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National Productivity and Computers

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National Productivity and Computers

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We are the first generation of Americans who think that our children will not live substantially better than we do. This article takes a hard look at US productivity, education, technology, and the prospects of improving national output.

We are the first generation of Americans who think that our children will not live substantially better than we do, and we don't know why.

In the United States, national output has been growing very slowly over the past twenty years, and the average real wage has been stagnant. What little growth there has been is due to a growing work force and largely to the entry of women into the working world.

While economists disagree on many things, they do agree that they don't understand this slowdown in national productivity. Since there seems to be no accepted answer, I feel free to set forth my personal and idiosyncratic views. While these views have been largely shaped by my exposure to the US experience, I hope my observations will have some global relevance and interest as well. In the long run, productivity matters to us all.

HISTORY

Although people often say that the US became the world's industrial leader after the Second World War when the economies of other industrialized countries were in ruins, this is really not the case. By the 1920s, the US had already become the world's leading industrial power. It produced more than two times the iron, steel, and electricity of France, Germany, and Britain combined and more than twice as much per capita. This huge industrial base was built on mass-production manufacturing methods and owed little to abstract science and still less to American science, which at that time was relatively undeveloped.

On this massive and efficient industrial base were built the overwhelming air and sea armadas of World War II. It was not World War II that produced US industrial strength, but US industrial strength that was largely part of America's contribution to winning that war. Then, while the economies of the war-ravaged countries took time to rebuild, US industry continued to grow. But that only increased the formidable industrial advantage that already existed; it did not create it. In fact, rather than being the origin of US competitive advantage, the lack of competition in some industries was a source of future inefficiencies and disadvantages.

The rise of science

The war's end brought about another change that had both good and bad effects. The great and very visible achievements of scientists during the war—for example, the atomic bomb and radar—gave both politicians

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and the public a feeling (and in my opinion a correct feeling) for the immense power that resides in scientific knowledge. And this thought—that science is power—led to a government emphasis on science and basic science support.

This emphasis had many consequences. On the positive side, it helped the rapid development of many branches of science. In the case of solid-state physics, for example, that development led quickly to the transistor, an invention that grew out of the basic understanding of solid-state physics in much the same way that the atomic bomb had grown out of the understanding of the atomic nucleus. The transistor in turn made possible that astonishing process of miniaturization that drove the rapid growth of the US semiconductor and computer industries.

However, this science emphasis also had a negative side. The wartime development of the atomic bomb was on everyone's mind. There, scientists not only invented and understood, they separated the necessary uranium. They not only designed but also tested and built the bomb. It appeared that all this was science, or at least it could be done—and done well—by scientists. As a result, engineering was overshadowed.

In some universities, engineering degrees were supplanted by degrees in engineering physics or in applied science. Companies that were really engineering companies called their chief technologist the chief scientist, even if that position had little to do with science. Manufacturing all but vanished from the engineering curriculum and, along with it, any emphasis on design for manufacturability.

US universities found that money came from the government, not from industry, and they turned their attention in that direction. The notion became pervasive in university and government circles that engineering was *merely* applied science. This widely accepted but fatally flawed view shortchanged the immense nonscientific, experience-based component of any large complex practical system, and it left the issue of manufacturing as an exercise for the reader.

In US industry, then, this science emphasis had its consequences. The semiconductor and computer industries boomed and research labs blossomed—many dedicated to pure research and many destined therefore to commercial failure. As a consequence, manufacturing went its own way toward an eventual rude awakening.

Sputnik

In the early postwar period, the US government's preoccupation was not the economy but the military and ideological race with the former Soviet Union, a race

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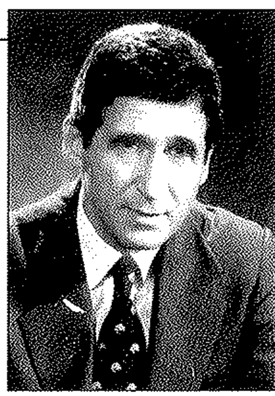

Ralph E. Gomory is president of the Alfred P. Sloan Foundation, after having been at IBM for 30 years.

Gomory graduated from Williams College in 1950, studied at Cambridge University, and received his PhD in mathematics from Princeton University in 1954. Gomory served in the Navy and was a Higgins Lecturer in Mathematics at Princeton before joining IBM's newly founded Research Division in 1959 as a research mathematician.

