TECHNOLOGICAL INNOVATION:
Its Environment and Management

This report, prepared by Daniel V. De Simone, represents the views of the Panel on Invention and Innovation, an advisory committee of private citizens convened by and reporting to the Secretary of Commerce. The views of the Panel do not necessarily represent those of the Department of Commerce or of any other agency of the federal government.

January 1967
Reprinted, September 1967

U.S. DEPARTMENT OF COMMERCE
John T. Connor, Secretary

J. Herbert Hollomon, Assistant Secretary
for Science and Technology

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Washington, D.C., 20402 - Price $1.25

and managing technological change? What characterizes the relatively uninnovative industries? Are they this way because they failed to exploit innovative opportunities? Because they possess excessive built-in barriers to technological change? Is it that their managements have not learned the importance of utilizing technological opportunities and innovative skills?

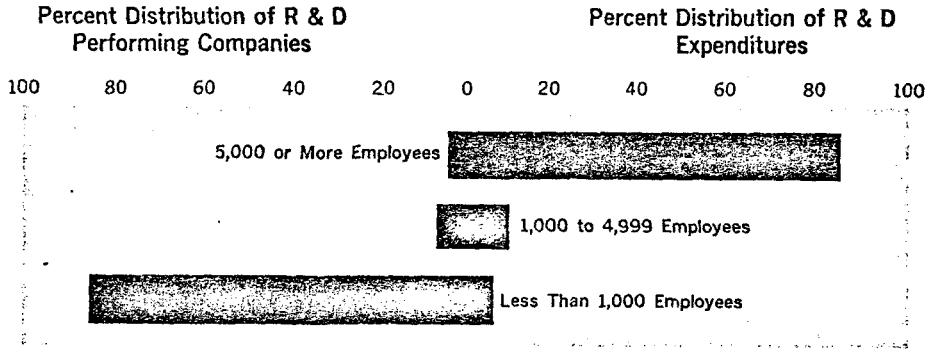
We find that we must answer each of these questions affirmatively. The major barrier is one of attitude and environment. It is primarily a problem of *education*—not of antitrust, taxation, or capital availability.

THE SIGNIFICANCE OF SIZE

We have examined variations in innovative performance between the public and private sectors, different regions, and different industries. We turn now to a consideration of innovative performance as a function of company size. Again, however—because we have no choice in the matter—we have been forced to resort to data concerning R&D, *not* the total innovative process.

CHART 12

VARIATIONS IN R & D, BY SIZE OF COMPANY



Source: Basic research, applied research, and development in industry, 1962, NSF 65-18, 1965.

The above data show that a handful of large companies (having 5000 or more employees) perform almost all of the R&D, although, as we have illustrated, this is not necessarily indicative of *innovative* performance.

It is important to distinguish between large and small sources of invention and innovation, for the resources available to them are different and, not surprisingly, the riskiness of a venture and the manner in which it is undertaken are generally a function of the available resources. We therefore analyzed several studies on the sources of invention and innovation. These studies were unusually consistent in indicating that independent inventors (including inventor-entrepreneurs) and small technologically-based companies are responsible for a remarkable percentage of the important inventions and innovations of this century—a much larger percentage than their relative investment in these activities would suggest.

—Professor John Jewkes, et al, showed that out of 61 important inventions

and innovations of the 20th century, which the authors selected for analysis, over half of them stemmed from independent inventors or small firms.[4]

—Professor Daniel Hamberg of the University of Maryland studied major inventions made during the decade 1946-55 and found that over two-thirds of them resulted from the work of independent inventors and small companies.[5]

—Professor Merton Peck of Harvard studied 149 inventions in aluminum welding, fabricating techniques and aluminum finishing. Major producers accounted for only one of seven important inventions.[6]

—Professor Hamberg also studied 13 major innovations in the American steel industry—four came from inventions in European companies, seven from independent inventors, and none from inventions by the American steel companies.[7]

—Professor John Enos of the Massachusetts Institute of Technology studied what were considered seven major inventions in the refining and cracking of petroleum—all seven were made by independent inventors. The contributions of large companies were largely in the area of improvement inventions.[8]

Chart 13, which is based on the above studies, illustrates some of the important inventive contributions made by independent inventors and small companies in this century. One finds the range and diversity of these inventions impressive. Indeed, the mercury dry cells in our electronic watches, the air conditioners in our homes, the power steering in our automobiles, the FM circuits and vacuum tubes in our Hi-Fi and television sets, the electrostatic-copying machines in our offices, the penicillin and streptomycin in our medicine cabinets, and the list goes on—all of these inventions, which are generally taken for granted, take a new meaning when one identifies them with their sources. The point to be made is that independent inventors and small firms are responsible for an important part of our inventive progress, a larger percentage than their relatively small investment in R&D would suggest.

