year is no exception. After this review of the FY 2000 budget, I want to open a dialogue with you—indeed, with the whole science and technology community—about how we can effect more than incremental change in the prospects for science and technology, and therefore for society as a whole in the 21st century.

I think you all know that this has been a tough year to put a budget together, but there are some notable high points. First among them is the fact that the President led us from a $290 billion deficit in 1993 to surpluses as far into the future as the eye can see. The Administration successfully combined fiscal restraint with continued investments in the future, including investments in technology.

21st Century Research Fund

The FY 2000 budget includes $38 billion for the 21st Century Research Fund. That's a three percent increase over FY 1999. The Research Fund provides a way to focus on balance, budget stability, and appropriate growth in the highest-priority research programs. This year, the Research Fund includes Department of Defense basic and applied research programs (6.1 and 6.2)—further evidence of the Administration's commitment to effective integration of the nation's university-based research portfolio. The Research Fund also helps ensure that research areas that cut across several agencies can flourish in the competitive budget environment. Let me mention a prominent example: information technology research.

Information Technology

This year's budget proposes a bold new initiative: Information Technology for the 21st Century (IT2). The initiative corresponds to an increment of $366 million, a 28 percent increase in overall spending on information technology research, bringing the total to about $1.8 billion in FY 2000. No one knows better than you the value of information technology in our national economy or the value of information technology to progress in science and engineering. Information technology now accounts for one-third of U.S. economic growth. Information technology offers the greatest return on investment of R&D dollars, producing not only more jobs, but also jobs that are more desirable because they pay more and can drive local economies.

Information technology also gave us the confidence to move from nuclear testing to science-based stockpile stewardship, through the Department of Energy's Accelerated Strategic Capacity Initiative (ASCI). And the new initiative will help move those hard-won advances into critical civilian uses, such as climate-change modeling and other applications. This initiative is what Thomas Jefferson would have described, if Gerald Holton is to be believed, as a research program by which science serves both the search for truth and the interest of society. I will return to Jefferson's views on science later in my remarks.

IT2 has three central goals:

- to carry out basic research to advance information technology;
- to use the most advanced information technology—for example, computer simulation—to enhance research across all areas of science and engineering and hasten the pace of discovery;
- to address the legal, ethical, economic and workforce questions that information technology raises.

The IT2 initiative is a team effort involving the White House and several federal agencies, and it's a high priority with the President and with the Vice President. IT2 will help contribute to advances in other cross-cutting areas, including, for example, the environment and national security.

Budget Summary

In summary, R&D fared well in the FY 2000 request. Non-defense discretionary spending was, essentially, flat compared to FY 1999, but non-defense R&D was up three percent. Among all the non-defense discretionary accounts, only education fared better.

I know that some of you are concerned with the National Institutes of Health (NIH) funding level, but it is important to remember that the $320 million increase in FY 2000 maintains the rate of growth the President set out in the FY 1999 budget request. And R&D spending is up at NSF, USDA, Commerce, Interior, and Transportation. Importantly, R&D is up at Education to support large-scale, interdisciplinary research in three key areas: school readiness for learning reading and mathematics; K–3 learning in reading and mathematics; and education of pre-K-12 teachers in mathematics, reading, and science.

The Clinton-Gore Administration has a solid six-year record in science and technology funding:

- Civilian R&D has increased seven years in a row. At almost $40 billion—a 31 percent rise since 1993—it now constitutes 51 percent of the federal R&D budget, fulfilling a Clinton-Gore campaign pledge.

- The FY 2000 budget boosts funding for basic research by 4.2 percent over FY 1999. The total is up 36 percent since 1993.

- R&D support to universities is up by two percent in FY 2000—a $353 million increase. That's up 33 percent since 1993.

- Finally, the President's budget presents a balanced R&D portfolio, which recognizes the interdependence of all fields of science and engineering.

This last point is extremely important. The President's request reflects his appreciation that diverse fields of research are intricately connected, with each breakthrough stimulating a chain reaction of advances in seemingly unrelated fields. The Senate budget resolution, which provides only for increases at NIH, stands in stark contrast to the President's vision for science and technology. Certainly, increases for NIH are important—but it is essential that we also see increases in the budgets of NSF and the science and technology programs in all the agencies. We want to work cooperatively in a bipartisan fashion with Congress to support R&D. But it is crucial that the support be comprehensive to ensure continued vitality and leadership across the broad frontiers of science so that we don't miss the next breakthroughs—in whatever field they may occur.

As leaders in the science community, you have strong voices that are heard and heeded. I urge you to speak out to all those involved in budget decisions—not only in the U.S. Capitol, but also back home in your own state capitals and across your regions. We hope you will join us in a concentrated effort now to sustain a balanced, comprehensive national science and technology enterprise.

In these years when two millennia converge, it is important to keep our perspective even as we engage in perennial political brushfires. We are plotting a course not just for the near-term future of the federal budget, but ultimately for the long-term future of our planet and its people.

We might take a lesson from an old budget debate among the faculty at an Oxford college. The dons were debating what to do with all of their college's money. Most seemed to agree that buying land would be the best use for the money, since, as one faculty member observed, "for the past thousand years, land has proven to be a very wise investment for the college." At this point, the college's whiskered old patriarch stood and said, "True, but the past thousand years have been atypical."

The past 50 years have been exceptional times for science and technology. But will they prove to be atypical, or will we successfully forge a new post-Cold-War partnership between science and society that secures benefits for all parties?

The Vice President has called on us—the scientific community—to look for new opportunities in the new millennium. He has called for the development of a "New Compact" between our scientific community and our government—one based on rigorous support for fundamental science, and also a shared responsibility to shape our breakthroughs into a powerful force for progress. He spelled out three prerequisites for a New Compact.

First, as we continue to probe the most fundamental questions of nature, we must do more to ensure the best use of science and technology to sustain our prosperity, create jobs, and grow the economy for the 21st century. To illustrate this need, he unveiled the IT2 initiative and announced the Administration's plan to request a renewal of the R&D tax credit.