At IBM Research in the early 1960s, Gomory published papers with Paul Gilmore on the knapsack, traveling salesman, and cutting-stock problems (the last of which won the Lanchester Prize of the Operations Research Society in 1964), and with T.C. Hu on flows in multiterminal networks and continua. In the late 1960s, he developed the asymptotic theory of integer programming and introduced the concept of corner polyhedra. In the early 1970s, he collaborated with Ellis Johnson in investigating subadditive functions related to group problems that had played a role in cutting-planes and corner polyhedra.

Gomory became director of research for IBM in 1970, with direct responsibility for IBM's Research Division comprising the research laboratories at Yorktown Heights, N.Y. (the Thomas J. Watson Research Center), San Jose, California (now the Almaden Research Center), and Zurich, Switzerland.

Gomory was elected a vice president of IBM in 1973, named to the company's Corporate Management Board in 1983, and elected a senior vice president in 1985. In 1986 he was named to the newly created position of Senior Vice President for Science and Technology, which combined responsibility for research with other technological functions. He retired from IBM in 1989 and became President of the Alfred P. Sloan Foundation, the position he now holds.

Gomory's research has been recognized (in addition to the Lanchester Prize) by the title of IBM Fellow, IBM's highest technical rank, and the Harry Goode Memorial Award of the American Federation of Information Processing Societies and the John von Neumann Theory Prize given jointly by the Operations Research Society and the Institute of Management Science. He was elected to the National Academy of Sciences in 1972 and the National Academy of Engineering in 1975.

Gomory's technical leadership has been recognized by the award of the Medal of the Industrial Research Institute (IRI) in 1985, and by the Institute of Electrical and Electronics Engineers (IEEE) Engineering Leadership Recognition Award in May 1988.

In June 1988 Gomory was awarded the National Medal of Science by the President of the United States, recognizing both his individual work and his technical leadership. In 1993 he received the Arthur M. Bueche Award of the National Academy of Engineering.

symbolized by Sputnik. Who can forget the extreme national reaction that greeted the Soviet launch of Sputnik? The well-known nuclear scientist Edward Teller, for example, asserted that the US had suffered a defeat worse than Pearl Harbor. Out of this disturbed national atmosphere came a political decision to put men on the moon and, because of the US science emphasis, to increase funding for science and science education.

At that time, I was a young naval ensign stationed at the Office of Naval Research and in a good position to see what was going on. I remember my surprise when I saw that Sputnik and the Soviet superiority in long-range rockets had produced sharply increased funding for the esoteric mathematical subject of algebraic topology.

US emphasis on science and technology has left the issue of manufacturing as an exercise for the reader.

As the Soviet threat became more contained, the realities of the international industrial scene began to hit home. But the ability to see and comprehend the reality of an evolving superior overseas manufacturing capability, with a superior, more rapid method of development were obscured by the US focus on science and on the most advanced technology.

High-tech developments

Many will remember the US reaction to high-tech events such as the Japanese VLSI program and knowledge-based Fifth Generation program and, more recently, to the Swiss discovery of high-temperature superconductivity. Each of these events produced a strong government reaction. In the latter case, the President of the United States even attended large public meetings to discuss superconductivity. There was very strong sentiment that the US couldn't afford to lose this great new technology because it would bring with it industrial dominance in that field. But behind that sentiment lay an almost total ignorance of the other factors that affect actual industrial success.

I was fortunate in being able to see these events more or less at first hand. I had the opportunity to visit both the VLSI lab and the Fifth Generation group, and the discovery of high-temperature superconductivity was made in a Zurich lab for which I was directly responsible. With respect to Japan's advanced computer research, it was clear that while these programs were of some value, the real strength of the Japanese computer industry lay elsewhere in its superior development skills, dedicated work force, and better understanding of manufacturing. However, these were not qualities that were readily perceptible in the US given its science and high-tech focus.

In the case of superconductivity, all of us involved saw the enormous gap that lay between the materials we had discovered and any practical application. But that did not prevent headline news about the subject: highly publicized and unrealistic visions of cheap electricity through superconducting power lines and rapid transportation through levitating trains. All was grist for the mill that equated discovery with industrial product. Unfortunately, that point of view left little room for the sustained development efforts that would be needed over a period of many years to produce practical results. It was easier, and it fitted the dominant paradigm, to spend science money in these areas.

It is only in the past few years that the American government has begun to realize that science and advanced technology are not the be-all and end-all of industrial productivity.