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[4] *J. Jewkes, D. Sawers, and R. Stillerman,* The Sources of Invention, *St. Martin's Press, 1958, particularly pp. 72-88, and Part II.*

[5] *D. Hamberg, "Invention in the Industrial Research Laboratory,"* Journal of Political Economy, *April 1963, p. 96. See also,* Concentration, Invention, and Innovation, *U. S. Senate Antitrust Subcommittee, 89th Cong., Part III (Government Printing Office, 1965), p. 1286.*

[6] *M. J. Peck, "Inventions in the Post-War American Aluminum Industry," in* The Rate and Direction of Inventive Activity: Economic and Social Factors, *National Bureau of Economic Research, (Princeton, New Jersey, 1962), pp. 279-92. See also, U. S. Senate Antitrust Subcommittee, op. cit., p. 1296 and 1438-1457.*

[7] *Hamberg, op. cit., p. 98. See also U. S. Senate Antitrust Subcommittee, op. cit., p. 1287.*

[8] *J. L. Enos, "Invention and Innovation in the Petroleum Refining Industry," in* Rate and Direction of Inventive Activity, *op. cit., pp. 299-304. See also, U. S. Senate Antitrust Subcommittee, op. cit., p. 1287 and pp. 1481-1503.*

CHART 13

SOME IMPORTANT INVENTIVE CONTRIBUTIONS OF INDEPENDENT INVENTORS AND SMALL ORGANIZATIONS IN THE TWENTIETH CENTURY

Xerography Chester Carlson	**Shrink-proof Knitted Wear** Richard Walton	**Mercury Dry Cell** Samuel Ruben
DDT J. R. Geigy & Co.	**Dacron Polyester Fiber "Terylene"** J. R. Whinfield/J. T. Dickson	**Power Steering** Francis Davis
Insulin Frederick Banting	**Catalytic Cracking of Petroleum** Eugene Houdry	**Kodachrome** L. Mannes & L. Godowsky Jr.
Vacuum Tube Lee De Forest	**Zipper** Whitcomb Judson/Gideon Sundback	**Air Conditioning** Willis Carrier
Rockets Robert Goddard	**Automatic Transmissions** H. F. Hobbs	**Polaroid Camera** Edwin Land
Streptomycin Selman Waksman	**Gyrocompass** A. Kaempfe/E. A. Sperry/S. G. Brown	**Heterodyne Radio** Reginald Fessenden
Penicillin Alexander Fleming	**Jet Engine** Frank Whittle/Hans Von Ohain	**Ball-Point Pen** Ladislao & Georg Biro
Titanium W. J. Kroll	**Frequency Modulation Radio** Edwin Armstrong	**Cellophane** Jacques Brandenberger
Shell Molding Johannes Croning	**Self-Winding Wristwatch** John Harwood	**Tungsten Carbide** Karl Schroeter
Cyclotron Ernest O. Lawrence	**Continuous Hot-Strip Rolling of Steel** John B. Tytus	**Bakelite** Leo Baekeland
Cotton Picker John & Mack Rust	**Helicopter** Juan De La Cierva/Heinrich Focke/ Igor Sikorsky	**Oxygen Steelmaking Process** C. V. Schwarz/J. Miles/ R. Durrer

It goes without saying that the United States could not depend solely on the innovative contributions of small firms. The large firms are indispensable to technological and economic progress. From a number of different points of view, however, we are persuaded that a unique cost-benefit opportunity exists in the provision of incentives aimed at encouraging independent inventors, inventor-entrepreneurs, and small technologically based businesses. The cost of special incentives to them is likely to be low. The benefits are likely to be high.