Second, the Vice President said we must "make sure that we not only generate the fruits of discovery, but also share them." That means working to ensure that more of our people have access to technology and to rewarding careers in science and technology, and also that we give our students the best education available in the world.

We put top priority on addressing the needs of the science and technology workforce of the 21st century. The National Science and Technology Council (NSTC) will soon recommend actions to revamp the roles community colleges play in preparing our technical workforce and the ways in which graduate students are supported in our research universities. We are also committed to strong policies that encourage international scientific exchange. Researchers from other countries enliven academia and industry and help keep this country strong. *Time* magazine recently featured scientists who number among the great minds of this century, noting that behind each great idea, great discovery, and great invention is one extraordinary human mind. We intend to create an environment in which those minds can work their wonders for the long-term benefit of this nation.

Finally, the Vice President urged us to do more to make sure our newest technology helps advance our oldest and most cherished values. One example of our ongoing effort in this area is the work of the National Bioethics Advisory Commission, which is providing crucial guidance on the complex issues raised by biomedical research. IT2 also emphasizes technology and values, with its allocation of $15 million to examine the social and economic effects of the information revolution.

Science and technology community leaders have also recognized the need to refocus our efforts. For example, a new study by economists Michael Porter of Harvard Business School and Scott Stern of MIT, published last month by the Council on Competitiveness, warns that the United States is failing to invest in the fundamentals—basic research and advanced degrees in physical sciences and engineering. It suggests that we are eating our seed corn while other countries are increasing their stores for the future.

In a recent opinion column, representatives of Genentech, Netscape, and TechNet—a bipartisan organization—echoed the same concern that the once-reliable flow of federal funds into basic research is now in doubt. To help reverse this trend, the authors advocate doubling federal appropriations for basic research over the next ten years and enacting a permanent R&D tax credit for corporations.

The National Academy of Sciences has also entered this debate with its recent report on capitalizing on investments in science and technology, *The Pervasive Role of Science, Technology, and Health in Foreign Policy: Imperatives for the Department of State.* The report asserts that there is a consensus that the context for U.S. science and technology policies has changed fundamentally, and that the framework that brought success in the past needs to be rethought for the future.

Congress, too, has expressed concern about the future of science and technology. The Frist-Rockefeller bill and Vern Ehlers' report for the Science Committee, *Unlocking Our Future: Toward a New National Science Policy*, try to point us in new directions. During my recent appropriations hearings, Senator Barbara Mikulski (D-MD) urged me to do more to communicate the rationale for broad federal investments in science and technology to her congressional colleagues.

In many ways, all of this ferment of opinion is encouraging—for if we agree strongly enough that the outlook for R&D funding is threatened, perhaps we can find common cause for unifying and concentrating our efforts to answer the threat. There is some urgency to this task associated with one of the Clinton Administration's proudest accomplishments: we have a surplus in the federal budget—not just for this fiscal year, but for as far ahead as we can see. The figures being quoted are as high as $2.8 trillion over the next decade. Yes, the President is committed to fixing Social Security and Medicare. Still, that leaves possibly hundreds of billions of dollars to make decisions about.

Many constituencies, armed with thorough documentation for their funding needs, will have their eyes on the surplus. We must be ready. One thing is certain—only political support for R&D ensures adequate attention in the final budget. And political support flows toward investments with real payoffs for real people who speak loudly, in unison—or at least in close harmony.

We have extremely compelling arguments at our command. The immense payoffs from long-term basic and applied research funding are evident throughout our economy—from laser surgery, to global positioning technology, to the microchip in your coffee maker. The contributions of science and technology are so woven into the fabric of our lives that it is easy to forget the effort that made them possible. Let us help people remember.

We already know the public believes in the value of science and technology, and especially R&D funding. According to the NSF's Science and Engineering Indicators 1998, a solid 80 percent of American adults agree that the federal government should support basic scientific research that advances the frontiers of knowledge, even when it does not provide any immediate benefits. Even more encouraging, this percentage has remained relatively constant throughout the last decade. The real question today is how we can translate this strong public confidence in our enterprise into a similar confidence among the federal budget decision-makers—who are elected by a public that strongly supports science.

We must pass along our own excitement to everyone who does not already sense it. The President's Committee of Advisors on Science and Technology (PCAST) is documenting the contributions of S&T to our daily lives. The NSTC will produce a document that describes the role of science and technology's contributions to the federal agencies' missions. I will be working closely with PCAST and the agencies in the NSTC over the coming months to help shape proposals to address the Vice President's call for a "New Compact." We will be reaching out to individuals and organizations like AAAS to get broad community input.

The "Cold War," the "Space Race," and the "Cure for Cancer" have been almost unassailable rationales for increased investment in science and technology. We revved up spending in this Administration with the "Engine for Economic Growth." Are there other ways to characterize a broad investment portfolio that can compete with other important discretionary programs when push comes to shove? I was thinking recently how appropriate it is that the year 2000—in the midst of the current revolution in science and technology—will not only mark the turn of a century and of a new millennium, but will also mark the 200th anniversary of Thomas Jefferson's election as President of the United States. I have a feeling that President Jefferson—who was passionate about science—would be proud of what we are accomplishing today, both scientifically and politically.

Jefferson knew that science investment could be risky, but could also have enormous payoffs. That knowledge guided his decision to commission Lewis and Clark to explore the vast Louisiana Purchase. Except for the tall tales and legends of a few mountain men and trappers, Americans at that time had no clear knowledge of what kinds of lands and waters lay west of the Mississippi. But Jefferson did know that it was essential to investigate this huge tract—not just in the sense of taking an inventory of goods, but also in the fundamental spirit of scientific inquiry. The expedition he commissioned, of course, did pay off. As surely as Lewis and Clark dramatically increased our knowledge of the geography, the geology, and the peoples of the Western United States, that new knowledge opened the Western United States to economic expansion that still drives this nation forward.