EDUCATION

Like science and advanced technology, education is something that the US turns to in moments of crisis. But it is often brought in as an explanation of more than it can explain. By "education," I don't mean self-education or knowledge gained on the job (like learning how to run an evaporator, or the ability to make disk heads that fly at incredibly low heights, or the ability to design or maintain complex pieces of software). The presence or absence of these skills is not lamented, or measured, or linked to productivity and industrial progress, whereas school performance is. The US lack of international competitiveness is often attributed to the shortcomings of its schools.

US schools below the college level are widely, and probably correctly, believed to have decayed. Their students certainly have test scores lagging behind those of many other advanced countries. Today we see many charts showing that Japanese and European school attainment is a lot better than that of US students, especially in science and math. As a result, there is now in the US a stress on performance in science and math at the high school level. The US has as a national goal to be the world leader in those test scores by the year 2000—although I don't know anyone who has the faintest idea how that is to be done.

In looking at these goals and these comparisons, I can remember almost identical charts from the Sputnik period, only then the charts portrayed Soviet performance in calculus and told us how many engineers the Soviets were producing. And there were a lot—it appeared at that time that the US would be swept away by a tidal wave of Soviet engineers. But that didn't happen because there were other factors that mattered a lot more.

I suggest that we should learn from the Soviet experience that there is so much more involved in productivity than education. And once again we need to be sure that our predisposition—in this case a predisposition toward assuming that education is the answer—does not blind us to reality. Not much time has been spent linking school performance in a causative way with industrial leadership or national productivity. It is simply assumed that the connection is obvious. As one who disliked intensely all but one of the many schools I attended in my life, and often wondered why we learned what we did, my personal predisposition is to doubt that simple connection.

What we learn in school

What is it that we learn in school anyway? We can split what we learn into two main components. First, there is the actual subject matter—for example, reading, writing, and arithmetic initially, and at a later stage history, French, or plane geometry. Then, there is something else called process.

SUBJECT MATTER. Basics are certainly essential to subject matter. Without reading and writing and some arithmetic, one has little chance in the modern world. But much of the rest of the curriculum is an artifact of history more than it is justified in terms of practical effect today. Until remarkably recently, Latin was an integral part of the curriculum and was justified on all sorts of grounds other than what was clearly the fact. It was there for purely historical reasons. Schools originally educated clerics, and clerics needed Latin.

Whether being world leaders in algebra and plane geometry is more necessary than learning Latin for most of the population is questionable. These subjects, or perhaps more accurately something like them, are certainly necessary for a part of the population, but probably not a very large part. The difficulty is knowing which part truly needs them, but I will return to this point later.

School learning is also curiously academic and intellectual. There are many skills that are valuable to our society that are not purely intellectual. When it comes to playing the piano, fingers know better than heads where the keys are. Much work requires a mixture of physical and intellectual skills, but we tend to undervalue this and prepare people as if they all were going to college, in spite of the fact that half don't.

We need to prepare people for useful lives that can be based on skills other than the classroom ones. Different people are good at different things and learn in different ways. We should respect a wide variety of abilities because we can use them. We should think about what we teach and why, rather than simply trying to do more of the same. Knowledge of computers and how they work might well be an improvement over plane geometry for most people.

PROCESS. There is something else in school that is more important than subject matter that I call *process*. This means learning to get to school on time, learning to sit through classes that can be interesting but are also often boring. Learning to get along with classmates. Learning to respond adequately to the teacher. Learning to do homework, which is often not what we want to do, but we learn to do it anyway. Learning to learn things that often appear pointless but nevertheless have to be learned. Basically, we learn to do what has to be done.

Learning process is necessary. It may well be that the primary purpose of school is not to teach us subject matter but to be a giant simulator of work life.

However, as a simulator, school has certain important failings. It generally is a place where you are told what to do. Ironically, one strength of the US economic system is that in this sense it is very unschool-like. The US economy has been greatly helped by the ability and inclination of people to go out on their own, whether splitting off from large companies or starting in something new from scratch. This attitude is not generally fostered in school. And since it isn't, it may be better to allow people to have some time that is their own and not connected with school. From this point of view, proposals to lengthen the school day or school year may be dead wrong. Or at least dead wrong once we get past the essentials. Getting better at plane geometry by lengthening the school year may have a cost that exceeds the benefit.

