SMALL, HIGH TECHNOLOGY FIRMS, INVENTORS AND INNOVATION

HEARINGS

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CONTENTS

WITNESSES

APPENDICES

man Research; and Professor Albert Shapero, from Ohio State University.

Gentlemen, we are delighted to welcome you here today. Without objection, the entire text of your prepared statements will be included in the record. We invite you to proceed with the presentation of any or all of your statement as you see fit. We would like to begin with you, Dr. Mansfield.

[The biographical sketch of Dr. Mansfield follows:]

STATEMENTS OF DR. EDWIN MANSFIELD, PROFESSOR OF ECONOMICS, UNIVERSITY OF PENNSYLVANIA; DR. AARON GELLMAN, PRESIDENT, GELLMAN RESEARCH; AND ALBERT SHAPERO, PROFESSOR OF MANAGEMENT SCIENCES, OHIO STATE UNIVERSITY

Dr. MANSFIELD. Thank you very much, Congressman Gore.

I have been asked to describe very briefly the role and importance of technological innovation in the American economy, which is obviously a considerable task, particularly in 10 minutes.

Technological change consists of advances in knowledge concerning the industrial, agricultural and medical arts. Such advances result in new and improved processes and products as well as new techniques of organization and management. The fact that technological change plays an important role in permitting and stimulating the growth of per capita output seems self-evident, but when one wants to go beyond such bland generalizations to a quantitative summary of the contributions of technological change to the rate of economic growth, a number of basic difficulties are encountered.

For one thing, it is hard to separate the effects on economic growth of technological change from those of investment in physical capital since, to be used, new technology frequently must be embodied in physical capital, that is, new machines and plant. Nor can the effects of technological change easily be separated from those of education since the social returns from increased education are enhanced by technological change and the rate of technological change is influenced by the extent and nature of society's investment in education.

Despite these and other problems, economists have tried to obtain quantitative measures of the importance of technological change to American economic growth. For example, Edward Denison, formerly of Brookings, and now with the Department of Commerce, concluded that the advance of knowledge is responsible for about 40 percent of the total increase in national income per person employed in the United States during 1929 to 1957.

To quantify the effects of technological innovations on the economy, economists have devoted considerable attention to the estimation of the social rates of return from technological innovations, the social rate of return being analogous to the rate of return earned on a private investment. Specifically, the social rate of return is the interest rate received by society as a whole from the investment in a new technology. Of course, there are many problems in measuring the social rate of return from an investment in new technology. Nonetheless, assuming that the innovation is basically resource saving in nature, a technique has been devised to provide at least rough estimates of an innovation's social rate of return. This technique has been used to obtain published estimates of the social rate of return for about 100 innovations.

The results of these studies, although obviously tentative, seem to be interesting from the point of view of public policy. First, the social rates of return tend to be very high indicating that if these innovations are at all typical, investments in new technology have paid off handsomely to society at large. For example, one study of 17 industrial innovations, most of which were minor, not major

In conclusion, the early eighties have been a period of reexamination of the American economy. Beset by extremely high rates of inflation, high rates of unemployment, deficits in our balance of trade, basic structural problems in major industries like steel and autos, and very low rates of productivity increase, the American economy, long the engine on which our people, and to some extent other peoples as well, could count for material progress, has seemed to be in trouble. Whether this trouble will prove only temporary depends upon the policies adopted by our Government, the actions taken by our firms and the attitudes of our people.

The policies, actions and attitudes required to revitalize the American economy are of many types. Proper monetary and fiscal policies are essential. So is proper attention by firms to long-range objectives and to such apparently mundane matters as quality control. In reacting to our current problems, it is very important too that policymakers both in the public and private sectors recognize the central role played by technology.

As pointed out above, it has been estimated that 40 percent or more of the long-term increase in output per person employed in the United States has been due to technological change. While estimates of this sort are subject to many, many limitations, it certainly is true that technological change has been responsible for a substantial share of our past productivity growth. Moreover, as indicated above, the rate of innovation in the United States has an important influence on the competitiveness of U.S. goods in the world markets and on our rate of inflation. Thus, there can be little question concerning the significance of technological innovation to the American economy.

Thank you.

[The prepared statement of Dr. Mansfield follows:]

working conditions, provided a wide variety of extraordinary new products, increased the flow of old products, and added a great many dimensions to the life of our citizens. At the same time, technological change also has its darker side. Advances in military technology have enabled modern nation-states to cause human destruction on an unprecedented scale, modern technology has contributed to various kinds of air and water pollution, and advances in industrial technology have sometimes resulted in widespread unemployment in particular occupations and communities. Despite the many benefits that society has reaped from technological change, no one would regard it as an unalloyed blessing.

A technological innovation is defined as the first commercial introduction of new technology. Research and development is only a part of the process leading to a successful technological innovation. The first part of this process takes place in the interval between the establishment of technical feasibility and the beginning of commercial development of the new product or process. This time interval may be substantial (although it is shorter now than 50 years ago). For example, it often was about a decade for important postwar innovations, like numerical control, freeze-dried food and integrated circuits. The second part of this process takes place in the time interval between the beginning of commercial development and the first commercial application of the new process or product. This time interval contains a number of distinct stages--applied research, preparation of product specification, prototype or pilot plant construction, tooling and construction of manufacturing facilities, and manufacturing and marketing startup. In all, this time interval has often been about five years for important postwar innovations.

a minor percentage of the increase was due to increases in the amount of capital employed per worker.

Solow's measure of the effects of technological change also included the effects of whatever inputs were excluded, such as increases in education or improved health and nutrition of workers, as well as economies of scale, improved allocation of resources, and changes in product mix. To obtain a purer measure, Edward Denison attempted to include many factors--for example, changes in labor quality associated with increases in schooling--that had been omitted, largely or completely, by Solow and others. Since Denison's study was relatively comprehensive, it resulted in a lower residual increase in output unexplained by the inputs he included than did Solow. Specifically, Denison concluded that the advance of knowledge--his term for the residual--was responsible for about 40 percent of the total increase in national income per person employed during 1929-57 in the United States.

4. Rates of Return from Investments in Innovation

To quantify the effects of technological innovations on the economy, economists have devoted considerable attention to the estimation of the social rates of return from technological innovations, the social rate of return being analogous to the rate of return earned on a private investment. Specifically, the social rate of return is the interest rate received by society as a whole from the investment in a new technology. Of course, there are many problems in measuring the social rate of return from an investment in new technology. Any innovation, particularly a major one, has effects on many sectors of the economy, and it obviously is very hard to evaluate and summarize these effects. Nonetheless, assuming that the innovation is basically

5. Innovation and Inflation

Inflation clearly is one of the most serious problems facing the American economy. Via its effect on productivity, innovation tends to reduce inflation, at least in the medium and long run. Total cost per unit of output equals total cost per hour of labor divided by output per hour of labor. Thus, the rate of increase of total cost per unit of output equals the rate of increase of total cost per hour of labor minus the rate of increase of labor productivity. If the rate of increase of labor productivity (i.e., output per hour of labor) is high, the rate of increase of total cost per unit of output will be much lower than the rate of increase of total cost per hour of labor. But if the rate of increase of labor productivity is low, the rate of increase of total cost per unit of output will be almost as great as the rate of increase of total cost per hour of labor. Of course, factors other than the slowing of our rate of productivity growth have been major culprits responsible for the excessive recent rates of inflation in the United States. But this factor nonetheless has been an important one.