And so, almost 200 years later, we find ourselves at another important crossroads of policy development, when similar levels of vision and courage are needed. I believe the Administration has an impressive record and an exciting vision for the future. And I look forward to working with you to translate this vision into a well-defined agenda and "compact" for the new century.

4 The Global Context for Technology and Trade

Robert J. Shapiro

The global context for technology and trade is a very broad topic. It involves understanding current global economic conditions, of which there are two features that particularly affect technology and trade: the current unevenness of economic growth around the world and the emergence of sustained worldwide disinflation.

We also need to address the role that technology plays in growth and the present state of American technology industries. Finally, there is the matter of the government's role in technology.

In economic strength the United States is currently the world's outlier. Last year our growth rate of 3.9 percent was the strongest in the OECD. By contrast, Western Europe grew 2.7 percent, Latin America 2.1 percent, and Asia contracted at a rate of 1.9 percent.

Total world gross domestic product (GDP) grew 1.6 percent last year. That is about half the decade's average. And we contributed half of world GDP last year, because while the world was growing very slowly, we were growing very fast. In fact, America's GDP has grown faster than the G-7 average every year since 1992, or throughout the current Administration. Compared to the 1970s and the 1980s, this is really quite extraordinary, and indeed could signify new trends on both sides of the comparison.

As the person who oversees the Census Bureau and the Bureau of Economic Analysis, I am not allowed to forecast. I am not allowed because if I get it right, people might think the books were cooked, and if I get it wrong, then I might look like I do not know what I am doing. So I do not forecast. But according to most private forecasters, this unusual global economic unevenness will continue this year. Right now

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Robert J. Shapiro is the under secretary for economic affairs at the U.S. Department of Commerce. *This article is based on remarks delivered at the 24th Annual AAAS Colloquium on Science and Technology Policy, held April 14–16, 1999, in Washington, DC.*

the consensus forecast sees the United States growing by 3.3 percent or more in 1999, while world GDP ekes out about 1.6 percent growth again.

The encouraging news is that there are some signs that Asia is beginning to recover. The private consensus forecast for the region is 0.4 percent growth this year and 1.6 in 2000, compared to the decline of last year. South Korea is leading the turnaround. It grew at an annual rate of two to three percent in the fourth quarter of last year, and other tigers are also showing improvement. Before we breathe more easily, however, Japan is still in a deep recession, even as its financial markets improve, and China may still be slowing as well.

The consensus forecast for Latin America is not encouraging. Led by Brazil's recession, the region, particularly South America, is clearly slowing. But Mexico, our third largest trading partner, is doing well, and the forecasts for 2000—at least for Latin America—are still solid.

The worry is Europe. Germany's GDP declined in the fourth quarter; its exports slumped. But the European Central Bank has cut interest rates, and the consensus forecast sees Germany rebounding, and all of Europe growing 1.9 percent this year and 2.4 in 2000. So even in this rebound, this pattern of not only absolute American economic strength, but also of relative economic strength is expected to continue.

This uneven pattern of world growth can have at least a modest stimulative effect on technology. For example, the recession in Asia reflects in part an excess of export-led investment in the 1980s and the 1990s, which has produced excess manufacturing capacity. When Asia comes out of its recession, businesses there will likely focus less on expanding their capacity and more on productivity and profits, which means more focus on technology. Such a global tendency towards greater technology investment would be reinforced by another feature of the current economy, which is the steady decline in inflation.

Consumer prices in all developed countries rose only 1.9 percent last year. They are expected to rise 1.3 percent this year. These rates are very low, but the trend is not new. In fact, inflation has been falling worldwide for about 15 years. There are many factors at work here, including weak demand for commodities worldwide, especially outside the United States, and until recently the sharp decline in oil price. But most of the factors in global disinflation are not tied to the current business cycle, but rather are structural, such as the huge built-up overcapacity in many Asian manufacturing sectors. Trade liberalization and deregulation around the world have also placed downward pressure on global prices.

The globalization of capital markets has brought a new kind of competition among currencies, since international investors will pull their funds out of any currency in which they lose confidence. This has produced a sustained bias toward tighter fiscal and monetary policies around the world to reassure international investors, thus holding down prices worldwide. We see this in Europe, where this bias toward tighter fiscal policy has been written into law in the Maastricht Treaty. We see it in the United States in a debate over the budget surplus, in which there is virtually no discussion of spending the surplus.

But technology also plays a direct role in the current structural disinflation because technological innovation has reduced the real cost of certain crucial goods, especially information systems, telecommunications, and transportation. U.S. personal computer prices, for example, measured on a real basis, fell 13 percent in the fourth quarter of 1998 alone. And the strong productivity gains—driven in part by technology—also keep inflation low, even when labor markets are very tight.

I think it also works the other way; that is, disinflation can play a role in advancing technology. That is because disinflation reduces the ability of firms to raise their prices, and that tends to shift the focus of business strategy to cutting costs—which often means substituting capital for labor—and the focus of business investment to increasing productivity.

It has been said that we have been in, in part, an investment-led economic expansion. One of the most extraordinary facets of the recent record in business investment is that measured in real terms, 45 percent of the growth in business fixed investment over the last five years has been in information technologies—that is, American business is becoming highly intensive in information technologies.

Apart from these dynamics, I think technology has played a critical part in the current strong growth in the United States. By one estimate, information technologies—which account for about ten percent of GDP—have accounted for more than one-third of U.S. growth over the last five years. But this is not new. Many economists—Robert Solow, Edward Denison, Michael Boskin, and most recently, the Council of Economic Advisors—have estimated that economic innovation, broadly conceived, can account for 40-to-50 percent of all U.S. growth over the last century.

Now, by "innovation, conceived broadly" I mean the development of not only new products, processes, and materials, but also new ways of financing, marketing, and distributing goods, and new ways of organizing the workplace and running a business.

Technology is not the only factor in growth, and in many cases it needs to be embodied in capital. So capital still counts for growth too. It needs to be operated by highly skilled workers, so education counts as well. So innovation and technology are clearly not the only factors, and they can not be fully separated from the other major factors in growth. Nevertheless, conceived broadly, it probably is the single most important factor.