Opening or closing minds

If you are very fortunate at school, you may also learn that learning can be exciting, that it opens new horizons, and that it is conceivably something that you can do for yourself outside of school. But this realization varies enormously with the individual and the individual circumstance. I don't know whether in that sense more minds are closed or opened to learning by ordinary school experience.

Learning outside school

But there are ways of learning outside school, and they are improving. People can learn all their lives. Many do learn on the job and a smaller number quite on their own. It is here that the computer can display its power in a decisive way.

Learning no longer needs to be limited to those who can physically attend school either full time or part time. Through computers and communication, with the technology that is widespread today and without waiting for the future broadband communication, we can create learning environments for those who want to learn at home, at work, or wherever. And this learning environment can include not only text or video equivalents, but—probably more important—people to interact with.

We learn from classmates as well as from faculty and from texts. And all of these can be provided synchronously over the wires. We can today have a bulletin board that you share with your 30 classmates where you can write "I can't do the problem on page 17, does anyone have an idea." Or you can talk (more respectfully) to the professor. Or your homework, when properly constructed, can be corrected, graded, and returned to you almost instantaneously over the wires by software, thus providing quick feedback, which is much better for learning than getting it two weeks later.

Much of the curriculum is an artifact of history more than it is justified in terms of practical effect today.

Training of every type can be provided remotely and asynchronously in this way. If learning can be done on demand at any point in one's life, the early choice becomes less critical. If you did not choose calculus, and you regret it, you can still learn. The barriers to this kind of learning today are not technical; they are mainly institutional. We are not yet organized to provide education in this way.

The US to date has narrowly focused on improving the traditional subject matter as the road to national salvation. The rationale for this is obscure. It is also a difficult path, and there may be better alternatives. It is also possible that this rather narrow focus on better schools is keeping us from seeing things that are more relevant to national productivity.

WAYS OF WORKING

In the 1970s, I had the opportunity to visit Japan and see what was going on in development. Although the VLSI effort was what the US saw because of its high-tech and science focus, there was much more to see. Indeed, there were striking contrasts with the US. There were other forms of government support, but much more important was the inherent excellence and rapidity of the Japanese development and manufacturing effort.

The Japanese computer manufacturers simply were producing things more rapidly and cheaply than we were, due to sheer manufacturing skill and to more manufacturable product design. These improved methods of work have subsequently made their impression on the rest of the world. However, it remains a question whether it is the actual methods of doing things (for example, just-in-time or lean production) that make the difference, or whether it is the attitude, the desire to succeed, the attention to detail, or the devotion to the company that calls forth an extra effort.

However, there is evidence that the *detail* of the way we work does make a difference—whether this detail is attitude or technique, whether it is conscious knowledge embedded in an organization's structure or in the unconscious habits, culture, and ways of doing things. Studies sponsored by the Sloan Foundation have shown that the same steel plants in the same country with equivalent technology can have major differences in productivity, and this is even more true for semiconductor plants.

Uncaptured detail

Clearly, detail matters. This point does not surprise those who have been in close touch with actual development or manufacturing, but it is not usually part of the thinking of outsiders, including economists and others who seek to explain the productivity or lack of productivity of nations.

There is something in the detailed way of doing things that makes not a small but a large difference. And that something is not easily measurable from the outside. This component of productivity is not due to advanced technology, nor to the level of education of the work force or of investment, nor to anything that shows up in the statistics that are a part of national accounts.

The way we work makes a difference—whether it is attitude or technique, whether it is conscious knowledge embedded in an organization's structure or in the unconscious habits, culture, and ways of doing things.

Macroscopic views. This dependence on the actual detail of how things are done does not deter people from taking much more macroscopic views.

During a recent talk, a senior US official emphasized the US underinvestment in R&D and its effect on US productivity. The official pointed out that Germany spends 2.5 percent of its gross domestic product (GDP) on R&D, that Japan spends 3.0 percent, and the US only 1.9 percent. In fact, the official suggested that there should be a small additional tax for the government to use for additional industry-related R&D. (American readers will recognize that this talk occurred before the last elections.)

Statements of this sort are often very persuasive. We hear much about the short-range mentality of US industry and about cutbacks in R&D. Connecting this to productivity seems both plausible and alarming. However, we have already warned about the effect of detail earlier, so we suspect that we are dealing with a difficult subject and that we should approach any sweeping statement with caution. In this case being cautious is rewarded. Let me explain why.

