



CLIVE GRANGER

Clive William John Granger

1934–2009

CLIVE GRANGER played a central role in establishing the basis for the econometric analysis of non-stationary time series. He enjoyed a distinguished career spanning more than forty years as a teacher, researcher, and practitioner, during which he made major contributions to most of the key concepts and methods of econometrics, particularly when Professor of Econometrics at the University of California at San Diego. He contributed to a remarkable number of areas in econometrics, including the analysis of non-stationary time series, causal relations between economic variables, long memory, non-linear models and modelling, forecasting economic and financial time series, modelling stock prices and volatility, and price formation. He was Emeritus Professor there when he died on Wednesday, 27 May 2009, in Scripps Memorial Hospital in San Diego after a brain tumour.

Clive Granger was born on 4 September 1934, in Swansea, Wales, but left as a baby when his parents moved to Lincoln while working for Chivers the (then well-known) maker of marmalades, jams, and preserves. When his father, Edward John Granger, joined the Royal Air Force during the Second World War to become a driver of large support vehicles in North Africa, Clive, who was an only child, and his mother, Evelyn Agnes (formerly Hessey), moved to Cambridge to stay first with her mother then later with his father's parents in the same city. His paternal grandfather made and sold shoes in his own successful shop in Cambridge. His maternal grandfather had been a gardener at Windsor Castle, where his maternal grandmother was a cook, but had later moved to Cambridge.

Clive first went to primary school in Cambridge. In his Nobel Prize Autobiography <http://nobelprize.org/nobel_prizes/economic-sciences/

laureates/2003/granger-bio.html>, Clive noted that a teacher there told his mother he ‘would never become successful’, and remarked that this ‘illustrates the difficulties of long-run forecasting on inadequate data’. He went on to pass the 11-plus and go to Cambridgeshire High School for Boys. In 1946, after his father returned from the war, the family moved to West Bridgford, Nottingham, and Clive started at West Bridgford Grammar School. There his mathematical ability became apparent, developed by two excellent teachers whom Clive credited for his interest in and understanding of mathematics. He took A-levels in pure mathematics, applied mathematics and physics, and became the first member of his family to go to university.

As he was interested in the practical applications of mathematics, Clive took up a place on the new degree course at Nottingham University in mathematics and economics, but switched after a year to a mathematics degree. He graduated in 1955 and was persuaded to stay on for a Ph.D., seeking a mathematical topic with relevance to economics. Having found that there was relatively little mathematical analysis of economic time series, he chose to research that topic under the supervision of Sir Harry Raymond Pitt, FRS, a renowned pure mathematician and probabilist.

His Ph.D. thesis very presciently concerned ‘Testing for non-stationarity’. A time series is stationary when its distribution is constant over time, so its mean and variance in particular must be unchanged. If the distribution or its moments shift, then the process is non-stationary. Most macroeconomic time series are non-stationary as they both trend and experience sudden (usually unanticipated) shifts in their means—so even their first differences are non-stationary—and sometimes in their variances, as during the so-called ‘Great Moderation’ preceding the financial crisis of 2008 onwards. Nevertheless, at the time almost all empirical studies and most econometric theories were predicated on an assumption of stationarity. Clive completed his Ph.D. in 1959. En route, he became a lecturer in statistics at Nottingham in 1956, was promoted reader in econometrics there in 1964 and then professor in 1965, only six years after finishing his doctorate.

Princeton and the USA

Clive spent the year 1959–60 at Princeton University on a Harkness Fellowship. In his autobiography, Clive tells the story about how while he was there, he and Michio Hatanaka were introduced to spectral analysis

by John Tukey, who taught them how to use this new tool of time-series analysis. At the end of a course that lasted almost a year, they had enough material for a book, but Tukey said he did not have time to publish the results, so Clive and Michio wrote them down and published *Spectral Analysis of Economic Time Series* (Princeton, NJ, 1964). This book became a Citation Classic.

While in Princeton, Clive applied the new ideas on the spectral properties of economic data to New York Stock Market Prices (with Oskar Morgenstern, in *Kyklos*, 1963, reprinted in *The Random Character of Stock Market Prices*, ed. P. H. Cootner, Cambridge, MA, 1964), as well as a book on forecasting stock prices with Morgenstern.