To illustrate how innovation exerts a restraining influence on inflation, consider petroleum refining. According to a careful study by John Enos, the cost of enough gasoline for 100 ton-miles of transportation would have been $1.47 in 1955 if the Burton process had still been used. Instead, because of a number of major cracking innovations, the actual cost was only 26 cents. Or take the case of ammonia production. The development and introduction of large-scale ammonia plants in the Sixties reduced the cost of ammonia by over 20 percent, according to SRI International. These are not isolated cases. In any R and D-intensive industry, it is relatively easy to find illustrations of this sort.

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Although it is very difficult to measure international differences in technological levels, the available evidence suggests that the United States long has been a leader in technology. But in the past 15 or 20 years, the U.S. technological lead has been reduced in many areas; in some areas, it no longer exists at all, according to the judgment of many leading engineers, scientists, and managers. Obviously, this has had, and will have, an important effect on our trade position in many major industries. (See Mansfield et al. (forthcoming).)

7. Conclusions

In conclusion, the early 1980s have been a period of reexamination of the American economy. Beset by very high rates of inflation, high rates of unemployment, deficits in our balance of trade, basic structural problems in major industries like steel and autos, and very low rates of productivity increase, the American economy, long the engine on which our people (and to some extent other peoples as well) could count for material progress, has seemed to be in trouble. Whether this trouble will prove only temporary depends upon the policies adopted by our government, the actions taken by our firms, and the attitudes of our people. The policies, actions, and attitudes required to revitalize the American economy are of many types. Proper monetary and fiscal policies are essential. So is proper attention by firms to longer-range objectives and to such apparently mundane matters as quality control.

In reacting to our current problems, it is very important that policy makers, both in the public and private sectors, recognize the central role played by technology. As pointed out above, it has been estimated that 40 percent or more of the long-term increase in output per person employed in the United States has been due to technological change. Although estimates

study we are in the process of completing for the Small Business Administration.

The title of this study is "The Relationship Between Industrial Concentration and Technological Innovation." It holds that small firms produce significantly more innovations per employee than do large firms. This is drawn from a different set of data than had previously been used and supports that hypothetical about the crucial importance of small firms on a macroeconomic level.

Second, the importance of small firm innovation as measured by technical and economic significance are approximately equal to those of large firms. Small firms bring their innovations to market much more rapidly than do large firms. They tend to pass more rapidly than large firms through this process we call innovation from ideation or conception on the one hand to market introduction in an arm's length transaction at the other end. In highly concentrated industries, small firms tend to innovate, to generate the raw materials and indeed, carry those exploitable raw materials forward into innovation more often based on the number of people employed than do large firms in concentrated industries. In concentrated industries, the corollary is that larger firms tend to innovate below expectation, with "expectation" being defined quite precisely in the study.

Larger firms in concentrated industries tend to acquire more of their innovations from other firms than do smaller companies; that is, large enterprises in concentrated industries more often tend to acquire the raw materials for their innovations from smaller companies, either by acquiring the small enterprise or by licensing or some other appropriate arrangement.

This leads to a hypothesis that I think is of extreme importance and which has rarely been advanced; namely, that what is good for small enterprise, particularly small technological enterprise in the United States, happens to be good for large enterprise as well.

One of the things which surprises me every time I get involved in this field is how few large enterprises support small enterprise explicitly, either through helping Congress understand the problem or taking explicit actions to support small enterprise themselves. It is not surprising, for example, that I find Control Data here today. They are one of the exceptions to the rule. But there should be so many large enterprises explicitly interested in this that Control Data's commitment should not be exceptional. I think that is a very important point. And the situation can be helped by some actions that Congress might take, which I will come to shortly.

The policy implications of what I just said include several, of which here are three. Given the fact that small firms appear to be more efficient than large firms in the way they use the R. & .D funds available to them, since we are finding that small firms innovate at a higher rate per employee; for example, there is an indication that funding of small-firm R. & D. is more cost effective than large-firm R. & D., at least under many circumstances. The cost effectiveness of investment in small firms is further enhanced by the fact that innovations seem to be brought to market sooner than those emanating from larger firms, as I earlier observed.

funds, whatever—that such purchases wherever possible, be carried out on a performance basis rather than on a design basis. That is, performance specification purchasing will introduce small enterprises into markets where they have been effectively barred by the overreliance on design specifications. I invite you to analyze, in terms of Federal procurement, one specific case in point: The FAA's method of procurement where they rely in the high technology area almost totally on design specifications. Talk to small entrepreneurs who would like to respond to FAA's needs, but can't meet the design requirements. They could help FAA move technology much further than the traditional design-oriented suppliers to FAA have been able to do.

Mr. SHAMANSKY. You are asking us to ask that question? What do you think? Why is that?

Dr. GELLMAN. I think there are two or three fundamental reasons for that. One is that I do not believe most Government agencies with substantial resources devoted to buying goods and services understand the potential of the small enterprise contribution to efficiency and innovation. I think there is a woeful ignorance of the differences between small and large enterprises in these settings where hardware and software are being acquired. I think this is true through most of the Federal Establishment and certainly through the purchasing agencies thereof.

The second is I do not think the process of technological innovation, especially on the high-technology side is very much understood by public agency officials.

Mr. SHAMANSKY. Do you think it is understood in private?

Dr. GELLMAN. It is not well enough understood in private, but a lot better understood in private than in public. Indeed, one of the unfortunate things we have found is that in procurement operations and the functions tied to them, such as the engineers that write the specs and so on, very few people in the public sector understand the free enterprise system and how investment decisions are made in the private sector. I marvel and blanch at the same time at how we go on forward with such ignorance rampant on the part of people with so much purchasing money.

Mr. SHAMANSKY. Whose fault is that?

Dr. GELLMAN. I think that is the fault of a succession of administrations.

Mr. SHAMANSKY. How about the market? We are a market-oriented society. Don't they have a reason to educate the public, a responsibility?

Dr. GELLMAN. Many enterprises serving the public sector have attempted to explain the process of innovation to all their potential and actual customers.

Mr. SHAMANSKY. How does that manifest itself?

Dr. GELLMAN. I think it manifests itself in the form of publications, in the form of speeches, in the form of people calling on procurement and engineering people throughout the Government establishments to try to explain why you need to do this to get from here through the process of innovation to there.