How this happens is a matter of some debate. In the late 19th century, Alfred Marshall articulated the terms of neoclassical economics by emphasizing continuity. Applying calculus to economic matters for the first time, he could explain economic development as a matter of continuous incremental change. By contrast, Joseph Schumpeter, in his 1939 classic work, argued that economies are marked by gradual continuous change for long periods, punctuated by short bursts of explosive activity or discontinuous leaps in technology.

Is the current period better described by Marshall or Schumpeter? Is the semiconductor, computer, and communications revolution improving the productivity of labor and capital in a distinctly new way—creating a long period of rapid non-inflationary growth, the new economy paradigm—or is this, as some believe, a "bubble.com" economy, changing but only marginally and slowly, with a big bubble at the top?

Without embracing the new paradigm view of the economy, this is clearly not a bubble economy. Our economic fundamentals are very, very strong because competition is strong in the United States, and because the economic policies of the current Administration have been sound.

But whatever the precise pattern of economic change in the current era, the global contexts and technology have clearly been key factors. Technological advances affect trade as well as growth. There is no doubt, for example, that the spread of standards created by information technologies promote investment and trade by intensifying the linkages among companies and countries around the world. Technology also affects the patterns of world trade. By importing technology, countries can go from exporting trinkets to exporting computers in one generation. Technology also enables highly advanced countries like ours to become very highly specialized, and to establish new economies of scale. So instead of using comparative advantage to export particular products, countries like ours increasingly produce only certain parts, highly sophisticated parts of a particular product, and then trade it for other components.

So technology has increased the vertical specialization in trade. This is not new. This has happened at various points in economic development for 200 years. At this moment, a country's comparative advantage may turn out to be only in one (or a few) aspects of economic activity—for example, in research and development (R&D), or in the assembly of a product, or in its marketing, or in business management. And falling tariffs—or increasing openness—to foreign direct investment pushes world production and world trade in the same direction. This could be a plus certainly for R&D in this country and for the business management sector.

But always remember, in a global system, the advantage conferred by any technology on a company and its country is short-lived, regardless of the patent or copyright protection applied to a particular application of an idea. The idea itself cannot be owned.

Moreover, since 1980, all the major industrial countries have spent large sums of money generating new ideas for products and processes, and the major countries now have roughly comparable degrees of R&D intensity, that is, ratios of R&D to their GDP.

Differences among countries in this ratio have narrowed to decimal points. In 1996, for example, it was 2.5 percent in the United States, compared to 2.7 percent in Japan, 2.3 percent in Germany and, incidentally, 2.6 percent in Korea. This is not a phenomenon limited to the most advanced economies.

There is also evidence that the diffusion of ideas in technology is narrowing differences in countries' labor productivity, especially between Europe and the United States. Put another way, on balance, the technological achievements of one country or of companies in one country, benefit others. Certainly foreign innovations have benefited us by providing growing foreign markets for our goods and new technological knowledge for our producers. This is a global technological system. And as more sources of potentially relevant knowledge emerge around the globe, American companies have reached out to tap into new research from foreign universities and foreign competitors.

This is clear in the evidence of the increasing use by American firms of international research partnerships, especially in high technology areas. In 1986, there were 400 such partnerships in the three core areas of information technology, biotechnology, and new materials. Over the next decade in information technology and biotechnology alone, U.S. companies formed nearly 3,600 cross-national technology alliances.

One result is that over the last ten years, U.S. firms' investment in overseas R&D increased half again as rapidly as their investment in domestic R&D. Another result is that R&D investment by U.S. companies overseas is now roughly equal to R&D spending in the United States by the affiliates of foreign countries. This is a very permeable system.

This globalization of technology, research, and ideas has clearly been very healthy for the United States. We are the world's leading producer of high technology goods, accounting for one-third of all world production. In the 1990s, we regained world market share in high technology areas where we had lost world market share in the 1980s, and we continue to enjoy a trade surplus in technology products, which is important given that U.S. exports have accounted for a significant share of U.S. growth in the 1990s.

We are also a net exporter of technological know-how. We know that because the royalties and fees from patents received from overseas by U.S. firms are nearly three times the level of those paid by U.S. firms to foreigners.

Since technology is crucial to growth and the global system, the last issue is what government can or should do about it. Now, competition is the single most important driver of all forms of economic innovation. This is true whether the competition is among Japanese oligopolists vying to make the smallest camcorder or small software designers facing off against Microsoft. In the past there has been a lot of evidence, especially in Europe and Japan, of government planning to promote technological development. Our competitive system has clearly served us better. This is not to say that the government has no role to play. Government is crucial in supporting R&D and broad-based education. It is also important in spreading the knowledge of technological advances, and in refereeing the competition itself.

And technology in a global context constantly raises new questions for government. For example, how do we best maintain competition in the face of technological innovations that create industry standards like Windows? We have been in the midst of a major merger and acquisition wave recently, and much of that has to do with buying and selling technology advancements and new technology standards. Sooner or later we will face a related issue, when foreign-owned technologies begin to set global standards—which our industry and consumers will want or have to use. Will we be open to foreign standards, as we expect the world today to accept the standards set by our technology companies?

It matters because openness to new ideas, new technologies, new ways of doing business, and new ways of conducting public life has been our best answer to the challenges posed by the global economy. Openness is one of the basic conditions for technological progress, and it will always be vital to American success.

5 Globalizing Industrial Research and Development

Donald H. Dalton and Manuel G. Serapio, Jr.

Executive Summary

Research and development (R&D) spending in the United States by foreign-owned companies is now more than $17 billion, substantially higher than in 1990. This report, an expanded and updated version of our earlier study, sheds important light on the magnitude, nature, and scope of this investment (see Dalton and Serapio 1995). It also explores the major factors influencing the location decisions of foreign R&D facilities in the United States. This information is important in increasing our understanding of the dynamics of R&D as well as the flow of high-value-added jobs.