The terms of the Harkness Fellowship required Clive to spend the last three months travelling around the United States. This he did with his wife, Patricia Anne (née Loveland, born in 1938). Clive initially travelled down the Eastern seaboard to Florida and back and, when Pat joined him, together they crossed the States east–west and back, camping everywhere for economy, which also helped them meet many people. Amusingly, en route they visited Granger, Indiana and Loveland, Colorado. He had first met Pat when she was a research assistant to David Chambers, an economic historian at Nottingham, and she consulted Clive on some statistical issues. They were married in Princeton University Chapel in 1960. They had a son, Mark (born 1964), and a daughter, Claire (born 1968).

In 1974, the family moved to La Jolla in the United States after Clive accepted a professorship in the Department of Economics at the University of California, San Diego (UCSD). This move proved to be a permanent one as Clive remained at UCSD till he retired in 2003.

Looking back on Clive's scientific achievements, it is possible to argue that much of his work has its origin in his lifelong interest in the properties of economic time series. These are not just statistical properties of models of economic series, but also properties one can 'observe' in the series themselves. 'Observing' in this context includes looking at the series in the frequency domain. Clive's first *Econometrica* paper, 'The typical spectral shape of an economic variable' (1966), is a good example of his interest in the properties of series. He noted that many economic time series have most of their spectral mass at the lowest frequencies of the spectrum and so discussed this phenomenon. His paper also contained a discussion of a 'trend'. According to the definition given in the paper, the trend of a series consisted of components of frequencies lower than $2\pi/T$ —i.e. the lowest observed frequency or the period equal to or greater

than the length of the series, T . Trends turned out to be a concept that intrigued him throughout his career. His last paper, in *Journal of Time Series Econometrics* (2011: with Hal White, who has sadly also died since), concerned the characteristic properties of trends, which could be stochastic or deterministic, linear or non-linear, constant or evolving, or subject to sudden shifts ('the trend is your friend until it doth bend'). Indeed, the later concept of cointegration was to concern stochastic trends that were common to all the time-series variables involved.

Causality

There is a close link between spectral analysis and Clive's interests in causality and forecasting. In his Nobel lecture <http://nobelprize.org/nobel_prizes/economic-sciences/laureates/2003/granger-lecture.html>, Clive explained how in 1969–70 the then new concept of cross-spectrum had made him think of connections between two variables and led him, after studying a paper by Norbert Wiener, to introduce a concept of causality that had the advantage of being applicable to data, and became known as 'Granger causality'. This concept was not only useful in applied work (its numerous applications were not restricted to economics), but was also an integral part of the definition of strong exogeneity, which in turn has implications for multi-period forecasting with econometric models.

Clive's first major publication on such causal relationships between economic variables was 'Investigating causal relations by econometric models and cross-spectral methods', in *Econometrica* (1969). Earlier notions of causality in econometrics concerned simultaneous equations systems, which might be called 'instantaneous' causality. Clive instead placed the 'arrow of time' at the centre of his definition, although he restricted the analysis to stationary series. When the joint distribution of a set of stochastic variables is changed by eliminating the history of a subset, he argued they must cause some of the first group, which can then be predicted more accurately with the subset than without. However, this notion was not operational, as it required knowledge of the joint distribution of all possible variables before and after elimination of a subset.

As an operational approach, Clive suggested testing whether the removal of a subset of variables from a model worsened the forecasts, relying on correlations with the 'real causes'. Then, non-causality between economic variables could be easily tested by statistical methods, which

Christopher Sims, later also a Nobel Laureate, developed. Clive's definition was popular because of its ease of implementation, and stimulated a considerable number of empirical studies, as well as much controversy as to whether it was a general definition of causality or just an example thereof. However, because not all possible variables are investigated, conclusions as to which variables Granger cause, or do not Granger cause, others can be reversed by adding further variables to the analysis, so causal inferences are not necessarily robust. Nevertheless, his operational definition of 'Granger causality' plays an important role in many areas of econometric modelling, including cointegration, distributions of estimators and tests, forecasting and policy analysis, even though only a subset of all the variables is analysed in practice. Clive was disappointed that his causality (or 'predictability') concept was mainly used for in-sample testing, although he had meant testing (non)causality to be a genuine out-of-sample forecasting exercise, as it was in his paper with R. Ashley and R. Schmalensee (*Econometrica*, 1980).