Mr. SHAMANSKY. If you say the people have the greatest motivation to do so, the private sector hasn't succeeded in educating, why would you think that the bureaucracy would be able to?

incidentally relates to one of the other suggestions that I have that relates to education.

I will jump to that to save time because it is consistent with your question. I think there is a role that the government can play with regard to education for entrepreneurship, education for small enterprise careers. Let me give you the two things that I think need to be done in very general terms.

One, I do not believe that in secondary education in this country when children, high schoolers, kids, when young people at that level of their education are considering what they are going to do with their lives from a career standpoint, I believe they are not given sufficient information and sufficient inducement to think about small enterprise kinds of careers whereas the large enterprise kind of career is indeed avanced to them as a possibility.

It is on their menu. The small enterprise career per se is not very often on the menu at the secondary level. I think there are a number of ways that public education could be induced to deal with that problem, which is a very low cost problem to solve with a very high payoff inherent in it.

Second, in terms of education, I believe there should be curriculum materials developed to assist certainly in the MBA type environment but perhaps in undergraduate levels, too, and particularly in engineering schools—to assist people in understanding the problems of small enterprise and help them recognize those problems and also point the directions toward solutions.

I don't think we have much in the way of special attention paid to the management training aspects of small enterprise. I feel this very strongly. In the private sector, if large companies recognized their community of interest with small enterprises, I think they would find it prudent to contribute greatly to reorienting the education process, through intellectual resources, if not capital.

Another matter that was the second element of the purchasing issue, I would just like to mention in passing because I do think it has importance. I don't know how much of it is direct economic importance but I think it has some psychological importance which results in economic importance as well.

We have some screwy concepts antitrust—not only laws—that go against small enterprise in a very important way for certain types of small enterprise such as consulting and other research-related firms. Let me be specific. Robinson-Patman is held not to apply to services. I my consulting firm, which was 20-some people at the time we sold our firm to a very large company, our car rental and hotel bills went down 35 or more percent instantaneously with the sale. I can assure you that the hotel chains and the auto rental companies bear more cost in serving us now than they did before because now they have to look up what the discount structure is for our particular parent, and so forth.

This sort of thing is highly discriminatory against small enterprise. There ought to be a search through the economy, if you will, to see where these kinds of nonsensical situations exist and, in fact, do discriminate against small enterprise—discriminate in a legal sense or in the more relevant sense which is the economic sense.

This sort of volume discounting without economic justification is unconscionable and it goes on every day. I think it ought to be

that an excuse or a reason that the private sector usually chooses not to take up such opportunities? You and I don't know because we haven't had enough experiments where Government gives up its proprietary position.

Mr. SHAMANSKY. I am concerned. You had great faith in the market. I am always told this magical thing called the market is going to do these things and you are saying the magical thing doesn't have any energy. It is not very effective.

Dr. GELLMAN. I think it is effective.

Mr. SHAMANSKY. It isn't effective here. Who is interfering with it?

Dr. GELLMAN. When the Government takes even nonexclusive rights to a technology, it is certainly limiting our system's working. We have a very great faith, generally speaking, in the patent system. While I don't know whether that faith is warranted or not, when we take away that sort of protection as a condition of granting an R. & D. contract, which is the usual case, perhaps we don't let our system work for us as it could.

By waiving nonexclusive royalty free use, by letting exclusivity lodge with the R. & D. performer, would that have the effect we would like to see? I don't know because we haven't conducted enough experiments across a broad enough front——

Mr. SHAMANSKY. Isn't it true that sometimes the Government is able to make an exclusive arrangement based on the willingnes to exploit it? There is such a possibility.

Dr. GELLMAN. Not much. There are some exceptions.

Mr. SHAMANSKY. There is a precedent that if someone wanted to market something, they could approach the Government and say I will do this if you do that.

Dr. GELLMAN. I have been involved in approaching the Government on those matters many, many times and never with complete success. The one that comes to mind where we did in fact achieve something, it took so long that the competitive edge was melted away. It took 2½ to 3 years, as I recall, to get the results you suggested.

Concluding as quickly as I can, I think we need to recognize also that the process of innovation is a very complex one consisting of myriad elements, and that there are many elements in the process of technological innovation that prevent our small enterprise community from providing for itself and for us all the economic growth, development and well being that they have the capability of providing.

In majy cases this is because there are certain elements of the process of innovation that are particularly difficult barriers for the small enterprise to climb over. For example, just one example, I suspect that there is an important role for Government to play, not so much as subsidizer but as provider for a fee of prototype and testing services in many fields of endeavor.

In analyses we have done on processes of innovation—specific outcomes and services, real innovations—we have found in many cases that prototyping and testing are two very important elements of the process of innovation that you must get over where the capital requirements and, indeed, some of the intellectual capital

between 1965 and 1975 and that the number of businesses in the national inventory is increasing each year.

Taking various estimates of failure rate into account, it is easy to reach a number that fits within the previously stated range. Consequently, I conclude there is no dearth of entrepreneurship in the United States.

Incidentally, to underline something that Dr. Gellman said, the data are atrocious. The only data we have on failures are provided by Dun & Bradstreet and anybody who has been in business would hardly base an estimate on that.

The estimates are nonsense. Any way you look at it, you hear conventional stories that 90 percent of all new companies fail the first year and 65 percent fail the third year. These are all based on the same poor set of data. Even admitting, Dun & Bradstreet whimpered a little and said nobody was supposed to use them to estimate these kinds of things.

There is a body of literature based on the reasons for failure based on the same nonsensical data. All we do know is that IRS data, in that data, the number has increased significantly.

A side comment, those failure rate numbers broadly believed are one of the real deterrents to entrepreneurship because they are very convincing that everybody is going to fail before they start.

Furthermore, despite many attempts at showing a drop in innovation through such surrogate measures of patents, R. & D. dollars, degrees issued, number of publications, there is no direct evidence of a drop in innovation. Measures of innovations are hard to come by and especially of the many surrogate measures that have been used to make a point about innovation is easily refuted by other learned studies. There is a recent article just came out in Business Horizons that I think does a very good job of reviewing the literature on the subject. I recommend it to anyone who wants to look at it.

For example, a Business Week article stated as evidence of the drop in innovation the fact that in 1969 there were 204 new public licensed technology based companies and the number dropped significantly in subsequent years.

What they left out was the fact that there were a total of 548 small business public offerings in 1969 and that number dropped to 4 in 1975, because the whole stock market had gone into decline. It had nothing to do with the innovation, it was just the matter of public issues.

If you compare the 204 publicly financed new technical companies to the ½ million to 1 million new companies formed that year, you can see it is a trivial number.

Let's go to the subject of venture capital availability. Venture capital has never been available in any significant quantity for high-risk items, except in periods of fad or glamorization. If I were right—right now we have a new-found interest in biologicals. There are two ads in the last issue of Nature magazine which offers funding help for any biochemical ideas.

They are just saying, come to us in Switzerland and New York and offering funding because there is a new-found, heated-up market for biologicals and genetics.