In a complementary trend to increased foreign R&D investment in the United States, U.S. companies have substantially increased their R&D spending abroad, more than tripling it between 1986 and 1997. Relative to domestic spending, R&D performed in other countries represents nearly 11 percent of the total, up from 5 percent a decade ago. The overall globalization of the R&D enterprise is illustrated clearly by the actions of both U.S. and foreign firms.

Donald H. Dalton is in the Office of Business and Industrial Analysis, Economics and Statistics Administration, U.S. Department of Commerce and Manuel G. Serapio, Jr. is assistant professor of Management and International Business of the Graduate School of Business and Administration at the University of Colorado at Denver. *Reprinted from* Globalizing Industrial Research and Development, *Donald H. Dalton and Manuel G. Serapio, Jr., The U.S. Department of Commerce, Office of Technology Policy. Washington, DC: Office of Technology Policy, pp. 7–9, 53–54, September 1999.*

Investment motivations for U.S. R&D abroad and for foreign R&D in the United States are strikingly similar. These motivations range from assisting the parent company to meet host country customer needs and monitor technological developments, to allowing the firms to take advantage of specialized skills in the host country. U.S. and foreign companies primarily conduct applied research abroad. The pharmaceutical and biotechnology industries also carry out large-scale basic research in offshore locations.

Foreign R&D Investments in the United States: Key Findings

- R&D expenditures by foreign-owned companies in the United States tripled from $6.5 billion in 1987 to $19.7 billion in 1997, and accounted for nearly 15 percent of total company-funded R&D.* R&D spending by foreign-owned companies in the United States increased at a faster pace than domestic R&D spending in the past 15 years, but domestic R&D spending began to outpace foreign R&D growth since 1996.

- Foreign companies accelerated the establishment and acquisition of R&D facilities in the United States in the 1990s. At the end of 1998, foreign companies owned 715 facilities designated as R&D centers in the United States. These facilities are owned by 375 foreign parent companies.

- The 251 Japanese R&D facilities in the United States outnumber the U.S. R&D facilities in other countries. Germany has the second largest number of facilities (107), followed by the United Kingdom (103) and France (44). The number of U.S. R&D facilities owned by Korean parent companies has more than doubled, from about a dozen in 1992 to 32 in 1998.

- At the end of 1997, foreign-owned companies conducting R&D in the United States employed more than 115,700 R&D workers.

*Figures for 1997 are the most recent available as of September 1999 for foreign R&D expenditures in the United States and U.S. R&D expenditures abroad.

- Switzerland and Germany rank first in R&D expenditures by foreign companies in the United States, with $3.3 billion in 1997, followed by Japan ($3.2 billion) and the United Kingdom ($3.1 billion).

- The largest recent impact on R&D spending by foreign companies in the United States resulted from several major acquisitions by foreign firms of U.S. pharmaceutical and biotechnology companies with large R&D budgets.

- Industries with the largest number of foreign facilities in the United States are drug and biotechnology (116), chemical and rubber (115), computer software (54), automotive (54), and medical device and instrumentation (53). Japanese firms have the largest number of R&D facilities in the automotive and electronics industries.

- Foreign R&D facilities in the United States are heavily concentrated in certain areas, such as Silicon Valley and greater Los Angeles (CA), Detroit (MI), Princeton (NJ), Research Triangle Park (NC), and Boston (MA).

- The most frequently cited reasons for investing are (1) to assist parent companies in meeting U.S. customer needs; (2) to keep abreast of technological developments in the United States; (3) to employ U.S. scientists and engineers; and (4) to cooperate with other U.S. R&D laboratories.

U.S. R&D Investments Abroad: Key Findings

- U.S. companies have increased their R&D spending abroad from $5.2 billion in 1987 to $14.1 billion in 1997, and represent nearly 11 percent of R&D performed in the United States. More than half of U.S. R&D expenditures abroad are accounted for by five countries: Germany, United Kingdom, Canada, France, and Japan.

- In recent years, R&D spending by U.S. affiliates in newly industrializing or developing countries, including Singapore, Brazil, China, and Mexico, has increased.

- Several major studies show that, while the amount of U.S. R&D abroad has increased, leading-edge R&D on a company's core technology almost inevitably is still performed at home. Nearly 90 percent of R&D expenditures by U.S. companies still is spent at their facilities in the United States.

- In 1997, most of the expenditures on U.S. R&D abroad were concentrated in drugs, automotive, computers, and electronic components.

- The drug industry showed the most global R&D, with a ratio of 30 percent of U.S. R&D abroad to 49 percent of R&D performed by foreign companies in the United States. The U.S. auto industry performs nearly 25 percent of R&D in Europe to develop cars and diesel engines for the European market, but the foreign share of U.S. R&D is only 5 percent.

- Of the 186 U.S. R&D facilities abroad listed, Europe contains 88 facilities, followed by Japan with 45 and Canada with 26.

Conclusion

Foreign R&D activities in the United States began to increase significantly in the mid-1980s and continued that increase during the 1990s. Their rapid growth raised questions about why, where, and in what sectors the investment was occurring. It also led to questions about the potential impact on U.S. competitiveness. Similarly, growth in U.S. R&D abroad led to questions about the possible displacement of domestic U.S. research and how U.S. R&D performed abroad would support innovation.

This study provides a comprehensive review of the extent of that growth and a basis for answering some of the questions raised. It is still difficult, however, to determine the real long-term effect of these activities on competitiveness and employment. The U.S. experience during the 1990s does appear to imply that the overall effect has been reasonably positive.

There are economic benefits from foreign-owned R&D activities in the United States. One area of consensus is that foreign R&D spending within the United States increases employment opportunities for U.S. scientists and engineers. University researchers have welcomed foreign funding of academic research and equipment purchases. In addition, a study by Jaffe, Trajtenberg, and Henderson (1993) documented local R&D spillovers in new products and processes from foreign investment to U.S. companies in the same industry and to spinoff companies. A study by Coe and Helpman (1993) suggests that international R&D may lead to increased economic growth.

