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A Dialogue on Competitiveness

Two thoughtful observers discuss what science, technology, and education can and cannot do to reestablish U.S. industrial leadership.

"Competitiveness," or the growing lack of it, has been a major issue in the United States for several years. But some are becoming concerned that the discourse remains too abstract—at the "bumper sticker" level—and not sufficiently attentive to where the real problems are and what to actually do about them. Unless we get down to the nuts and bolts, they say, there will be more talk but little action, and solutions that do get implemented will be misguided and ineffectual.

*Coming from different backgrounds and positions, **Ralph E. Gomory** (senior vice president for science and technology at IBM) and **Harold T. Shapiro** (president of Princeton University) have each begun lobbying for greater directness, simplicity, and realism about the things that may, or may not, help the United States to compete: Where we really need to be "the best," and where such distinctions do not necessarily translate into leadership; where the limits of universities lie, and where industry must pick up the reins; where greater science literacy is needed, and where the good old three R's are quite sufficient; where technical savvy is good, but working with and respecting many types of people is better.*

Intrigued by the usefulness of their approach and its likely appeal to our readers, Issues in Science and Technology*—with the aid of the Government-Industry-University Research Roundtable and the Committee on Science, Engineering, and Public Policy—arranged a meeting between Drs. Gomory and Shapiro last May in New York City. What follows is an edited transcript of their provocative discussion.*

GOMORY: A lot has been said about the connections between basic research in universities and economic competitiveness, but that relationship is often extremely remote. The competitiveness "process" takes place in industry, at the level of the individual company. What happens in the university laboratory, no matter how promising from a scientific point of view or how potentially important to industry, is often irrelevant because companies cannot or will not use it.

SHAPIRO: The remoteness is even worse than that, I think. Not only is there a chasm between developments in a university lab and industrial competitiveness, even when the new ideas *originate* in industry there is likewise a very big gap between that knowledge and its effective use. Being first in science doesn't mean that someone else can't capture the associated economic and social dividends through better implementation.

GOMORY: That's right. And I think it fits into kind of a life-cycle model about new ideas: You can be the first to introduce a new product based on a new idea—say, the transistor—and universities can play a major role in the early stages. But once it is a product and is out there, the ground rules change—it becomes subject to the process of successive refinements. And that is the race we lose—a race largely run by industries. You can say in an oversimplified way that the universities are doing their job, which is the generation of new ideas, but that industry is doing less well at refining those ideas.

SHAPIRO: I have an interesting example of exactly what you're talking about, Ralph, and that's in the American automobile industry. It takes five years to go from concept to what they call "Job One"—the first car rolling off the line. Meanwhile, our competitors are roughly in a three-year cycle, which puts us two years farther from the market in consumer tastes.

GOMORY: There's also the technical dimension: If one company has a five-year development and manufacturing cycle and the other has a three-year cycle, the latter will look like a technical leader. When its car comes out, the product will have a more recent design, more modern materials, and more highly evolved technology. None of this has anything to do with whether the company with the shorter product cycle invented these features; it just means that it's using ideas at a level of knowledge that is two years more advanced.

SHAPIRO: Most of the examples people use in this kind of discussion come from the manufacturing sector. But I'm worried about the productivity of our service sector as well. I studied in one case an accounts payable function for a very large U.S. corporation and it turned out that a staggering flow of paper was involved just to deliver a part to a machine. I studied the same function with a Japanese firm and it required only one-eighth the support. At the heart of this difference was a qualitatively different relationship between purchaser and supplier, as well as between workers and management at the production facility itself.

GOMORY: I share that worry, Harold. And in the comparison you cite, it seems to me that the difference is directly related to how groups work together. Where there is closeness and trust, between manufacturer and suppliers or between different sections of the same firm—built-up levels of confidence, in other words—those huge paper flows are unnecessary.