At first we thought this was personal and whimsical. Later on, we found they did better than most venture capital firms do. Incidentally, we were accused that it wasn't even America, it was only in Texas. I got a doctoral dissertation student and a French student and had him do it in France.

It was really obvious, because he cried all the way to France, insisting that there was no venture capital in France. I got him to go to France, which is as different from Texas as can be, and found the same kinds of responses. Except for moderate differences, because of local law, the same kinds of people responded in the same kinds of way to new ventures.

Another thing I must point out is that the venture capital firms under the best of construction do very few startups. Stan Pratt, who keeps track of these events, told me that there were 550 venture capital firms in the United States.

I know Diebold Associates made a study and found out that they made about three investments per year, of which less than 10 percent were for startups. That doesn't amount to very much in terms of new companies.

Again, we did other studies of loan offices because loan offices play an important role in the early stages of new companies or whether the entrepreneur will get the loan as interpreted by the loan officers in terms of the three Cs, one of which being character.

We took venture capital situations, many of them technical, young, new and different companies which are the essence of development, taking them to 200 loan officers in 40 banks in six States, and we found tremendous variation. Two loan officers sitting next to each other, one would make the loan and the other wouldn't.

Both would say it is the bank's loan policy. The vice president of the bank would say neither was the loan policy of the bank. We found differences between banks and differences between cities. I have been involved in a similar study in Columbus and it is as different from Texas as France. Mr. Shamansky can probably attest to that.

Mr. SHAMANSKY. I can't even recognize what you're saying. [Laughter.]

Dr. SHAPERO. Again, at the local level, how the local financial community responds makes all the difference in whether a company gets started and nurtured in its most critical years. Most of the attention at the national level on the stock market and on venture capital firms, is interesting, but ho-hum from the viewpoint of entrepreneurship in general throughout the country.

Another point I would like to make is about where the money is most needed. I call it shovel money but I didn't invent it, though I wish I had. A very perceptive and astute Canadian venture capitalist, Burke Brown, in Toronto, has coined that term to describe the term "shovel money," to describe the moneys required to bring a new business notion to the point where it can be intelligently and properly responded to by potential sources of capital.

As he puts it, there is money lying in the street, but you need a shovel to pick it up and it's getting the shovel that's the hardest problem for the would-be entrepreneur or inventor. He needs support for those activities ordinarily done by staff people in large corporations, and not very well, incidentally. But they have the

area. For example, if you look at finance textbooks, there is usually a half sentence about private local investors discussed among other sources of venture capital. Therefore, it is hard put to say explicitly what should be done, except to say that we must look at how local people respond and find a way to encourage that investment. Invention does not only occur in Boston, the Silicon Valley, or Washington, D.C. We have a large and very dynamic country with invention and potential entrepreneurship throughout its length and breadth.

Some of the current attempts at policy are defeated when you look at them from the local level. In our study at Columbus a local investor went through our list of companies and their description and indicated what he'd invest in. We then asked him policy questions such as, "Sir, if you could roll over your investment, would it change your decisions?" His answer was very good, "Generally, yes; specifically, no." He liked the policy idea in general but when it came to a specific company the policy wouldn't change his mind one bit. He looks at the specific situation at the local level. Little is understood about this local response dynamic.

I suggest we have to do something to tune banking at the local level. Banking varies tremendously by city and by region, but the potential in just changing the perceptions of loan officers to where 1 percent of commercial money is shifted toward new and young companies has more potential in it than 10 times all the federal programs that have been funded in the last several years. Tuning of the existing system has more potential than all new programs that have to be proven and debugged combined.

We need "shovel" moneys. We have to design programs that are not as restricted as the one in the National Science Foundation, which is restricted to very high technology. I suggest that we encourage the proliferation of such programs not only through Federal programs, but out to the States and out to communities using a much broader construct of technology than is now applied by NSF. I think this could have tremendous effect and also stops this regional disproportionate attention on two or three areas of the country.

Finally, just again, whatever programs we have to broaden should broaden the nature of what we call technology. Thank you.

[The prepared statement of Dr. Shapero follows:]

SMALL BUSINESS, INDEPENDENT INVENTORS AND EARLY FINANCING FOR NEW TECHNOLOGY

by

Albert Shapero, Professor
Ohio State University

In this testimony I would like to contribute some data-based ideas somewhat at odds with what appears to be the conventional wisdom that American innovation and entrepreneurship have been declining in recent years primarily due to a lack of venture capital. I would also like to suggest some policy directions that I believe can significantly increase desirable new company formations and their subsequent survival and growth.

First let me make the following points:

1. There is little convincing evidence of a decline in entrepreneurship or innovation in our country.
2. There is no less venture capital available to innovative companies today than has been available historically.
3. Capital for company startups comes predominantly from personal and local sources and is not a function of such highly publicized institutional sources as venture capital firms or the stock market.
4. Perhaps the most critical capital gap for inventors and potential entrepreneurs is the money required to do those things (feasibility studies, testing, business plans) that will enable them to get capital from conventional sources.
5. There is an inordinate interest in "high" technology which is more romantic than useful from the national viewpoint.

Entrepreneurship and Innovation

Over the past several years the rate of new company formations has been steadily rising in good times and remaining at a very high level in hard times. The indicators are strong though there are no valid statistics on the number of company formations or failures in the United States.[1] Estimates of startups by knowledgeable people range from 500,000 to one million startups per year. We do know that the IRS showed a net increase of 2,563,000 businesses in the ten years between 1965 and 1975 and that the number of businesses in the national inventory is increasing each year. Taking various estimates of failure rate into

[1] Shapero, A., "Numbers that Lie," INC, May 1981 (See attached).

resources available and charge it to their overhead in terms of feasibility studies, testing, development of market research to get together the materials that will make a plausible argument that can be presented to sources of finance. We do have some very intelligent programs in the Federal Government and I must say surprisingly so.

In the National Science Foundation, you're going to hear from Mr. Roland Tibbetts, and he has an excellent program. There has been a program funded in the Department of Defense but fighting a bureaucratic battle because they gave him the authorization but took away his staff.

These are programs that have been financing the shovel money. They essentially bring the Government in at the proper point when the risks are very high and when the cost is very low. It is a cost for seed money for these early activities.

The program is so designed that when the risks are down by some feasibility have been demonstrated and the costs are going to go up, it is then geared to go into the private sector where those who will gain and profit by it can now put up the money.

So, we have some recognized efforts in this area, but in general, this is a very great lack. There have been attempts by some agencies to put centers in universities but not always having been a university person I'm not very sanguine about universities being able to find their derriere with both hands with regard to this activity. There is nothing in the university to prepare it to do this job.

I would like to make is a few policy suggestions. I think there is more to innovation than high technology. Rocks do not have spirits. Things do not have a life of their own. Technology has no meaning without people.