Recent studies have not found much evidence of a negative impact on U.S. competitiveness. A survey by Kuemmerle (1996) concludes, "It would be precipitous, however, to assume that foreign firms investing in local R&D facilities are free riders. Foreign firms also create spillovers for the local environment because R&D sites provide employment and learning opportunities for local researchers." The National Academy of Engineering (Reid and Schriesheim 1996) study on foreign R&D also emphasizes the local benefits of R&D, regardless of nationality.

Some empirical research by Patel and Pavitt (1991) also shows little evidence of displaced research. It finds that large multinational companies file most of their patents in the home country. The results from patent data are supported by the expenditure data on U.S. firms' R&D. These data show that U.S. companies spend 90 percent of R&D expenditures at their facilities in the United States. U.S. companies also told the authors that they are benefiting more and more from access to knowledge produced abroad that their foreign facilities afford them.

The Council on Competitiveness (1998) has concluded that the globalization of R&D investment does create new challenges for the United States. If the challenge for the United States in the next century comes not from low-cost producers but from low-cost innovators, then the United States must make a strong, sustained commitment to investment in science and technology, develop the means to rapidly integrate new knowledge and technologies into products, and gain access to growing global sources of innovation. Vernon (1997) argues that policy makers will now have to take into account the increasing presence of foreign-owned R&D in the United States and strategic alliances by U.S. industry.

The data presented in this report support that conclusion. While there has been additional research on this issue since the authors' 1993 benchmark study, much more research needs to be undertaken. It is clear that industrial R&D has become increasingly globalized, with significantly more foreign R&D in the United States and U.S. R&D abroad. Motivations for both are remarkably similar, with access to foreign—especially human—resources and knowledge becoming increasingly important. Patent and other indicators show that a capacity for world-class research is increasing around the world, and that foreign countries, including some smaller countries, increasingly have high-impact patents.

The United States is the creator and repository of much of the world's industrial R&D. It retains a clear technological advantage in most sectors. Foreign corporations still come to the United States to establish R&D facilities because of the size of the U.S. market and, just as important, because it pays to benchmark yourself against the world's best science and technology. The real question is how to continue to tap the incredible dynamism of global R&D so that U.S. companies can remain the leaders in building new industries and creating high-wage jobs.

6 Are New Global Rules Needed for High-Tech?

Kenneth S. Flamm

The topic of globalization is one that sends chills down my spine because of the broad expanse of potential approaches. So I have narrowed the focus to ask and try to answer this question: Are new rules for high-technology trade needed? Within this question are four other questions:

- Why should we be concerned about high-technology trade?
- Why should we be concerned about trade rules?
- Why are current trade rules a problem or, to put it another way, are there problems with current trade rules that are affecting high-technology goods?
- Finally, if we have problems what should we do about them?

First, why should we be concerned about high-technology trade? The most obvious answer is that it is important. High-technology made up about ten percent of U.S. manufacturing in 1980. By 1995, it made up about 15 percent of U.S. manufacturing. Over the course of 15 years it increased by roughly 50 percent. And this is not just a U.S. phenomenon. If you take all the countries you can easily get statistics for, lump them together, and look at it on a global basis you come up with roughly the same rate of increase. In 1980, high-technology made up about 7.6 percent of global production. By 1995 that had grown to about 12 percent. We see about a 50 percent growth as a share of world output.

Kenneth S. Flamm is the Dean Rusk chair of international affairs, at the Lyndon B. Johnson School of Public Affairs, University of Texas-Austin. *This article is based on remarks delivered at the 24th Annual AAAS Colloquium on Science and Technology Policy, held April 14–16, 1999, in Washington, DC.*

In 1980, high-tech products, calculated with respect to either imports or exports, were about nine percent of world trade. In 1995, 15 years later, it doubled to about 18 percent. Clearly, it is growing about twice as fast as trade in manufactures in general.

What we cannot easily talk about, of course, are high-tech services. It is very difficult to try to measure them. However, one generalization, which seems obvious, is that the growth rate in services is probably even greater than in manufacturing. Although, of course, that is debatable. (Not having numbers puts that conclusion at risk).

Is this a quantitative phenomenon that we have to worry about or is there something about trade that is critical to high-technology industries? The answer, of course, is the latter. The reason trade is critical here goes back to the economic structure of these industries. By definition, a high-tech industry is an industry that spends a lot relative to other industries on research and development (R&D). To a first approximation, the amount you spend on research and development does not vary with the amount of output you produce making use of that research and development. Therefore, the wider your market the more you sell. This makes your unit of cost lower and you get a higher rate of return on your investment in technology.

These economies of scale in the use of research and development have made virtually all high-technology industries unremittingly global in outlook right back to their beginnings. Consider the semiconductor industry, for example. Within ten or fifteen years after their invention 50 percent or more of their sales were in global markets. That is no accident. It is critical to a high-technology industry that you reach out to the widest possible market.

So high-technology is something to be concerned about and high-tech trade is something to be concerned about, but what is the problem? What is wrong with the trade rules? We must begin by asking what exactly these trade rules are that affect high-technology industry.

First, trade rules govern what we can and cannot do when we go out to international markets and try to sell our goods to others and consider buying their goods. These rules are a recent innovation. We did not have a system of trade rules before World War II. The trade rules of the General Agreement on Tariffs and Trade (GATT) system, which we take for granted today, are a post-war innovation. In coming up with the basic principles for the GATT system after World War II four fundamental principles were embedded.

The first and perhaps most striking was the principle that we should progressively lower taxes on trade (that is, tariffs). A process of continual negotiation under the aegis of trade rules has tried to get countries to agree to irrevocable and negotiated declines in the level of taxes they place on trade. These negotiations have been largely successful over the years.

Second, countries agreed to eliminate less transparent barriers (other than taxes) to trade. These include non-tariff barriers and restrictions like quotas. Countries also agreed to reduce or eliminate distortions like subsidies to trade and subsidies to individual industries.