But closeness and trust are unlikely when there is separation between principal players, and that is the case within most U.S. companies—development and manufacturing people, for instance, live in different worlds. In U.S. industry, the high prestige is in development. That's where the engineers are, that's where design is, that's where the education is. The manufacturing task is considered to be relatively dull, repetitive, and for uneducated people. Therefore production considerations have not been an early part of the design, say, of a new car or computer or printer. Until very recently, the product was not designed to be manufactured. It was designed to work, to make good print, or to run fast, but it was not designed to be manufactured. When the prototype was ready, you simply handed it to a different group of people—the manufacturing people—and you said, "okay, I made one, you make 10,000."

In Japan, curiously enough, it is the other way around: Manufacturing calls the shots. Manufacturing people are highly trained, but people also move back and forth a good deal between various functions. The distinction we tend to make between the engineers in development and those who replicate their designs doesn't exist in Japan.

Similarly, there are harmonious relationships between manufacturers and suppliers. Often the company *owns* a lot of its suppliers. But even with those they do not own, long-term and trusting relationships are the rule. I would contrast that with our own situation, which is very often arm's-length: We have bidders, we take the low price, and there is a real gap.

Attending to "everything else"

SHAPIRO: You know, Ralph, you said something that to me goes right to the very heart of this issue: that things depend on "how groups work together." If we applied that concept across the board, instead of worrying about just how good our science is at the moment compared to someone else's science, we'd be a lot farther ahead. I'd like to write an essay on this subject, with the title "Science, Technology, Economic Growth, . . . and Everything Else." That is, if we want to get economic growth out of new science and technology, we have to pay attention to what I call "everything else." And the everything else really could not be summarized better than by saying "how groups work together"—how we relate to each other, how we treat each other, and how we *trust* each other.

Being first in science doesn't mean that someone else can't capture the associated economic and social dividends through better implementation.

GOMORY: The natural tendency is to assume at first that the guys in your area are good and the other guys are bad. In my early years as director of research at IBM, my people would often come to me and say, "my thing is really much better than what 'they'—in development, or manufacturing—are doing, but they do not appreciate it, or they are committed to something else, or they are just plain crazy." But I found that when our scientists really understood what the other folks were doing—after they had worked with them on something, seen what they were up against—then they started to understand that those development and manufacturing guys were good guys too.

They live in a different world, though, and they have to abide by different rules. It's true that they didn't accept our "better" way of building the front end of a display, for example, but it is also true that we brought it to them when they were already 11 months into a two-year cycle to finish the product. There was no way that they could adopt our suggestions without slipping the product's timetable six or eight months, which was totally unacceptable.

SHAPIRO: I think there is another great dividend that comes from having different groups—in research, development, manufacturing, and so on—working together, and that is the important and entirely beneficial impact on the science agenda. Many people have the notion that scientists are separated from the rest of us—that they only march to the beat of some special kind of drummer. But history tells us that this is usually not the case. The best science happens when the agenda is informed by issues that bother all of us—the people in development and the people in manufacturing, for example. And needless to say, it produces work that in the competitiveness sense is much more relevant.

But while social and economic dividends can clearly flow from a better understanding of the natural world, we also have to look at this "everything else" category—things other than what is going on in the lab and in researchers' heads.

Two extremely important issues come to mind that affect our competitiveness and that in many ways are independent of our current capabilities in science and technology. One is the question of our overall economic policy: Are we getting an adequate amount of investment in our society or not? My own judgment is that our country has suffered in the past few decades because we're doing too much consuming and not enough investing.

The second issue has to do with education, and by that I mean primarily K-12. A lot of people are working in manufacturing who have high school educations; with modern technology, it's very important how good those educations are. Even if you don't know probability theory, you should still be able to use statistical process control in a manufacturing facility. But one of the things we are suffering from is that, by and large, our high school graduates can't do this, whereas some of our competitors have high school graduates who can.

Who's on first?

GOMORY: I'd like to go back to something discussed at the start. I think that we must better understand a very important distinction—between the economic dividends that come from basic science and the economic competitiveness that comes from being the *leader* in basic science.