We heard before that the Japanese take much of our technology and exploit it successfully. I would like to suggest that this is an example of the romantic and primitive view of innovation. I have studied entrepreneurs for two decades and I am fascinated by them. I have seen several companies that started with a hot technological idea that didn't work, but they didn't go out of business. They are doing something else. They started with an aerospace contract and now they are making a ski binding. The entrepreneurial event is our real source of innovation. No other country in the world has the number of company formations, the relative number of companies formed, and the friendly environment to enterpreneurship in the popular culture outside the universities.

I would like to suggest that we are having our brains beaten in when it comes to glassware, shoes, production techniques, and that there is far more to be gained by the development of new methods of joining metal and cutting metal and new materials than there is in just such narrow construction of high technology as is popularly put forth.

I would like to make some policy suggestions, and I wish I could be more explicit but the data do not permit. We should consider how to expand and encourage local investment in new ventures and not concentrate so much on the national marketplace. The trouble with doing something in this area, however, is that we know very little about it. There is no interest in research in this

If I called a company the Columbus Cheese Co., it couldn't get a hearing from anyone. But if I were to call it the Silicon Valley Mold Technology Co., which is cheesemaking, I could probably get 30-to-1 price earnings ratio in short order and get all kinds of people wanting to take me public.

Historically, new technologies have always found it tough. They are high risk and that makes new ventures have a hard time getting money anyway, but higher technology, which has higher risk, has a harder time.

Many of us have a perception that there were better days before because of the "go-go" years of the sixties stock market. Many of us would like it to return and lots of people are pushing for a return because they missed their chance the last time and we can still remember it.

However, if you look back into the way aircraft were financed and the way automobiles were financed, you found a fad fetish with the aircraft industry. The aircraft industry was hard put to get public moneys until 1927 after Lindbergh flew the channel.

There was a popular interest in aircraft and the stock market was heating up on its way to 1929. Then they got support.

Automobiles had a tougher time. They forced their dealers to finance them. They got up-front money from dealers so the automobile industry could get its financing. There has always been a hard time for new technology.

So today is not much different. How one removes the risk from it, except through Government guarantee, and I don't advocate that, because we will mask bad from good technologies. Today what is current, is a question.

The next point I would like to make and I think it's probably one of the more important points I can make, is that no venture support is essentially local.

Every study that's been made, and there aren't many, of how new ventures get their funds, new startups, shows that 99.9-something percent of all new ventures get their money from personal savings, personal borrowing, at the bank, family and friends, and what we used to call when I was at the University of Texas, good old boys, local people of wealth who invest in the business.

I would like to add the following: We did studies, and I think they must be among the only studies—I had some of my students working on a dissertation of how local people responded to new and different companies. We took investment situations to private investors to two cities in Texas.

They were in the same social cultural milieu, in the same economic region, in Austin and Waco. One city had grown, one city had not. One city had lost population. We found how local people would invest.

Interestingly, we found significant differences between the way people invest in the cities that grow versus the cities that didn't grow. What we found was that private individuals invest in a way that's rational, but not as described in the textbooks. They invested—the returns had to be above a certain threshold and they invested after they looked at the person and the deal and the subject matter of the company. They had to like both of them.

required is not practical or possible for a small enterprise to accumulate and exploit a sufficient percentage of the time.

I would think without anticompetitive effects, there are mechanisms that could be employed by the Government that would return to the Government any expenses it might incur while still encouraging quite dramatically small enterprise exploitation of what we call technological possibilities.

I am prepared to conclude at this point. I have many more things I could say over a much greater length of time but I will forbear.

Mr. SHAMANSKY. Thank you, Dr. Gellman. Our next witness is Prof. Albert Shapero of the Ohio State University which I am proud to note is in Columbus, Ohio, my home. I have been a longstanding fan of Dr. Shapero. I am still thinking about all the issues he raised. It is a great pleasure for me to welcome you, Professor Shapero, to our committee.

Dr. SHAPERO. Thank you very much. This is a pleasant surprise to be in front of a fellow Columbusite.

In this testimony, I would like to contribute some data-based ideas somewhat at odds with what appears to be the congressional wisdom that states that American innovation and entrepreneurship have been declining or are in disarray primarily due to the lack of venture capital for one thing, as well as many other items that are brought to bear.

I would also like to suggest at the end of my prepared statement here some policy directions that I believe could significantly increase desirable new company formations and their subsequent survival and growth in both high technology and other technology areas.

First, let me make the following points: First, I think there is little convincing evidence of a decline of entrepreneurship or innovation in our country.

Second, there is no less venture capital available to innovative companies today than has been available historically. That's not very comforting but it's not very different.

Third, capital for company startups comes predominantly from personal and local sources, and is not a function of such highly publicized institutional sources as venture capital firms or the stock market, which occupies possibly 99 percent of the discussion in public media circles.

Fourth, perhaps the most critical gap for inventors and potential entrepreneurs is the money required to do those things, such as feasibility studies, testing and business plans, that will enable them to get capital from conventional sources. There is an inordinate interest in high technology which is more romantic than useful from the national viewpoint.

Over the past several years, the rate of new company formations has been steadily rising in good times, remaining at a very high level though flattening, in hard times, such as today, when interest rates and inflation are high. The indicators are strong though there are no valid statistics on the number of company formations or failures in the United States.

Estimates of startups by knowledgeable people range from a half million to 1 million startups a year. We do know that the IRS showed a net increase of over 2½ million businesses in the 10 years

stopped even though I am currently the beneficiary of that discrimination. That is a purchasing sort of problem of the more mundane sort.

A more thorny problem for the public sector to deal with relates to the small R. & D. firm. I am not convinced that the public is well served or the economic development of this country is well served by the U.S. Government's funding so heavily enterprises that do research and development and only research and development.

I am not sure we are ill served, I just don't know.

But then again, nobody else appears to know, either. Probably there is much talent, entrepreneurial talent, locked up in these small R. & D. firms—talent which is sufficient to get them to the marketplace with an R. & D. result other than a research report. The only goal for them now is an intermediate product—an R. & D. report. I am not sure that anybody's interest is well served if we overuse talented, high-technology enterprises to produce only R. & D. results which when, delivered to the Government customer, may or may not be exploited in the marketplace.

Such firms that have no commitment to go to the market in exploiting their promising R. & D. results, it seems to me, are the sound of one hand clapping: they don't do much for the economy.

Mr. SHAMANSKY. Excuse me, Doctor. You are eluding me here. Maybe I don't have enough business background. You have R. & D. firms who have contracts to do what?

Dr. GELLMAN. Produce R. & D. results.

Mr. SHAMANSKY. For whom?

Dr. GELLMAN. Government primarily.

Mr. SHAMANSKY. Why does the Government ask them to do it?

Dr. GELLMAN. The Government defines an R. & D. need.

Mr. SHAMANSKY. You mean to say someone in the Government has an idea they want an R. & D. result on with no end product except the mere existence of the R. & D. report?

Dr. GELLMAN. That has happened.

Mr. SHAMANSKY. Is that the norm?

