

## STONE, JOHN RICHARD NICHOLAS (1913–1991)

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Sir Richard Stone, knighted in 1978 and Nobel Laureate in Economics in 1984, was the outstanding figure in postwar British applied econometrics. His work in social accounting has had a profound influence on the way that measurement is carried out in economics, and his econometric model building changed the way that economists analyze those measurements. In contrast to many of his British contemporaries, he was a scientist and scholar whose command of methodology and theory was always at the service of the interpretation and measurement of the evidence. He was the inheritor of the British empiricist tradition in economics that saw its first flowering among the ‘political arithmeticians’ of the English Restoration, men such as William Petty, Gregory King and Charles Davenant. To a large extent, he abstained from providing short-term policy advice, preferring to concentrate on the advancement of his science. But his contributions have had an incalculable effect on economic policy and his career provides eloquent testimony to the long-run social value of scientific scholarship in economics and a contrast to the sometimes unenviable record of his contemporaries who involved themselves in the day-to-day conduct of British economic policy.

Richard Stone was born in 1913, attended Westminster School, and set out to follow his father’s profession by reading law at Gonville and Caius College, Cambridge. He moved to economics midway through his undergraduate career, and came under the influence of Colin Clark, who was then lecturing in statistics to the economists and who was himself deeply involved in the measurement of national income (see particularly Clark, 1937). Stone’s interest in modeling, in measurement and in estimation was immediate. During the summer prior to his graduation from Cambridge, he set out to estimate a two-factor Cobb–Douglas production function, a pioneering effort the results of which excited little interest or understanding from “the Prof” as Pigou was known, perhaps the first evidence of a Cambridge attitude to econometrics that was later to be reinforced by Maynard Keynes’s reactions to Tinbergen’s work (Keynes, 1939) and was to be maintained long after similar perceptions had died out elsewhere. After a brief spell in the City of London, during which he devoted his spare time to producing a monthly bulletin of current economic trends, Stone moved at the outset of World War II to Whitehall, where eventually he came to work, with James Meade and initially under his direction, on the construction of wartime national accounts. At Keynes’s instigation, their results were published in the 1941 Government White Paper, *An analysis of the sources of war finance and an estimate of the national income and expenditure in 1938 and 1940*. In 1945, and again under Keynes’s stimulus, the Cambridge Department of Applied Economics was founded and Richard Stone was appointed its first Director with an indefinite tenure in the position. Stone brought enormous distinction and worldwide recognition to the department until he was maneuvered out of the directorship by the Cambridge ‘Keynesians’ in the mid-1950s; he remained in Cambridge as the P. D. Leake Chair of Finance and Accounting until his retirement in 1980. The 1984 Nobel Prize in Economics is perhaps the greatest of many professional honors bestowed on Sir Richard. He was a Fellow of King’s College, Cambridge from 1945 and of the Econometric

Society since 1946. He was president of the Econometric Society in 1955 and President of the Royal Economic Society from 1978-80.

The work for which Stone received the 1984 Nobel Prize in Economics was his 'fundamental contributions to the development of national accounts' that 'greatly improved the basis for empirical economic analysis'. The full history of the development of modern national income accounting remains to be written, and any attempt is beyond the scope of an article such as this. It is of course not true that Stone was responsible for the basic concepts of national product, consumption, investment and so on, nor that he provided the first estimates of these magnitudes for the United Kingdom or anywhere else (see for example Stone's brief history of the subject in his Nobel Memorial Lecture: Stone, 1984). What Stone (along with Meade, whose original vision Stone developed and made his own) should be credited with is the construction of an interlocking *system* of balanced national accounts, and the implementation of that system on a worldwide basis. Stone's system of national accounts, the SNA, published by the United Nations Statistical Office in 1953 with several subsequent revisions, is not simply a set of tables containing the national income magnitudes, but a set of interlocking accounts in which the principles of double-entry bookkeeping are scrupulously maintained. Each outlay for each agent must be matched somewhere else by an inflow for some other agent, so that each entry in each account must appear somewhere else in some other account. Of course, this is only of value because each account, whether for production, accumulation, consumption, or international trade, is independently filled in so that in the end the whole system provides its own complete set of internal consistency checks. Of course, there are always errors and omissions, and some magnitudes cannot be independently measured from both sides of the account, but the credibility and usefulness of each of the numbers hinges on the systematic framework in which they are set. It was Richard Stone, first with James Meade in the Cabinet Office in London, and later on the world stage at the United Nations and the Organization for European Cooperation and Development, who was largely responsible for the way in which national accounts are today collected and presented throughout the world (Stone, 1947; OEEC, 1952).