The third principle that was embedded in GATT was the idea of most-favored nation. That is, whatever concessions you make to one country you have to automatically offer to other countries. You cannot play favorites and discriminate in the way you deal with countries in trading with them.

The fourth principle, not to be underestimated, was the idea that when we have disputes we should have consultation and negotiation rather than simply taking unilateral action without consultation. These principles seem innocuous enough but they have been a great success.

However, rules were not made about some things, or rules were not enacted. One of those issues is antitrust, which was put off-limits when GATT was negotiated. There were attempts to put it on the table, but basically it was decided that it was too difficult a problem and would be postponed. One of the consequences of this postponement was that antitrust became one of the loopholes in GATT. Countries had to lower formal barriers, quotas, and tariffs, but nothing was said about private barriers to trade. For example, you could tolerate or you could even encourage private companies to engage in various kinds of anticompetitive conduct, which might have the effect of making imports more difficult. Without pointing fingers it suffices to say that, in certain situations, it could be argued that that sort of creative exercise did take place and it was relatively successful. As a result, today we increasingly see antitrust on the table.

The second issue not addressed by GATT was the rise of so-called antidumping policy, which is related to antitrust in terms of its theoretical basis. Without getting into details of what this policy covers, essentially rules on fair-pricing policy were enacted in various countries. Limits were placed on how you could price your products when selling in international markets. This is extremely relevant to high-technology industries because these industries have a very peculiar cost structure. They have a cost structure with a lot of R&D before they even start selling a product. The R&D is a fixed, sunk cost before they ever get to market. When you start selling products there will be many times when the economically rational thing to do is to price it at your variable cost of production. You try to recover your costs over the life cycle, but you do not necessarily try to recover your full life-cycle cost at every moment in time. Antidumping issues and arguments about how we should price these things have repeatedly occurred in the high-tech industry.

Finally, intellectual property rights are obviously important in a high-technology industry, but this is another issue that was never directly addressed during the GATT negotiations. Their importance was not clear back in the late 1940s, when the modern high-tech economy was just beginning. You would have had to have been very far-sighted to understand that this was going to become a critical issue in international trade. But it did.

What exactly are the problems with the current rules? I will focus on the critical issues for high-technology products. My main point is complicated and focuses on the rules for subsidies. There are very few countries in which the government does not play some role in funding R&D. At what point do these subsidies start to overlap on the GATT disciplines on subsidies to individual industries? There are a lot of points of intersection. This is something that will be an increasing concern. The rules that currently govern high-technology products in terms of subsidies are a highly imperfect, compromise solution to a couple of fundamental economic problems.

The main economic issue deals with what we call spillovers, or appropriability. The basic idea is this: An inventor producing a new innovation basically creates information. Information is very difficult to control or capture. In many ways it is often difficult for an inventor, innovator, or discoverer of a new scientific algorithm, theorem, or whatever to build a fence around that concept that prevents others from making at least partial use of it in some way. When you develop information, others can observe what you are doing. Thus there are spillovers beyond the boundaries of the organization or individual that is doing the inventing. The consequence from an economic perspective is that in many situations you have a social rate of return to an invention or investment that is greater than the private return. Very few things are as widely accepted within the economics profession as this, although defining this becomes an opportunity for hot and often hostile debate. But as a general principle most would agree that in cases where social return exceeds private return some reasonable argument exists for the government to step in and play some role in promoting, subsidizing, or in other ways stimulating those kinds of investments because the market tends toward underinvestment (from the social perspective) in these areas. This argument has absolutely nothing to do with trade.

A second argument that is commonly recognized today (and again it is a hot argument about its practical import) is that strategic trade policy can at times be in a nation's interest. Basically, strategic trade policy argues that in imperfectly competitive industries where economic profits are being generated it is possible under ideal circumstances for a government to engage in policies that give its own companies, rather than foreign companies, market power in world markets, which are generating these monopoly returns. If nothing else, you have to have at least a temporary monopoly on technology for investment to be worthwhile. Therefore, you can transfer profits out of the pockets of foreign companies and into your own companies' pockets.

This argument for taking steps to make sure that your firms succeed in world high-tech markets does depend on trade. If you were not engaging in international trade this argument would not exist. You would just be transferring from the pockets of your consumers into the pockets of your corporations. You would see no net gain nationally. But dipping into the pockets of foreign consumers is a different story.

There is a noble motivation: a social return greater than private return. And there is the ignoble motivation: dipping into the pockets of foreign consumers and grabbing monopoly profits. That is the ignoble motive for engaging in an activist government intervention or a technology policy.

How do the rules deal with this? The obvious social motive for engaging in investment in R&D, which has been recognized since the end of World War II, suggests that the government is going to want to intervene. But there is always the possibility of ignoble action for zero-sum gain, where you are basically transferring from the other guy and you are not creating necessarily something that benefits all. How do the rules deal with this? The rules really did not deal with this in a very articulate way until 1994, when the latest round of GATT was negotiated. We now basically deal with it by classifying the problem.

The National Science Foundation and most science and technology organizations basically define different categories of research and development. The standard categories are basic research and applied research. Basic research typically has been defined as research undertaken with no material objective in mind other than pushing knowledge forward.

Applied research is research for which you have a practical application in mind. It is somehow "less pure." Then, of course, there is development that takes research and translates it into products. This is, of course, a crude approximation. Typically, economists and policymakers have assumed that these classifications are correlated with the spectrum of appropriability. Basic research is the least appropriable, or the least prone to capture. Development is the most appropriable and the most prone to capture. Empirical economic studies have tended to support at least in a gross way this general correlation.

If you took arrows and linked basic to applied to development you have the familiar and now discredited linear model of technology development. But the arrows do not matter. The point is the appropriability. You can have arrows going in all directions. You can parse basic research into basic research that is oriented toward pure knowledge (understanding of phenomena) and basic research that is oriented toward trying to get a handle on practical problems that may be soluble somewhere down the line. The most elegant articulation of this is Donald Stokes' quadrant model of scientific research where he argues that you have to distinguish between pure basic research and use-inspired basic research.