Dr. GELLMAN. I would say when the R. & D. contract is let, when the procurement of the report cycle is started, there is usually in mind a specific technique for producing a product or service that gets to some market.

But more often than not, I think it is fair to say, the post R. & D. report activities are thwarted or are exploited very slowly and indeed, we don't get much as a country out of R. & D. results of this sort.

Mr. SHAMANSKY. Aren't those things available to the public?

Dr. GELLMAN. Yes; but you have another set of problems like exclusivity. When the Government pays for the study, it obtains either exclusive or nonexclusive rights to the technology and there are problems for entrepreneurs who might want to exploit the technology.

Mr. SHAMANSKY. Wouldn't that be a marvelous opportunity for some entrepreneurs to get that stuff and do something with it?

Dr. GELLMAN. I agree. What you are saying is we need to know how much of a barrier it is, in fact, that the Government maintains at least nonexclusive, royalty free use to R. & D. that it sponsors. Is

Dr. GELLMAN. I have never served as a Federal employee except in uniform and that certainly didn't prepare me to answer this question from personal observation. But I do believe that one of the roles that the Small Business Administration should have been playing and I think has played very little is in fact to educate government procurement people with regard to the effective, beneficial use of their purchasing power—for example how much more they can get out of a dollar with small enterprizes compared with large in many areas. FAA happens to be one I am reasonably familiar with but there are others I am sure.

I think the SBA could have done and indeed should be doing a somewhat more effective job in making small business efficiency, as it were, better known and better understood in the Federal procurement establishment.

I also believe that private industry warrants criticism being hurled at it. Indeed, however, it should be clear that where design specifications are employed primarily as the procurement technique, the large entrenched firm really cannot have much interest in educating the procurement people to the power of the performance specification to bring competitors in against itself.

So, I on further reflection, I do not expect that large, entrenched enterprises are very often going to try to educate public procurement people.

Mr. SHAMANSKY. You can apply that analogy to the automobile industry; can't you?

Dr. GELLMAN. I suppose so. I believe that is probably a good analogy. I would have to think about it some more. But it seems sensible to me. By the way, this business of design and performance specifications is not nearly as well understood as it ought to be in any sense, in my judgment. There is no burden of proof that a design specification should not be used and a performance specification should be used, either explicitly or implicitly, in public procurement or in private procurement in most companies, either.

I think, however, that the performance spec is a very powerful tool to improve the innovative performance of the American economy which has special relevance here given the very substantial amount of funds that are in the hands of government for purchasing purposes in the United States.

Mr. SHAMANSKY. You are flanked by two academics. Are you satisfied that the business schools are doing their share?

Dr. GELLMAN. I should warn you, sir, that I am an adjunct professor at the Wharton School at Pennsylvania.

Mr. SHAMANSKY. Since we have a panel of three academics, what are you guys doing?

Dr. GELLMAN. Earlier I referred to Professor Schumpeter who was an academic; he cried in the wilderness about much of this as far as the private sector is concerned for many decades. I think the academic community has too few people who understand the process of innovation, too. But the few are trying.

Mr. SHAMANSKY. I know the gentleman on your left. I know he knows.

Dr. GELLMAN. Yes. I have known him for a long time. I know he knows for two reasons, not the least of which is the fact he has been out there in the real world. I think it is important, and it

R. & D. in concentrated industries should be directed to smaller firms where the economic performance appears far better than the that of the larger firms.

Now, with time short, I would like to make a couple of general points and then four specific suggestions for improving the environment for small, high-technology enterprises. You have perhaps noted that I use the term "small enterprise," more often than "small business". The reason is that I believe we have come to see the term "small business" applied to what we consider manufacturing and distribution-type firms. By "enterprise," I think we want to convey two things in addition to that: First, small agricultural enterprises which are not often thought of as businesses though they are indeed that, and second, the small public enterprise, the small airport, the small hospital. Our country is increasingly finding itself reliant on public enterprise and among the public enterprises are a growing number of small public enterprises. I think we ought to recognize that many of the problems small public enterprise faces are not unlike those of small private enterprise.

I think we need to have a much broader understanding, also, that innovation that is "high technology," that is R. & D.-intensive, often requires the support of small enterprises that may not themselves be R. & D.-intensive. There are many services to be provided in support of high-technology innovation that small enterprises are especially well-equipped to provide. In addition, there are small enterprises that, in support of high-technology innovation, can produce support or service activities that are not very technological at base under any definition.

So, we want to recognize the complexity of the process of innovation and indeed the support that small enterprise can provide all along the line and in all degrees of technology intensity.

Let me return to one point that I made before, adding one more point, namely, that there is a community of interest between small and large enterprise in this country and that it exists and has been demonstrated repeatedly. One of the most interesting ways to see this is by looking at certain industries and considering that each industry has a certain amount of preeminence, let us call it, and a certain amount of predominance in world markets.

By "preeminence," I mean to convey the intellectual capability to address the market and by "predominance," I mean basically share of the market enjoyed. Much research suggests that small enterprise is often more efficient in the exploitation of technology but that larger enterprises are more efficient in exploiting some markets which need such technology. We need to maintain preeminence in many fields where we also want to be predominant. It is possible to separate the two and we must do so to develop the proper public policy conclusions. Among such conclusions is that small and large firms may often have to work together in vertical arrangements in terms of the process of innovation in order for both to be successful and for U.S. preeminence and predominance to be established and maintained.

Let me conclude by making several specific suggestions. One of the most powerful things, it seems to me, that can be done to support high-technology small enterprises is to require that purchases made with Government funds, with Federal funds, State

of this sort are subject to many limitations, it certainly is true that technological change has been responsible for a substantial share of our past productivity growth. Moreover, as indicated above, the rate of innovation in the United States has an important influence on the competitiveness of U.S. goods in world markets and on our rate of inflation. Thus, there can be little question concerning the significance of technological innovation to the American economy.

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Mr. GORE. Thank you for that fascinating overview, Dr. Mansfield.

The subcommittee considers you one of the two leading experts in this field. We are delighted to have you here.

Dr. Gellman, we would like to hear from you next. You have been looking at this issue at least since 1967. We are most honored to have you with us on this occasion.

Dr. GELLMAN. Thank you very much, Mr. Gore. It is a pleasure to be here. I think there is ample evidence to advance with some vigor the hypothetical that small enterprise is very important in general to economic well-being and development in the United States and that high technology or technology-rich small enterprise has a very special place, special role to play. Indeed, Professor Mansfield set the stage very well for that observation.

We can go back to Schumpeter, the famous economist, or even further. Joseph Schumpeter spoke eloquently about the "rise of new men" and he spoke of inventors and entrepreneurs when he used that phrase. It is difficult to imagine that there was ever a more important period in American history to encourage the use of such new men than there is today.

