Economics: Nobel Prize for 1970 Awarded to Samuelson of M.I.T.

The most significant achievements of Paul Anthony Samuelson, the recipient of the 1970 Nobel Prize in economics, have been in formulating and solving, with the help of mathematics, basic problems in theoretical economics. But Samuelson has not confined himself to the ivory tower of pure research activity. He is the author of a remarkably successful and effective elementary text (*Economics: An Introductory Analysis*), has acted as economic adviser as well as outspoken critic of presidents of the United States, and now writes columns for newsweeklies and dailies.

Born in Gary, Indiana, in 1915, Samuelson received his B.A. degree in 1935 at the University of Chicago and a Ph.D. in Economics at Harvard University in 1941. Now an Institute Professor at the Massachusetts Institute of Technology, he has been on its economics faculty since 1940. Despite his varied activities, he has produced a steady stream of always important and sometimes history-making scientific papers. A two-volume collection, cut off in mid-1964, contains 129 papers, among them the path-breaking 1938 note (by the then 23-year-old Samuelson) on the revealed preference approach to the theory of consumer's behavior. Samuelson's *Foundations of Economic Analysis*, largely conceived and written (according to its author) in 1937, although not published until 1947, has attained the status of a classic. A joint work by Robert Dorfman, Samuelson, and Robert Solow (*Linear Programming and Economic Analysis*, 1958) has played an important role in a number of fields, including especially the theory of economic growth. Casual perusal of recent journals shows Samuelson's undiminished creativity.

Yet the volume of output is neither an adequate measure of its value nor an explanation of Samuelson's profound and continuing impact on economics in the last three decades. This impact is, I believe, due to the fact that his work has typically constituted, perhaps to a unique extent, a "leap forward" in new formulations, results, and methodology without losing touch with the questions and conjectures characteristic of the mainstream of economic thought, whether current or ancient, whether rigorous or intuitive. By tackling problems many economists had previously dealt with or thought they had solved, Samuelson assures himself of "relevance" and also of an attentive audience. By explaining, in nontechnical terms, the relationship of his often quite technical contribution to the work of others, he educates a broader public and encourages further development. In fact, the wealth of research stimulated by Samuelson's results and *obiter dicta* is by itself a major gift to economics.

To gain proper perspective on Samuelson's work, one should bear in mind that the mathematical approach to economic theory by far antedates the era of the electronic computer. Cournot's seminal work, focused on market models, appeared in 1838, while mathematical foundations of the theory of general equilibrium, consumer choice, firm's behavior, and welfare were laid by Walras, Edgeworth, Pareto, and others in late 19th and early 20th centuries. Yet, despite some contact and interaction, the main body of economic thought developed largely in ignorance of, if not outright contempt for, the actual and potential value of these foundations. At the same time, many of those who were developing a mathematical approach to economic analysis failed to relate their results adequately to the accomplishments of their "literary" brethren whose intuitive grasp of issues was powerful enough to compensate for deficiencies in techniques of analysis.

A radical change in this climate of scientific opinion occurred in the 1930's. The arrival on the scene of a group of individuals capable of and interested in mathematical formulation of classical as well as new problems—among them Hicks, Allen, Kalecki, and Lange, as well as the 1969 Nobel laureates Frisch and Tinbergen—created an atmosphere favorable to a creative synthesis of the best in the two streams, mathematical and "literary," of economic analysis. As a result, economic theory is well equipped to resist the temptation to splinter into "schools" so typical of earlier eras, despite tendencies toward fission due to diversity of methodological predilections and to conflicts in value judgments and ideologies related to policy applications.

A number of writers contributed to this synthesis, but Samuelson's role has been outstanding. A characteristic example is a model of the business cycle constructed by Samuelson in 1939 from two simple linear difference equations, one of which relates consumption to lagged income and the other postulates investment to be proportional to the rate of change in consumption. As Samuelson himself has stressed, his model was a simple formulation of ideas already set forth by Keynes, Harrod, and Hansen. There had been earlier formalizations of dynamic models arising in economics, including more sophisticated ones involving probabilistic disturbances. Yet Samuelson's model and his analysis of the relationship between parameter values and properties of solutions dealt (in his own later evaluation) "with fundamentals easy to grasp, [yet] was just deep enough to pique the interest and curiosity of business cycle students and to serve as a pedagogical introduction to dynamic economic models." Thus a short early paper, perhaps low on its author's own scale of originality and depth, has had a significant impact on the average economist's (as well as many experts') understanding of macrodynamic phenomena and has ultimately influenced teaching and research as well as policy formulation.