Whichever way you look at this, you still come up with a rough categorization of appropriability. It seems logical that pure basic research will have the least degree of appropriability. The use-oriented research might be hard to capture, but there is a notion of capture somewhere. In pure applied research you care only if something works. You will expend a lot of effort to make sure you are working on things that will give you a commercial return, that is, things that are more capture-able.

The key issues here are appropriability and capture. That is one way to categorize research (from basic to development). You can run the appropriability or capture scale in that direction. You can even argue that there are other important factors.

Within these different categories of effort there are incremental gains. There are radical innovations when you are exploring totally new territory. It is inevitable that others can observe these innovations. To put it in economic terms, you are looking for a demand function that people know nothing about when you start working on something. If you have just invented the first automobile, do you know that it will replace horseless carriages? You do not. But if you are going from one model of automobile to another model of automobile with a different type of engine, you are making an incremental innovation. You have at least a rough idea of what the demand curve is going to look like. But if you are going from horse-pulled carriages to autos you are leaping into the unknown. Others, simply by observing your success or failure, will get information about the demand curve. Inevitably, with a radical innovation, information will be generated that is going to be very difficult to capture.

If you want to take a two-dimensional approach to the appropriability issue, you can think of it as a wedge. The upper part—basic research or radical innovation—is the logical place for the government to focus its resources if you are looking for appropriability or capture as a criterion for subsidy.

In 1994, when the rules on subsidies were revised, the final result was a line drawn at the first prototype (basically). That is, up until the first prototype of a new product or process you are permitted government subsidies of up to 50 percent of the R&D. After that first prototype, you can do whatever you want, but it is a countervailable subsidy.

These rules have not been in operation very long. They are obviously a compromise attempt to deal with this appropriability issue. The people who pushed the rules through in the government were aware of this appropriability issue and that is why they pushed them. The rules seem to be working, but they have not really been tested yet. The reason they have not been tested is because of the blossoming of issues and cases in the operations of the World Trade Organization, which came into existence in 1994. We are seeing an incredible growth industry in trade cases.

Governments are going to try to structure their programs in a way that they do not cross that green line of 50 percent on subsidies. But what are the incentives? The incentives are to favor programs that can be captured. They are not going to favor programs that will create benefits that everybody gets. If you look at our own technology programs you will see we are financing R&D, as well as development projects, within private companies. People are going to try to cheat and people are going to do things anyway that seem to benefit their private companies in development and capture.

It is only a matter of time before we start getting trade cases on this issue. We will be taken to court because that little company we funded to develop this, which is now a huge success in world markets, crossed that green line. And we subsidized it. What do we do about this?

The problem that I see with the way we are dealing with the subsidy issue right now is that with the globalization of the economy the inappropriable, least-captured elements of research and development are speeding about the globe ever more rapidly. Governments are going to get more and more pressure to take a free-rider approach. (That is, let other people do the work that we are all going to get anyway. We will focus on work that will help our people). Governments will give in to the inevitable temptation to back off from the pure seed-corn type of research. If everyone is going to get the benefit why should we pay the bill? For that reason I predict that the programs are inevitably going to be pushed by purely economic incentives. How do we deal with this?

One way to deal with this is some kind of international cooperation on the least appropriable elements of research and development. That same process of globalization makes international operations cheaper and more feasible to do. We can have international cooperation among different companies or countries even on basic research. We will need some kind of agreement, at least among countries doing the major R&D work. We are going to have to fund the basic seed-corn type of research that everybody has difficulty capturing. And we will have to maintain resources for that kind of effort. Of course, we also have to find a way to permit countries to subsidize technology programs while at the same time rendering them immune from the temptation to make them strategic-trade oriented, or rent or profit-transferring programs rather than programs that focus on inappropriable elements of technology.

I think the answer is to negotiate reciprocal access to national technology programs. We will open our firms (or programs) to your firms that are resident in the United States if you will open your programs of roughly equal value to our firms that are resident in your market.

I will conclude with three problems. The first concerns antitrust. Slowly but surely minimum international standards on antitrust are going to evolve. We are already down that road. A good example is the recent European Union review of the Boeing-McDonnell merger. Their Justice Department opened a dialogue with our Justice Department, which is very informal at present. But I predict it will ultimately become the basis for a new trans-Atlantic antitrust standard.

Second, I predict the dumping rules are ultimately going to be revisited when our people start getting hit with dumping suits from their countries. We are starting to see dumping cases, for example Japanese cases against the Koreans. It is only a matter of time before we see a Japanese dumping case against the United States. We will have to start discussions on what correct pricing standards in high-technology industries look like.

Finally, intellectual property is the most difficult of the trade rule issues that have not been resolved yet. This is basically a "have" versus "have-not" issue, a north-south issue. The whole existence of a system of intellectual property in a developed economy is a trade-off between two divergent sets of interests. On the one hand, from a static efficiency viewpoint, once technology is created the most efficient thing society can do is diffuse that technology as widely as possible. The problem with that, however, is that if you give it away (which often is the marginal cost of diffusing technology), nobody has an incentive to create new technology for the future. So we give a temporary monopoly. That is a patent system.

We can work those trade-offs on a national scale because we have both technology producers and technology consumers. But on a global scale some nations are almost exclusively technology consumers. They are not going to be technology producers of any significance, at least in the very near future. It is clearly not in their interest to go with a system that impedes diffusion. Their interest is not the same as the advanced industrial countries that are developing the technology. This is a tough issue because there are very different interests between different groups of countries. A clear solution is not feasible.

For example, the European Union has moved toward a single European-wide patent system. You can now get a European patent in Europe. The problem with that, however, is that these patents are still being enforced by national patent courts. You can get a European patent, but it is very difficult, and costly, to enforce. You have to go into all these national markets and do things differently in each one. This is a very simple illustration of the kinds of difficulties we are going to face if we try to determine the logical solution to the patent issue, which is a world patent system. That seems very, very difficult and very unattainable. It is a very tough bargaining issue because of these divergent interests.