One of the tragedies of our times in terms of small enterprise is the lack of data to tell us with the required precision what the role of small enterprise in high technology is in the United States. Part of the tragedy—or one of the reasons that I consider it to be a tragedy of some importance—is that there are quite a lot of raw data that can be massaged, can be treated to gain insights beyond that which we already have. As an illustration of that point, and also to indicate in another way, and I think a new way, the importance of small high-technology enterprise, I would just share with you a few conclusions that will be published very soon from a

6. Innovation and U.S. Competitiveness in World Markets

Besides affecting productivity and economic growth, as well as the rate of inflation, technological innovation influences how competitive American firms are in world markets. Although economists have been aware for over a century that technological change is one determinant of the nature and size of a country's imports and exports, there has been increasing emphasis on this factor in the past 10 or 15 years. Both from case studies and statistical analyses, economists have found that U.S. industries that spend relatively large amounts on R and D are the ones that lead in manufactured exports, foreign direct investment and licensing. Needless to say, there is an enormous amount that remains to be learned concerning the relationship between technological change and our foreign trade. But the available evidence seems to suggest that technological innovation has had a major influence on American exports, receipts from licenses, and direct investment abroad.

In many areas where we have a favorable balance of trade, our comparative advantage seems to be based on a technological edge. In R and D-intensive manufacturing industries, such as nonelectric machinery, aircraft, chemicals, electrical equipment, and instruments, the United States has maintained a favorable balance of trade for many years. On the other hand, in non-R and D-intensive manufacturing industries, the United States has experienced a very large negative trade balance in the past decade. Of course, many factors--such as exchange rates, tariffs, quotas, and the aggressiveness and effectiveness with which firms try to market their products abroad--influence our trade position. But there seems to be widespread agreement among economists and others that the role of technology in U.S. foreign trade is important.

resource-saving in nature, a technique has been devised to provide at least rough estimates of an innovation's social rate of return. This technique has been used to obtain published estimates of the social rate of return for about 100 innovations.

The results of these studies, although obviously tentative, seem to be interesting from the point of view of public policy. First, the social rates of return tend to be very high, indicating that, if these innovations are at all typical, investments in new technology have paid off handsomely to society at large. For example, one study of 17 industrial innovations--most of which were minor, not major improvements--found that the median social rate of return from the investments in these innovations exceeded 50 percent. Second, the private rates of return from investments in new technology seem to be lower than the social rate of return. For example, among the 17 innovations cited above, the median private rate of return was about 25 percent. Third, in about 30 percent of the cases in this sample, the private rate of return was so low that no firm, with the advantage of hindsight, would have invested in the innovation, but the social rate of return from the innovation was so high that, from society's point of view, the investment was well worthwhile. Although this evidence is very limited and by no means unambiguous, it seems to suggest that there may be an underinvestment in certain areas of civilian technology. Obviously, however, the available data are too sparse to indicate where the shortfall--if one exists--is greatest, but for what it may be worth, the gap between private and social rates of return seems to be relatively large for more important innovations and for the innovations that can be imitated relatively cheaply by competitors. (See Mansfield et al. (1977).)

3. Technological Change and Economic Growth

Technological change consists of advances in knowledge concerning the industrial, agricultural, and medical arts. Such advances result in new and improved processes and products, as well as new techniques of organization and management. The fact that technological change plays an important role in permitting and stimulating the growth of per capita output seems self-evident. But when one wants to go beyond such bland generalizations to a quantitative summary of the contribution of technological change to the rate of economic growth, a number of basic difficulties are encountered. For one thing, it is hard to separate the effects on economic growth of technological change from those of investment in physical capital, since, to be used, new technology frequently must be embodied in physical capital--new machines and plant. For example, a numerically controlled machine tool (or control mechanism) must be built to take full advantage of some of the advances in the technology related to machine tools. Nor can the effects of technological change easily be separated from those of education, since the social returns from increased education are enhanced by technological change, and the rate of technological change is influenced by the extent and nature of society's investment in education.

Despite these and other problems, economists have tried to obtain quantitative measures of the importance of technological change in American economic growth. In a seminal article published in 1957, Robert Solow attempted to estimate the rate of technological change in the nonfarm U.S. economy from 1909 to 1949. His findings indicated that, for the period as a whole, the average rate of technological change was about 1.5 percent per year. Based on these findings, he concluded that about 90 percent of the increase in output per capita during that period was attributable to technological change, whereas only

IMPORTANCE OF TECHNOLOGICAL INNOVATION TO THE AMERICAN ECONOMY

Testimony before the Committee on Science and Technology, U.S. House of Representatives, July 21, 1981

Edwin Mansfield
University of Pennsylvania

1. Introduction

I have been asked to describe very briefly the role and importance of technological innovation in the American economy. To begin with, I'll define technology and innovation. Then I'll try to indicate the relationships between technological innovation, on the one hand, and our nation's rate of economic growth, inflation rate, and international competitiveness, on the other.

2. Technological Change and Innovation

Technology consists of society's pool of knowledge concerning the industrial, agricultural, and medical arts. It is made up of knowledge concerning physical and social phenomena, knowledge regarding the application of basic principles to practical work, and knowledge of the rules of thumb of practitioners and craftsmen. Although the distinction between science and technology is imprecise, it is important. Science is aimed at understanding, whereas technology is aimed at use. Changes in technology often take place as a consequence of inventions that depend on no new scientific principles. Indeed, until the middle of the nineteenth century, there was only a loose connection between science and technology. However, in recent years, technology has come to be much more closely intertwined with science.

The fundamental and widespread effects of technological change are obvious. Technological change has permitted the reduction of working hours, improved

improvements, found that the median social rate of return from the investments in these innovations exceeded 50 percent.

Second, the private rates of return from investments in new technology—in other words, the rate of return to the innovators, to the firms that put up the money for the innovations—seem to be lower than the social rate of return. For example, among the 17 innovations cited above, the median private rate of return was about 25 percent.

Third, in about 30 percent of the cases in this sample, the private rate of return was so low that no firm with the advantage of hindsight would have invested in the innovation. But the social rate of return from the innovation was so high that from society's point of view, the investment was well worthwhile. Although this evidence is very limited and by no means unambiguous, it seems to suggest that there may be an underinvestment in certain areas of civilian technology.

Let me turn to inflation, which is clearly one of the most serious problems facing the American economy. Via its effect on productivity, innovation tends to reduce inflation at least in the medium and long run. Total cost per unit of output equals total cost per hour of labor divided by output per hour of labor. Thus, the rate of increase of total cost per unit of output equals the rate of increase of total cost per hour of labor minus the rate of increase of labor productivity. This is merely an identity. If the rate of increase of labor productivity—that is, output per hour of labor—is high, the rate of increase of total cost per unit of output will be much lower than the rate of increase of total cost per hour of labor. But if the rate of increase of labor productivity is low, the rate of increase of total cost per unit of output will be almost as great as the rate of increase of total cost per hour of labor.

Now, this exercise in arithmetic is of some importance in understanding recent inflation. Of course, factors other than the slowing of our rate of productivity growth have been of major consequences in accounting for the excessive recent rates of inflation in the United States. But this factor nonetheless has been an important one.