I don't think there's a shadow of a doubt that scientific understanding has resulted in tremendous economic advance *for the world.* Basic research leads to understanding, and understanding enables people to do things that they couldn't do before. But there's a major difference between the global economic benefit from some new piece of scientific knowledge and its effect on the competitiveness of any particular country—including the country of origin. There may be many reasons why the basic research cannot be well appropriated locally. Meanwhile, the idea is out there, and whoever can grab hold of it to make something useful can enjoy its benefits.

In the modern world, which has well-developed companies everywhere that are capable of assimilating whatever is new and potentially useful, it's not clear that you have a large advantage by being in the country where an idea first arose. Moreover, industrial competitiveness depends on many factors, some of which we have already talked about—a rapid product cycle, working together, relations with your suppliers—which are critical even if you *are* doing well at appropriating the benefits of science.

So there are two important, but frequently unrecognized, links connecting basic research with industrial leadership: You do not have to be the science leader to be the best consumer of science; and you do not have to be the best consumer of science to be the best product manufacturer.

SHAPIRO: I basically agree with the distinctions you've made; processes are now getting sophisticated enough and changing often enough that as long as a country is a good consumer or implementer of science, it doesn't have to be in first place. But I increasingly get the feeling that it cannot be too far behind, either. If you're in 17th place, you probably can't compete.

GOMORY: Yes, it's hard to imagine that Nigeria, for example, will beat the United States in transistors, even if its companies have a very good work-together spirit. But it's quite possible to be "not first" in science and beat the United States handily, as long as the capabilities that matter are in the right places. One of Japan's great advantages, for example, is that a lot of its technical strength is in entities that are tied to industry or *in* industry, whereas America's scientific strength is pretty much vested in the universities, with a couple of companies thrown in. So even though Japan's universities compared to ours are scientifically weak—and they don't help so much in the idea-generation process—its industries function well in the appropriation process.

SHAPIRO: That's a very interesting point, and it calls into question whether it's in our country's long-term interests to have such a high proportion of scientific talent inside universities, as opposed to other establishments.

Why pull beats push

GOMORY: American companies have to do a better job of reaching out and getting what they need, which may mean more in-house scientific capability and whatever else it takes. I don't think you can put the burden on the universities to do it for them, although there is a lot of talk about that, because of the basic difference between "pull" and "push."

If people are building something as part of a development and manufacturing team, what they can accept depends a lot on what they've got. It depends on what tools they have, whether they accept square shapes or round, whether their engineers are familiar enough with any particular approach being proposed.

Now, you can have a great idea up in the university, and you can go to these product developers and say: "Look, I can make a better valve." But believe me, even if it *is* a better valve, the odds are overwhelming that they cannot accept it. Putting a better valve into their equipment may mean that they've got to change 43 tools, which will make them say "to hell with it."

On the other hand, if the people in industry are familiar with advances in science and technology, they can go out and pick the ones that they can accept—the ones that fit. That's the phenomenon of "pull." By contrast, it is very important not to assign to universities the responsibility for "push"—for transferring ideas into industry. I don't think they can do it. (I'm making a distinction, by the way, between a new idea and something that is established. My remarks here relate to improvements on an existing product. Universities can certainly help new ideas to get started, and they have a superb record in that area.)

SHAPIRO: Let me support the two points you're making—that it may be desirable for firms to have more in-house capability in research and development than they currently have; and that "pull" really works most effectively—with an example from the agricultural chemical industry. A particular manufacturer was trying to tap into the next generation of insecticidal chemicals—and given that the avoidance of toxic waste problems (from its existing product line) was a matter of life and death for this company, it was much more concerned than any university professor could ever be.

Company planners developed a concept that satisfied a bunch of different things they needed, and then they went out and looked for it, all around the world. They pieced together what they needed, based on what they found in four or five different labs in widely different spots. They had enough in-house scientific talent to understand the problem, formulate the concept, test it out with their marketing people and others who would be involved, and then pull from the world of science—in this case, from quite a few nations—what was required.

If we want to get economic growth out of new science and technology, we have to pay better attention to "everything else"—in effect, how groups work together.

