Box, George Edward Pelham

(1919–2013)

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- https://doi.org/10.1093/ref:odnb/109283
- Published online: 01 January 2017

Box, George Edward Pelham (1919–2013), statistician, was born on 18 October 1919 at 52 Cobham Street, Gravesend, Kent, the younger son of Harry Box, assistant manager at a tailors and outfitters, and his wife, Helen, *née* Martin. He had an elder sister, Joyce, and brother, Jack. He won a scholarship that funded secondary school and, until the age of sixteen, studied at the Gravesend County School for Boys. Following school, he worked as an assistant chemist at the local sewage treatment plant.

At the outset of the Second World War, Box joined the British army. He was assigned to a unit developing antidotes to poison gas at Porton Down and much of his work involved analysing the unit's experimental data. The experience piqued his interest in statistics and led him to enrol at London University, where he graduated BSc in 1947 and PhD in statistics in 1952 under the supervision of H. O. Hartley. London University later awarded him a DSc degree, in 1961. Alongside his postgraduate studies he also worked as a staff scientist at Imperial Chemical Industries (ICI) in Blackley from 1948 to 1956; his work to improve industrial processes at ICI stimulated many of his early scientific contributions.

Box visited the United States in 1953–4, in response to an invitation from Gertrude Cox to be a guest scholar at North Carolina State University. He returned to the USA in 1957 when John Tukey invited him to direct the Statistical Techniques Research Group at Princeton University. He left Princeton in 1959 to found the department of statistics at the University of Wisconsin–Madison. In 1971 he was appointed Ronald Aylmer Fisher professor of statistics and in 1980 he was recognized with a Vilas professorship, the highest honour granted by the university. In 1985 he joined Bill Hunter in founding the University of Wisconsin–Madison's Center for Quality and Productivity Improvement, which achieved international renown for conducting and disseminating research on quality.

Box left a substantial intellectual legacy. His ideas had a major influence and the insightful and efficient methods that he pioneered achieved widespread use in diverse areas of science and technology. Many scientists and engineers learned about the advantages of designed experiments from his text *Statistics for Experimenters* (1977), written with Bill Hunter and Stu Hunter. ‘Box and Jenkins’ (*Time Series Analysis: Forecasting and Control*, 1970, written with Gwilym Jenkins) became synonymous with their paradigm for analysing time series data, and ‘Box and Cox’ ('An analysis of transformations', written with David Cox and published in the *Journal of the Royal Statistical Society, Series B*, 1964) with the effective use of data transformations.

Box was especially well known for the development of response surface methods, research that was stimulated by the need to improve the yield of chemical processes at ICI. His article with K. B. Wilson, a colleague at ICI, 'On the experimental attainment of optimum conditions' (published in the *Journal of the Royal Statistical Society, Series B*, 1951) set out an overall strategy of sequential experimentation, exploration, and optimization, and introduced an important new class of designs, the central composite family. Subsequent work by Box and his colleagues defined new design concepts, such as resolution and rotatability, and other classes of designs for fitting polynomial regression models. The theoretical research on response surface methods was fuelled by practical problems, where the new ideas found immediate application. This interplay between theory and practice was a recurrent theme in Box's scientific career.

Box made significant contributions to the analysis of time series data. His book with Jenkins, subsequently revised together with Greg Reinsel and published in a second edition in 2008, guided many researchers and practitioners. One of the key features of their approach was an iterative modelling strategy, which began with informative statistics and graphs to identify models, followed by estimation of an assumed model, and then diagnostics using residuals to criticize the model. The analysis might involve several cycles of identification, estimation, and criticism.

In the 1960s Box became a strong proponent of Bayesian statistical inference. He and George Tiao—with whom he published *Bayesian Inference in Statistical Analysis* in 1973—examined both foundational issues and applications, including the choice of prior distributions, random effects models, and inference for variance components, estimating common regression coefficients, data transformation, and the role of assumptions.

Box returned to the areas of quality improvement and designed experiments in the early 1980s, spurred by the revival of interest in quality in American industry and by the quality engineering ideas of Genichi Taguchi. Designed experiments were one of the key tools in quality engineering. Box, along with several students, critically examined the use of experiments for quality improvement. An important aspect of Box's work was to frame the methods by placing them in a broader scientific quality context; a key paper was 'The scientific context of quality improvement', co-written with Søren Bisgaard and published in *Quality Progress* in 1987.

Box collaborated with Alberto Luceño, a visitor to the Center for Quality and Productivity Improvement, to study the links between statistical process control and the feedback and feed-forward control strategies used by engineers. The two approaches appeared, on the surface, contradictory: statistical process control advocated tracking processes and intervention only when there was a clear signal of an assignable cause, whereas engineering control made regular adjustments to the process. Box and Luceño showed how these approaches could complement and improve one another in a series of articles and then in their book *Statistical Control by Monitoring and Feedback Adjustment* (1997).

Box emphasized the role of statistics as a basic component in scientific discovery. A good introduction is his article 'Science and statistics' (*Journal of the American Statistical Association*, 1976), which features a diagram of scientific iteration, proceeding from induction (model criticism and forming hypotheses) to informative data collection, to deduction (estimation). The diagram is a blueprint for using statistics to learn. Box wrote critically of the tendency for statistical theory to focus on single steps in the process, treating science as a one-shot experiment. The role of scientific context is evident in Box's research in experimental design. His first major contributions were the fruit of his collaboration with scientists at ICI who needed to study and improve processes. The rapid feedback from their experiments was quite distinct from the slow feedback in agriculture, the focus of most previous statistical research on experimental design. Box's ideas on sequential experimentation took advantage of that context, with the design adapting to the results. That might entail dropping some factors or adding new ones, moving factors to higher or lower values, or adding new intermediate levels of a factor. The technical research that followed provided tools for implementing the sequential strategy.

Box made a number of contributions to the scientific lexicon. Perhaps the single most memorable phrase is his comment that 'all models are wrong, but some are useful' (first used as a sub-heading in 'Robustness in the strategy of scientific model building', in R. L. Laurier and G. N. Wilkinson, *Robustness in Statistics*, 1979, 201–36). He also introduced the term ‘robustness’ to the statistical vocabulary.

George Box received numerous awards and honours, including the Deming, Shewhart, and Wilks memorial medals, and the Royal Statistical Society's Guy medals in silver and gold. He delivered the prestigious R. A. Fisher lecture in 1974. In 1985 he was elected a fellow of the Royal Society. He served as president of both the American Statistical Association (in 1978) and the Institute of Mathematical Statistics (in 1979). In the final year of his life he published a personal memoir, *An Accidental Statistician*, an excellent source for detailed information on his life and his career. He was known for his wit and sociability, and at the University of Wisconsin–Madison for his long-running Monday night ‘beer and statistics’ sessions which he hosted at his home. He was married three times: first on 5 May 1945 to Jessie Ward (*b*. 1918), daughter of Charles Ward, salesman; second in 1959 to Joan Gunhild Fisher (*b*. 1927), daughter of the statistician and geneticist R. A. Fisher, with whom he had a son and a daughter; and third in 1985 to Claire Louise Quist. He died at his home, 911 Western Road, Madison, Wisconsin, on 28 March 2013, and was survived by his third wife, Claire, and the children of his second marriage.

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