Almost all R&D (92 percent) is done in the manufacturing sector. This squares with common sense observation—whoever saw a bank report with any R&D expenditure? The same holds for most service firms. The manufacturing sectors of Germany and Japan are bigger than that of the US as a proportion of GDP. (The numbers are: Germany, 30.6 percent of GDP; Japan, 30.8 percent; and the US, 19.0 percent.) If all manufacturing firms in all three countries were equally R&D intensive, R&D as a percentage of GDP would come out in the same proportions as the size of the manufacturing sectors. It wouldn't mean that foreign firms are more R&D intensive, just that the manufacturing sector is larger in Japan and Germany. This suggests that US firms individually are spending on R&D at a rate that equals Japan and exceeds Germany.

Underinvestment. There are similar difficulties with the similar conclusions that are often drawn about US underinvestment as the source of slow growth. This argument, like the R&D argument, has emotional appeal. It fits well with the notion that Americans spend too much and live on credit. It seems only just that this disregard for the future should be found responsible for slow growth. But it is not clear that this is really the case.

Perhaps productivity will be understood only by more detailed studies at the industry level or even at the corporate level. But people do seem to want simpler, across-the-board explanations.

MYTHS AND THE MACROSCOPE

There are real difficulties in obtaining such explanations. National economic performance is harder to see and understand than one might think. We are all used to the idea that there are objects such as microbes that matter but are too small to see without a microscope. We are less used to the idea that there are things too big to see, but there are, and a national economy is one. We cannot see the functioning of the economy. That functioning is spread out in thousands of locations; it depends on the efficient or inefficient actions of millions of people in plants or offices; it depends on the motion of hundreds of thousands of trucks and on the trillions of calculations by our computers.

Statistics and the macroscope

It would be wonderful if we had a macroscope to see this huge economy function, but we don't. Statistics is in fact our attempt at a macroscope, and it only functions erratically. It functions erratically because if we have the right overall picture, then the statistics can size it correctly and tell us more about it, but if we don't, the statistics won't tell us that we don't have it right. The example I gave about R&D illustrates this. If we have (either explicitly or unconsciously) a picture of R&D as being done right across the economy, our statistics tell us one thing. If we have another picture, which gets down to sectors and their R&D tendencies, it tells us quite another thing. And we don't always have the right picture of these large complex things.

Why people believe

Given this lack of an overall picture, people will tend to believe what they want to believe or what makes rough sense to them. If the economy is not growing and some-one attributes it to the schools, and your local school isn't good, and you know that schools matter, then this explanation makes sense to you.

Similarly, if we know that R&D is important and that as a nation we do less than some other developed countries that grow faster, lack of R&D makes sense as an explanation of low growth. The same applies to the investment argument. Unfortunately, complex realities do not always match these homey truths, but these homey beliefs die hard when the facts are unclear.

The Columbus story

The most striking example of a myth's power to persist not only in the face of uncertainty but in the face of facts is the Columbus story. The version of the Columbus story that most of us know is straightforward. Columbus knew the world was round and that he could reach China from Europe by sailing west. Most people at that time thought the earth was flat, and that instead of reaching China, Columbus would reach the edge and fall off. This widespread belief made it difficult for him to obtain venture capital.

This flat earth/round earth contrast is very satisfying, since the good guy, Columbus, is right and is rewarded in the end by discovering America. However, what really happened is different.

Both Columbus and the Court of Spain knew that the earth was round. They disagreed on its size. Columbus had in fact an incorrect and very small earth size. On Columbus' small round earth, China was about as far away from Spain as the Caribbean actually is, and that is why he thought he could get there. The Court had a correctly sized earth, which was not surprising, since the size of a round earth had in fact been known from classical antiquity. The court's view was that Columbus' chance of sailing nonstop to the actual location of China and then getting back was slight.

Columbus was wrong, but in the end that didn't matter. We prefer the myth to the reality, and this particular myth has withstood both the test of time and the presence of the facts right up to the present.

PROGRESS ACROSS THE ECONOMY

While the difficulty of "seeing" very large objects applies to all sectors of the economy, many of the aspects of science, advanced technology, and engineering that I have described have been most relevant to the manufacturing sector.

Historically, manufacturing sectors have had high rates of productivity growth, higher than most other sectors. This contrasts with people-intensive service industries that don't seem to get cheaper year after year, but at least until recently seem to get more expensive for the same result. Classroom teaching and nursing are significant examples of this.

