States can easily take several courses in microeconomics without hearing of him. For such purposes, his ideas have been "economized" into a general consideration of search and information costs, into a more elaborate consideration of expectations, or into a brief footnote on the possibility that the classic portrayal of choice may not necessarily describe what happens at the individual firm level.

Simon's ideas on decision-making have had their primary direct impact in economics among those concerned with embedding economic theory into a behavioral understanding of actual decision processes within the firm. Those effects can be illustrated with a few examples, drawn from a longer list. The key con-

Speaking of Science

Weather Modification: A Call for Tougher Tests

Since the inception of weather modification in 1946, various techniques have been enthusiastically adopted, but have all too often failed in the end to modify the weather. A case in point is rainmaking. In the early 1950's, some experts began to take a dim view of the then current penchant for rainmaking, believing that the rainmakers did not have a full appreciation of the complexities of the atmosphere.

Since then, it has become obvious that cloud seeding—that is, the addition of enough particles to clouds to promote condensation of water vapor—can produce complicated effects. For example, rainmaking may fail both because of too little or too much seeding. Rainfall can actually be reduced by seeding under some conditions. Both increases and decreases in rainfall may extend far beyond the area directly seeded, some researchers now believe. Reliably detecting these effects is made particularly difficult by the limited ability of experimenters to predict how a cloud would have behaved if it had not been seeded.

A recent report* to the congressionally mandated Weather Modification Advisory Board from its Statistical Task Force concludes that researchers have not always coped well with this sort of complexity. "The inherent difficulties of the situation and the well-founded need for completely anchored conclusions," the report says, "have not been taken seriously enough." A strict evaluation of seven rainmaking experiments of the past 5 years left only one that the task force finds statistically convincing. This experiment, the second of two successful Israeli experiments, appeared to achieve a 15 percent increase in rainfall. The other experiments yielded results that fell short of statistical significance or their interpretations were confused because of their questionable design.

When considering techniques to affect other kinds of weather, the panel notes that the major American effort to suppress destructive hail production, modeled after reportedly successful Soviet experiments, was terminated 2 years early for lack of positive results. On the other hand, they describe as wholly successful two earlier attempts to increase mountain snowfall, and consequently spring runoff, in Colorado.

In contrast to the reserved tone of its task force's report to it on past experiments, the WMAB, in a report† to the Secretary of Commerce, expresses optimism about the future of weather modification. Citing a broader basis for its conclusions, the WMAB declares that, with more money and some hard work, significant modification of many kinds of weather seems to be probable in the next two decades. It estimates that snow in the mountains and rain in the High Plains and Midwest could be increased by 10 to 30 percent by the late 1980's. Hail reduction, up to 60 percent in some kinds of storms, could be realized by the 1990's. While more specific in its hopes and expectations, the report reflects the optimistic tone of previous requests for increased funds made in 1973 and 1966 (National Academy of Science committees) and in 1957 (a presidential committee).

The WMAB finds encouragement today in the suggestive results of experiments conducted in Florida and southern California that were positive but were not judged to be statistically convincing. These results, plus an increasing understanding of cloud physics and an estimation of the impact of their recommended increased funding, led the WMAB to go beyond its task force's conclusions, according to Harlan Cleveland, chairman of the WMAB.

The statistical task force of the WMAB does not proscribe future experiments with the weather, but it does conclude that researchers must exercise greater caution in designing and evaluating experiments if the results are to be convincing. Toward this end, the panel provides a demanding "guidebook" of standards and procedures that may become de rigeur in the field. It contains a strict procedural regimen, including statistical requirements compared by some with those that have been adopted for the best clinical investigations in medicine.

Such a regimen must continue to include thorough randomization of seeding operations, the report concludes. In addition, an exploratory phase, in which likely situations susceptible to seeding are identified, must precede a confirmatory phase, in which the highest standards of experimental design are imposed in order to answer a single question. Too little data have sometimes been used in the past to answer too many questions, the task force says. Even the appearance of possible subjective influence must be avoided. The task force also recommends making the details of experiments available within 1 year after completion of fieldwork, and serious consideration should be given to parallel, independent analyses of results.

The statistical task force concludes that "in view of the great importance of enhancement [of rainfall] if it exists, . . . it is quite reasonable to go forward" with experimental cloud seeding, but only if investigators adhere to the highest standards. While philosophical differences may exist concerning the status of weather modification, most WMAB members welcome the development of the guidelines and agree that they will probably become a standard for all proposed work in the field. Some researchers believe it is the only way a concensus will ever be reached.

—RICHARD A. KERR

**The Management of Weather Resources* (Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 1978), vol. 2.
†*Ibid.*, vol. 1.