GOMORY: What your example illustrates is that "pull" consists of people who know what they need going out and looking for it—and finding it—in a vast universe, rather than asking outsiders who don't know the company's situation to throw pieces at it. "Pull" is much more likely to succeed, moreover, because the burden of finding uses for research belongs not with universities but with the companies themselves.

But by and large, American companies are not doing a very good job in this area, whereas Japanese firms are quite successful at it. They have a different psychology about "not invented here." Not burdened with the Western notion that the important thing is to be the inventor, they are very relaxed about taking other people's ideas. The essential point, they believe, is to have a good product; that is what they are proud of. They will show you something and say: "Look at what I've got. I took this thing, that thing, the other thing"—they will name all the sources—"and here it is, the best product of its kind in the world." By contrast, I have known people in IBM who tended to be defensive about the fact that the original PC was put together using a lot of parts from other companies. If we had been Japanese, the thought would probably not have crossed our minds.

Science and math: Not for everyone

SHAPIRO: As we discussed before, while there is no necessity for us to always be first in science, we cannot be last. Even if we're quite willing to use other people's ideas, that alone requires considerable sophistication. Thus we've got to worry about the training of our industrial people, even of those who are just high school graduates.

But we have the problem that a growing proportion of our population, especially the minority population, simply is not participating in the technology side of our educational system. More and more, students are not taking science and not taking math. I wonder whether this education "deficit" will undermine our efforts, regardless of how much insight we gain on the competitiveness problem. Will we have the human capital necessary to man the system, even if we could design it right?

GOMORY: That's an interesting question, Harold. Everyone instinctively says that we've got to teach young people more math and we've got to teach them more science, but do we need to do so for everyone? I'm not sure. I am sure, though, that they've got to be able to read and write.

SHAPIRO: You'll settle for old-fashioned literacy, is that it?

GOMORY: Well, I would certainly say it's a prerequisite. Beyond that, I don't know. For one thing, I've never seen a survey that estimated how many people we actually need who are scientifically literate, in addition to people who can work together and write letters. It's more of a gut reaction on the part of scientists that everyone should understand science in order to make informed political judgments. And I'm not convinced that it would help much there, so let's put that one aside.

Although I don't know how many people need to understand science, my guess is that it's a minority. What we really need, in my opinion, is to educate everyone in the three R's, which we clearly don't do well enough today. Then we need to devise strategies to identify those students who find science and math interesting or are amenable to learning about them.

Meanwhile, it's not clear to me that we would serve the nation by trying to jam science and math down everyone's throats. In fact, it may be counterproductive. When I was growing up, the high schools always taught algebra and geometry. But believe me, very few of the people who were taught all that knew what they were learning or ever used it again. Teachers argued that it was good mental discipline—they said the same thing about Latin—but for most students, the results were pretty negative.

Today in IBM, we find that there is a need at some of our manufacturing plants to teach technicians a bit of physics in order to do their work. Often, the biggest deterrent in this is math. People are frightened to death of math because they've had such bad experiences with it in school. Ironically, you could get a pretty good intuitive grasp of the physics with next-to-no math, but that would go against convention. In this case, that's the long way around.

SHAPIRO: You raise a very interesting point, Ralph. But don't you think we need more students who finish high school with at least some meaningful exposure to science and math?

GOMORY: If I had to make a guess, I would say yes. But I would also guess that the way to get them is not to try to raise the level of science and math education for everybody, which strikes me as very hard—especially in the short run—but to allow different tracks. Suppose, for argument's sake, that the number of people who now emerge scientifically literate from our educational system is 5 percent. Suppose further that we must double that—to 10 percent. It's a terrible task to try and raise the level of everyone's education when you only need to find the 10 percent of the people who are interested and wish to be taught.

Perhaps a more practical approach in the short run would be to improve a few selected schools—including some with heavy minority enrollments, in order to correct imbalances not based on competence. We could try to attract and keep good teachers there, and incorporate incentives for students to learn. But we should confine these actions to a relatively small number of schools, because only then could the program be feasible.