Stone always favored the presentation of his national accounts in a matrix format, so that each account appears as the row (incomings) and column (outgoings) of a single matrix. In this social accounting matrix (SAM), the standard magnitudes such as national product, consumption or the balance of trade all have their place, but the detailed entries provide a rich picture of the structure and functioning of the economy. For example, the Leontief input-output matrix of inter-industry transactions is the submatrix corresponding to the detail of the production accounts. Demand patterns of households appear in the submatrix with industries in the rows and households in the columns, while the incomes generated in production flow into households through the value added submatrix. Such social accounting matrices can be disaggregated to show any amount of data, and they can be supplemented by balance sheet data (the opening and closing stocks corresponding to the national income flows); and they can be related to socio-demographic variables in a set of demographic accounts. For a typically elegant and lucid account of this with simple examples, see again Stone (1985). One of the most important features of such 'tableaux économiques' is that it is almost impossible to look at them for long without being led into attempts to model the behavior that they reveal. For some cases, the SAM is close to *being* a model; the input-output matrix can be thought of both

as a record of transactions, and as a succinct description of the technology of production. Similarly, the links between production, accumulation and consumption lead naturally to models of the allocation of household income between saving and the purchases of goods and services. Together with his first wife, Stone had published one of the very first empirical papers on the marginal propensity to consume (Stone and Stone, 1938), and his work on modeling, particularly of consumer behavior, continued along with his work on national accounts through the late 1940s and 1950s.

Perhaps Stone's greatest work lies in his empirical analysis of consumer behavior and the contributions to econometric methodology that came with it. In a series of papers (Stone, 1945, 1948, 1951; Stone and Prais, 1953) that culminated in 1954 in a book, *The Measurement of Consumers' Expenditure and Behaviour in the United Kingdom, 1920–38*, which to this day remains one of the classics of applied econometrics, Stone presented models that analyzed the determination of consumers' expenditures. The book contains a dazzling display of all of the elements of the econometrician's art as of the mid-1950s, and there is very much that can be learned from it even today. There is a great deal of very careful and painstaking description of the data, not tucked away where the details cannot be seen, but proudly and prominently displayed for readers to see and quarrel with should they choose. There is a masterly exposition of the theory of demand and of revealed preference, and there is a chapter on econometric methodology that reads like a text until one realizes that this is where the texts originated. The standard matrix algebra formulation of the general linear model  $y = X\beta + u$  appears in its modern form, together with such now standard diagnostics as the Durbin–Watson test, then just invented in the Department of Applied Economics by two young statisticians.

For each of the commodities that he analyses, Stone begins with a loglinear formulation in which the logarithm of the quantity of the good is related to the logarithm of income and the logarithms of other prices, together with a number of other factors that vary from commodity to commodity. For example, the demand for beer is influenced by the average strength of beer as measured by its specific gravity. Stone's major practical problem is lack of degrees of freedom; with only nineteen annual observations, disentangling the separate effects of prices, income, and other influences requires generous application of theory and or of prior information. Stone uses both. In the first place, he uses the Slutsky decomposition to absorb the income effects of prices into the income term through what is now known as a Stone index, thus converting the latter into real rather than money income. Second, he uses zero degree homogeneity to convert prices to relative prices, saving one degree of freedom. Third, he uses elasticities estimated from Engel curve analysis on cross-sectional household budget data to estimate the income elasticities so that, with these imposed, the time-series data are liberated to estimate as many price effects as precisely as possible. Fourth, Stone recognizes the difficulties presented by strong positive autocorrelation in the residuals and to counteract them takes first differences of model and data prior to estimation. Stone's recognition of the non-stationarity of his data, and his first-differencing procedure, though less than perfect, is much superior to and less misleading than the ignoring of the problem that characterized most applied work for the quarter of a century after Stone's book. His general procedure set up, Stone then goes on to analyze commodities one by one, reporting results and testing alternative specifications with a

care and conviction that has been a model for generations of those of us who have tried to follow him.