Besides affecting productivity and economic growth, as well as the rate of inflation, technological innovation influences how competitive American firms are in world markets. In many areas where we have a favorable balance of trade, our comparative advantage seems to be based on a technological edge. In R. & D. intensive manufacturing industries such as nonelectric machinery, aircraft, chemicals, electrical equipment and instruments, the United States has maintained a favorable balance of trade for many years.

On the other hand, in non-R. & D. intensive manufacturing industries, the United States has experienced a very large negative trade balance in the past decade. Of course, many factors such as exchange rates, tariffs, quotas, and the aggressiveness and effectiveness with which firms try to market their products abroad influence our trade position. But there seems to be widespread agreement among economists and others that the role of technology in U.S. foreign trade is very important.

Dr. Edwin Mansfield

Edwin Mansfield was born in Kingston, New York, on June 8, 1930. He received an A.B. from Dartmouth College in 1951, an M.A. from Duke University in 1953, and a Ph.D. from Duke University in 1955. During 1954-55, he studied at the University of London and received the Certificate and Diploma of the Royal Statistical Society in 1955. In 1971, he received an honorary Master of Arts from the University of Pennsylvania.

From 1955-63, he was Assistant Professor of Economics and Associate Professor of Economics at the Graduate School of Industrial Administration at Carnegie Institute of Technology. In addition, he was Director of Carnegie's research program on technological change and economic growth. During 1961-62, he was Visiting Associate Professor of Economics at Yale University. During 1963-64, he was Visiting Professor of Economics at Harvard University. During 1967-68, he was Visiting Professor of Economics at California Institute of Technology. In 1963, he was appointed Professor of Economics at the Wharton School of the University of Pennsylvania.

In 1979, Mansfield was elected to the American Academy of Arts and Sciences. In 1979, he was the first American economist invited by the People's Republic of China to lecture there under the Sino-American scientific exchanges. During 1974-75, Mansfield served as U.S. Chairman of the U.S.-U.S.S.R. Working Party on the Economics of Scientific Information. In 1971-72, he was a Fellow at the Center for Advanced Study in the Behavioral Sciences at Stanford. He received a Fulbright Fellowship in 1954-55 and a Ford Foundation Faculty Research Fellowship in 1960-61. He was elected a Fellow of the Econometric Society in 1969, and is a member of the American Economic Association, Delta Upsilon, and Phi Beta Kappa. He was Associate Editor of the Journal of the American Statistical Association from 1964-67, and has been an associate editor of the American Economist since 1969. In 1981, he gave the Andersen Lectures at the University of Brussels.

Mansfield is a member of the Committee on Science, Engineering, and Public Policy of the American Association for the Advancement of Science. He is, and has been, a consultant to many government and other organizations, such as the RAND Corporation, the National Science Foundation, the Federal Power Commission, the U.S. Army, the Small Business Administration, the President's Commission on Government Procurement, the Institute for Defense Analyses, and the President's Commission on Automation. He was a member of the Advisory Committee on Planning of the National Science Foundation from 1967-1970, and a member of the Governor's Science Advisry Committee. Also, he was a member of the Ford Foundation's Committee on the Economics of Technological Change from 1963 to 1967, and the National Academy of Science's Evaluation Panel for the National Bureau of Standards. In 1979, he received the Certificate of Appreciation from the U.S. Secretary of Commerce.

Mansfield has published 19 books, including Industrial Research and Technological Innovation (W.W. Norton for the Cowles Foundation for Research in Economics at Yale University, 1968), The Economics of Technological Change (W.W. Norton, 1968), Microeconomics: Theory and Applications, Third edition, (W.W. Norton, 1979), Research and Innovation in the Modern Corporation (W.W. Norton, 1971), Economics, Third edition, (W.W. Norton, 1980), The Production and Application of New Industrial Technology (W.W. Norton, 1977), Monopoly Power and Economic Performance, Fourth edition (W.W. Norton, 1979), Managerial Economics and Operations Research, Third edition (W.W. Norton, 1974), and Defense, Science, and Public Policy. Also, he is the author of over 100 articles dealing with economics, statistics, and operations research, many of which appear in the American Economic Review, Journal of Political Economy, Review of Economics and Statistics, Econometrica, Journal of the Royal Statistical Society, Management Science, Journal of Business, and Quarterly Journal of Economics. In addition, he is author of the article on "Industrial Research" in the Encyclopedia Britannica.

This subcommittee has had a longstanding interest in innovation and I will use, as its latest chairman, every possible means at my disposal to insure that all unreasonable barriers to innovation are removed. We must encourage the small, high technology firms and independent inventors to produce the new technology which will fuel the reindustrialization of America. That is why we are here today and this hearing is so timely and vital.

Today we will hear about private programs designed to increase technological innovation through small, high technology firms and independent inventors. Tomorrow we will hear from three Federal agencies, NSF, SBA, and DOE/NBS about their programs to stimulate innovation.

Today, we will hear from four panels. The first panel will discuss the importance of technological innovation to our country and the role small, high technological firms and independent inventors have played despite many barriers that confront them.

Our second panel will discuss the large corporation/small firm/independent inventor interface. We are pleased to have Arthur D. Little, Inc. and Control Data here today as both corporations are leading the way to promote innovation.

The third panel consists of two university innovation centers, one at the Wharton School in the University of Pennsylvania and the other at Georgia Tech. Universities combine the technical and business skills to assist the inventor and small firm at the earliest stages of prototype development and market analysis.

The fourth panel consists of two venture capitalists, one representing Technology Partners in Chicago and the other representing International Technology Resources, Inc. in New York. Most inventors and startups rely on their personal savings, family, friends or local wealthy investors to finance prototype development. Venture capital firms generally invest 25–30 percent of their capital in startups, but shy away from preprototype funding because it is so risky. This seed capital is nonetheless important and relatively new.

As an innovative approach to these hearings on innovation, we have invited a distinguished panel of inventors and chief executive officers of high technology firms who are literally on the firing line to interact with each panel at the conclusion of his oral statement. It should result in a most informative interchange.

It is my hope that this hearing will form only the overture of a continuing effort by this committee to spotlight and focus upon problems and opportunities which surround the returning the United States to its place among the great innovative nations of the world. The Jeffersons and the Edisons are no doubt still among us. We have only to reach out and rescue them from the regulatory underbrush and the frantic rush of modern society.

I would like to call upon our ranking minority member, Mr. Walker.

Mr. WALKER. Thank you, Mr. Chairman. I would certainly like to go along with the statement that you have just made. I think it represents the kind of thrust that we want these hearings to take. I have no further statement. I look forward to the hearing.

Mr. GORE. Our first panel is Dr. Edwin Mansfield, with the University of Pennsylvania; Dr. Aaron Gellman, president of Gell-

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*On assignment to Budget Committee for 97th Congress.