SHAPIRO: You know, it's quite extraordinary that a very small set of high schools in this country has produced most of its scientists and engineers.

GOMORY: Is that right?

SHAPIRO: Yes. I don't remember just what the number is, but it is quite small. Where something important is going on, it is often income-related, but often it is not; a lot of the rich schools are not in this set.

GOMORY: The smallness of that set suggests that doubling its size—giving us a still-small set—is something we can afford to do. We don't have to boil the ocean of the United States.

SHAPIRO: We could double that number not in any arbitrary or elitist way, but simply in a way that is open—for example, in magnet schools, where people with the appropriate motivation and capacity who wanted to take advantage of the opportunity could do so.

Not by science alone

GOMORY: Since we're talking about education, I cannot help but throw in something else. The United States is a market economy, but where in people's education are they taught how this system operates?

SHAPIRO: Let me connect that with something you said earlier—that it's important how we work together. The market system—driven by the profit motive, or self-interest, or whatever you want to call it—is really a very subtle form of cooperation. At its best, it is a mechanism for cooperation that generates productivity and efficiency.

GOMORY: I agree. But such ideas are rarely taught in our educational system. Other countries are usually more rigorous in teaching their children the advantages of their economic systems.

SHAPIRO: Actually, I think some healthy skepticism may be in our best interest. But what may *not* be in our best interest is the belief that superiority in science alone—at the expense of "everything else"—will ensure this country's economic strength.

The lessons of history tell us otherwise. For example, it was not Britain's science and technology superiority that made it first in the Industrial Revolution. It was political stability, it was the society's concept of private property, it was decentralization of authority in British institutions. It was *not* that the British had better science than did Belgium and France. It is very, very seldom that a monopoly on science alone has produced a tremendous spurt in sustained economic and social dividends. Why is it that we do not read that lesson?

GOMORY: One reason is that the people doing the talking are often the scientists. And the distinction we were discussing earlier—between the economic benefits that derive from science and the competitiveness that being the *leader* in science does or does not bring—is often overlooked. Our very powerful scientific community, in my opinion, does great good for the world—not the United States alone, but the *world.* So as long as we're being cosmic today, maybe the time has come to justify science in a different and more appropriate way. Maybe we could, over the next 10 years or so, gradually transit into a system in which science—because it is good for the advancement of all humanity—would to a greater extent be fostered on a worldwide basis. Things such as the superconducting super collider, if they are to be done at all, could then be done internationally. Problem is, I don't know how to make that transition.

SHAPIRO: Neither do I. But at least we ought to have a certain amount of truth in advertising; we need to be straight about what it is that we are trying to accomplish. When we want to fund work in science that is meritorious for a wide variety of important reasons, we ought to be clear about what those reasons are, where the benefits are, and who will enjoy the benefits. We must avoid the frustration of having paid for all the science and watching someone else get most of the rewards.

What we need to do before anything else, however, is get the message out. Important people—not simply those who make up the government budget but principal players, say, in the IBMs and the school systems of the nation—should have a more informed idea about what is necessary if our country is to achieve leadership. Without any more money, they can make adjustments that will improve our economic competitiveness.

Meanwhile, we have to get rid of the attitude that government is our enemy. We must try to think of the government as an extension of ourselves for purposes that we cannot achieve by working separately. In my view, those purposes should include the development of decent public policies for encouraging investment rather than consumption, for promoting economic growth, and for establishing appropriate regulation (or, alternatively, avoiding overregulation). And despite our remarks about paying attention to "everything else," I am all in favor of even greater funding for science because that enables great things to happen.

However, the question an economist always asks is: Given limited resources, where are you going to put them? Great things can happen *wherever* you place your emphasis, so the challenge is to pick the areas of maximum impact. In order to achieve such impact, people have to start thinking somewhat differently. Any one person—even the CEO of Ford or the head of the Senate Budget Committee, for example—can't make enough of a difference. That will require some fresh insights from a whole lot of people. But the problem isn't difficult as it may appear. The debate doesn't have to be radically transformed, just sort of rotated a bit.