The other work of Stone's that is of lasting importance is his paper on the linear expenditure system that appeared in the *Economic Journal* in 1954, the same year that the book appeared. The transition from the models of the book to the model in the paper is in some respects one of the most important transitions in modern applied econometrics, and the methodological issues that are involved are still far from settled. In Stone's book, the influence of the theory of demand is pervasive throughout the discussion of specification and interpretation, but the functional form of the demand equations is essentially *ad hoc*, the double logarithmic form having been widely adopted because of its convenient parameterizations of the elasticities which are routinely used to describe demand behavior. The consequences of using such an equation, and of treating demand equations one by one, is that certain aspects of the theory cannot be used nor easily tested. In particular, the symmetry of the compensated substitution effects could not be imposed within the analysis of the book, much as it would have been desirable to do so to gain degrees of freedom and precision of estimation. In the *EJ* paper, Stone comes up with a solution. Starting from a *system* of expenditure equations that are linear in prices and total expenditure, the theoretical requirements of adding-up, homogeneity, and symmetry are imposed algebraically to yield a set of estimating equations, the linear expenditure system, that is fully consistent with demand theory. Although the model cannot be estimated by linear methods, Stone invents an iterative Gauss-Seidel procedure that allows him to obtain estimates for a small system using the interwar data. There are many things to admire in this paper, and many things that can be criticized, especially with the benefit of hindsight. The linear expenditure system is a rather primitive model, and Stone's estimation technique was a poor one; similar things could no doubt be said about many great innovations. It is also true that Stone did not solve out for the linear expenditure system utility function, even though the theory of the model had been fully analysed some years before in papers by Klein and Rubin (1947), Samuelson (1947–8), and Geary (1950–51). The real originality and importance of the paper lie elsewhere. Nowhere is the previous literature had anyone ever had the extraordinary idea that it might be possible to use economic theory to confront the data so directly; demand equations had been estimated before, but no one had ever attempted to estimate the parameters of a *utility* function. Economic theory might be used as a general guide as to what to look for, but not to yield estimating equations directly. The two main currents in applied econometrics today, structural estimation of "deep" parameters versus more eclectic, atheoretical, or implicitly theoretical estimation, can be seen in Stone's paper and book of 1954. Today, when structural estimation is so familiar, it is easy to forget that 'taking theory to the data' is a relatively young methodology. I believe that Stone's linear expenditure system is a major landmark along the route that leads to where we are now.

In an article of this length it is impossible to give any detail on more than a tiny fraction of Stone's contributions to economics, although see my own more detailed (and somewhat more personal) memoir, Deaton (1993). In addition to his work on the detail of commodity expenditures, there are a set of important papers on savings behavior (Stone and Rowe, 1962; Stone, 1964, 1966, 1973) and on the development of the stock-adjustment model for explaining the dynamic demands for durable goods (Stone and

Rowe, 1957, 1958, 1960). A fuller appreciation of this work and other papers on demand analysis can be found in Johansen (1985) and in Houthakker (1985). Stone has published important work on the theory of price indexes (1956), on seasonal adjustment (1970), and on methods of handling errors of measurement in national accounts (Champernowne, Stone and Meade, 1942; Stone, 1984). He was one of the first to use principal components analysis as a practical data reduction procedure in economics, Stone (1947). Over many years, he supervised the construction of the Cambridge Growth Model, in which social accounting matrices and behavioral equations for demand and production were integrated so as to provide a tool for planning and policy evaluation (see in particular Stone and Brown, 1952, and Stone 1964). He also extended his work on economic accounting to incorporate demographic accounts (Stone, 1971, 1975; Stone and Weale, 1986). At the very end of his life, he acknowledged his debts to his predecessors in a set of quantitative biographies of twelve British empiricists in the social sciences, William Petty, Charles Davenant, Gregory King, William Fleetwood, Arthur Young, Patrick Colquhoun, John Graunt, Edmond Halley, William Farr, Frederick Morton Eden, Florence Nightingale, and Charles Booth, Stone (1997).

There is another very great contribution that Stone has made to economics and econometrics that is not reflected in his own published work, but in that of those who have been associated with him over the years. Stone was never really a teacher in the conventional way. He was a reluctant lecturer, especially to students, and he participated very little in the routine of Cambridge instruction over more than thirty years of formal attachment to the faculty. However, his personal influence has been extraordinarily strong, partly because of the compelling lucidity of his writings, but also by the example he set to the stream of economists and statisticians who spent time in the Department of Applied Economics with him. That stream flowed for many years, but there is no doubt that the best years were at the beginning, in the late 1940s and early 1950s, when Stone himself was working on demand and on the econometric techniques of estimating demands. I have no complete list of those who passed through, but a partial list of those who were there for extended periods includes Brumberg working on life-cycle models, Houthakker working on revealed preference and applied demand analysis, Prais working on family budgets, and Tobin working on demand analysis and on rationing. On the more statistical side, Durbin, Watson, Cochrane, Orcutt and Anderson spent time in the Department working on auto-correlation in economic time-series, early visitors included Tintner and Duesenberry, Geary, Klein, Leontief, Samuelson, Koopmans, Wold, Frisch, Ruggles and Hoffman. Farrell began his academic life in Stone's department and did fine empirical work on dynamic demands and on aggregation theory. Prest worked on demand analysis and on time-series problems. Alan Brown worked on Engel curves and wrote a distinguished book with Aitchison on the uses of lognormal distribution. Afriat began his work on price indexes in the Department. Not only did all of this work owe much to Stone's presence and to the existence of the Department of Applied Economics, but the joint output of all of these people represents an explosion of econometric and economic knowledge that has never been exceeded in the history of the subject and has perhaps only been equaled by the work of the Cowles Commission.

Angus Deaton

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