Among the many analogous examples, I shall mention just one, Samuelson's (1954) theoretical model of public expenditures and collective consumption goods. A simple algebraic characterization of the distinction between public and private goods (consistent with earlier public finance formulations) provides a basis for the derivation of optimality conditions that differ from those of the familiar market type. In an era of increasing interest in the priorities among public expenditures, as well as concern for (methodologically related) externality problems such as pollution, Samuelson's model has both stimulated and facilitated important research.

Given the fruitfulness of his mathematical formulation, synthesis, and exploration of relatively simple models of applied importance, one is all the more struck by the innovative power of his work in the domain of "pure" theory. In this work, laws governing physical dynamic systems seem to have played an important role as inspiration for conjectures and modes of analysis. Thus, for instance, the Le Chatelier principle of thermodynamics makes repeated appearance in situations where equilibrium is defined by the extremum of some function (energy in physics; cost or profit in economics).

In the last two decades, much of Samuelson's work has been focused on problems of economic growth and capital accumulation. In a series of papers, the most recent in 1969, he has related the requirements of efficient or optimal growth to the balanced growth mode obtained by von Neumann. The remarkable phenomenon, conjectured by Samuelson in 1949 and subsequently dubbed by Robert Solow, Samuelson's close collaborator, the "turnpike theorem," is that for a sufficiently distant maximization horizon one will be arbitrarily near the von Neumann balanced growth path an arbitrarily large percentage of time. The numerous proofs and elaborations of the "turnpike theorem" found in recent journals bear testimony to the interest that the theorem has evoked among economists.

Samuelson's own papers in this field, especially those employing the calculus of variations approach with continuous time, show his constant awareness of the related problems in classical mechanics. There are references to the Principle of Least Action and comments on the parallelism between the identities governing capital accumulation and the constant energy constraint. One also finds Samuelson drawing on Poincaré's *Méchanique Céleste* and Birkhoff's *Dynamical Systems* for a theorem on the characteristic roots associated with the Lagrange-Hamilton differential equations in the neighborhood of a stationary equilibrium point.

Among the highly significant contributions with a close relationship to

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the mathematical theory of physical systems is Samuelson's work on the stability of economic systems. Against the background of a dynamic model of price adjustment represented by a system of ordinary differential equations with time rates of price change proportional to excess demand for the corresponding commodity, he showed in particular how properties of the characteristic roots could be related to dynamic stability properties of the system and how these findings differed from earlier attempts at market stability. "One interested only in fruitful statics must study dynamics."

Yet physical analogies are not blindly followed: the analysis is firmly anchored in the economics of the problem. In fact, perhaps the most important aspect of the influence of physical sciences on Samuelson's scientific work lies in the methodological attitudes. The original (1941) version of his *Foundations* carried the subtitle, "The Operational Significance of Economic Theory." The notion of operationalism is at the root of his revealed preference formulation of consumer choice theory. First, he distinguishes carefully between the observable phenomena (represented by the demand functions) and the underlying explanatory model (utility maximization hypothesis), as one might perhaps distinguish between the spectrum of an element and the electron-orbit model explaining it. Second, as against Slutsky who pioneered such analysis, he is particularly interested in observable criteria that justify the rejection of the underlying model on the basis of a *finite* number of observations. Finally, by his stress on the nature and value of "meaningful" theorems, Samuelson directed the economists' attention to the potentialities of the axiomatic method.

The modern economic theorist's tendency to codify results as rigorously stated and proved theorems has received considerable encouragement from Samuelson's work, although it obviously has other important roots as well. Things may in fact have gone further in the direction of formalization than he would regard as optimal. His own tastes often seem to move him toward a somewhat informal style of presentation of results. Also, he frequently focuses on theorems exhibiting not so much the general properties of systems (for example, the existence of equilibrium) as the special features to be observed when the system is endowed with an appropriate structure. The "turnpike theorem" and the international factor price equalization theorem are among instances of such results. Yet another illustration is found in the so-called nonsubstitution theorems, one of which (also obtained independently by Georgescu-Roegen) specifies conditions under which relative prices and input proportions are, in contradistinction to the situation in the general Walrasian model, independent of demand conditions.

But no casual listing could do justice to the totality of Samuelson's achievement. It would have been difficult for the Nobel committee to have picked an economist whose contribution commands more universal appreciation among such diverse segments of the economics fraternity as mathematical theorists and practitioners, and specialists in public finance, international trade, business cycle, or the methodology of science, and including many who disagree with him on theory, policy or politics.

But those who have had the privilege of closer association would have a valid complaint if we failed to note the extent to which Samuelson's intellectual brilliance and wit are complemented by personal helpfulness and capacity for friendship.—Leonid Hurwicz

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