Progress in manufacturing is not enough. Progress across the board is necessary or else things will actually get worse in the other sectors. Let me explain why, courtesy of my friend the economist William J. Baumol.

Suppose there is a sector of the economy that makes rapid progress in productivity. Because of the rapidly increasing productivity, which means value of output per capita, higher wages can be (and are) paid. Now workers in other sectors can in many instances choose jobs in this highly productive sector. Less productive sectors will have to offer somewhat higher wages than before to obtain or keep employees.

Consequently, real wages go up in other sectors as well, and they will go up whether there is any improvement in productivity or not. The result is that these sectors will actually get worse in the sense that it costs more to get the same service. And of course that is what we see happening in classroom education and in nursing.

THE SERVICE SECTOR AND COMPUTERS

While much scientific knowledge does apply preferentially to the manufacturing sector, this is not true of information processing. Information processing is usable across the board. Computers seem like the ideal weapon in the battle to make progress in the service industries. Surely, they have a natural role in education. Surely, they have a natural role in retailing by, for example, enabling the wholesaler or manufacturer to restock rapidly based on instantaneously updated information. Surely, there is productivity inherent in the ability to develop programs that use the history of all previous mortgages to decide on the creditworthiness of today's applicant.

We are all used to the idea that there are objects such as microbes that matter but are too small to see without a microscope. We are less used to the idea that there are things too big to see, but there are, and a national economy is one.

The lack of productivity

In spite of this obvious applicability, and despite the fact that computers are of course widely used in service industries, their contribution to measurable productivity has been slight until recently. This may in part be a measurement problem. However, it may also be something else.

A recent small-scale Sloan study indicates that when reengineering or its equivalent was done in the past, and the reengineered work required fewer steps and fewer people, the tendency was to find other things for the displaced people to do. I find this easy to believe because it is the natural human tendency to want to find jobs for the displaced people. And as to the ability of an organization to find or create those jobs, if you believe with C. Nothcote Parkinson that work expands to fill the time available, it is only a short step to believing that work expands to use up the people available. Many reengineering discussions recognize the difficulty of obtaining the potential productivity increases made possible by computers but are inhibited by various aspects of organizational and individual behavior.

However, in today's harsher climate (in the US), with corporate downsizing and so forth, there are signs that tolerance of the established way of doing things is changing. There are strong indications that reengineering and the use of computers today may well mean the same output from fewer people. This is increased productivity. But it may also be a problem for those people who have been displaced by technology.

Technology and the problem of jobs

We touch here on the old question of whether technology destroys or creates jobs. We have just described job destruction. But technology also creates jobs.

Thomas Edison, the great pioneer of the electric light, said "we will make electricity so cheap that only the rich will burn candles." And they did. And there are far fewer candle makers now than then, but more people employed in the electric power and lighting industries than ever could have made candles. Because the cheapness of electricity lifted lighting to an entirely new level of usage.

So both job destruction and job creation can happen. So far, the evidence points far more to job creation than job destruction, but that observation does not ease the pain for the individuals involved.

The job problem

Two hundred years ago most people lived on farms and could make most of what they needed. If they were willing to work, they could be productive members of society. To a considerable extent they could grow their own food and even make their own clothes. Outside of the army and the navy there were at that time almost no large organizations.

In today's harsh economic climate, there are signs that tolerance of the established way of doing things is changing.

Today this has completely changed in highly industrialized countries with their complex products. Certainly, no one person can make a car. To make a car requires a huge and complex organization. Even to make clothes the way they are made today requires a huge and complex organization.

The individual cannot be a productive member of society if he or she cannot fit in somewhere as a cog in one of those giant wheels. It is not enough to want to work or be willing to work. You must have either the ability or the training to fit into one of those organizations. And this is complicated by the possibility that the same skills you have may be available in a less developed country at a much lower price. And cheap sea transportation and cheapness of information transmission are rapidly making that competitive person into the person next door.

Societies today tackle this job problem in different ways. Some put the burden on the individual, some on corporations, some on the government. Nowhere is it done well, but it is a problem that will not go away. We must in the long run solve our national productivity problems in a way that allows people to have jobs and remain productive.

THE PROBLEM OF NATIONAL PRODUCTIVITY is not well understood, yet it matters enormously. It may be that the answer cannot be obtained from those who look on from a great distance. Perhaps the causes of productivity are too detail sensitive for that. Computer professionals more than any other group are contributing to the improvement of productivity. Perhaps they can also contribute to its understanding.

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