Cointegration

Cointegration is Clive's most important contribution to econometrics, and in his autobiography he explained where the idea came from. (Readers interested in a more complete history of the developments leading to cointegration could consult the first author's 'The Nobel Memorial Prize for Clive W. J. Granger', *Scandinavian Journal of Economics*, 2004.) He recorded that David Hendry had claimed that the difference between two non-stationary times series could be stationary, and many were so in practice, including the so-called 'great ratios' (e.g. consumption to income; capital to output; etc.) noted by Lawrence Klein, later a Nobel Laureate, in his 1953 *Textbook of Econometrics* (Englewood Cliffs, NJ). Clive set out to prove that claim was wrong, and instead was a variant on the well-known problem of 'nonsense correlations'.

Strange and unlikely correlations between variables, such as a positive correlation of murders in the UK with membership of the Church of England, had puzzled early users of Francis Galton's then recently developed regression methods. Udny Yule, in his Presidential Address to the Royal Statistical Society in 1926, explained the source of such correlations as being due to the non-stationarity of the time series. Yule used the simplest model that generated non-stationary time series, namely an

autoregression with a unit root usually called a random walk process. Yule proposed autoregressive processes to explain serial correlations in time series in 1927, as an addition to the moving-average process which Judy Klein notes in her 1997 book *Statistical Visions in Time* (Cambridge) were used from 1797 by the Bank of England to conceal the dire shortage of its bullion reserves during the Napoleonic Wars, and were formally analysed by Eugene Slutsky, also in 1927. Yule's 'nonsense correlations' paper revealed that tests of significance between unrelated random walks badly over-rejected at conventional critical values (e.g. t-tests at the 5% level of around 2 rejected the null hypothesis of no connection more than 70% of the time). In the USA, Bradford Smith proposed a model formulation that could handle such problems by nesting both levels and differences (published in *the Journal of the American Statistical Association*, coincidentally in 1926, and brought to light again in 2010 by Terry Mills in the *Oxford Bulletin of Economics and Statistics*), but neither Yule nor Smith seemed aware of the other's findings, so neither the problem nor its solution were remembered and had to be rediscovered.

With Paul Newbold, Clive illustrated the difficulty for static econometric models of what they called 'spurious regressions' (Yule had in fact discussed spurious correlations in 1897, as two variables being apparently related because each was related to a third), but the new epithet stuck. This work was published in 1974 in the *Journal of Econometrics*, and showed by Monte Carlo simulations that if one random walk was regressed on another to which it was in fact unrelated, regression coefficient estimates would seem 'significant' on conventional critical values far more often than in unrelated stationary processes. Consequently, empirical econometric equations that appeared to fit well but with autocorrelated residuals were a warning sign that such a relationship might be spurious. Their 'solution' of differencing the variables to reduce the non-stationarity before testing for a relationship between them was a step back from Bradford Smith's formulation, and Denis Sargan's 1964 notion in his famous Colston paper (later called error-correction mechanisms: the paper was reprinted in Hendry and Wallis (eds.), *Econometrics and Quantitative Economics*, Oxford, 1984), but was consistent with the arguments in George Box and Gwilym Jenkins's 1970 book *Time Series Analysis: Forecasting and Control* (London). Unfortunately, differencing eliminated the long-run relationships between the levels of the economic variables, which were often the relationships of interest to economists. Since the distributions of estimators of parameters in models involving random walks were non-standard and non-normal, so that larger than conventional critical

values were necessary for valid tests of significance, Clive doubted the legitimacy of analysing the levels of non-stationary time series. As the literature on error-correction mechanisms did not address that problem, Clive set out to prove that spurious results would still occur. However, he ended up showing the opposite and, among other things, stating what was later called the Granger Representation Theorem.

In his 1980 paper in the *Journal of Econometrics*, Clive had used the spectrum to define the concept of an integrated variable. Roughly a variable is integrated of first order, usually denoted $I(1)$, if it does not have a stationary distribution but its first difference is stationary, although higher degrees of integration are possible, so the differencing may need to be of a higher order, and the degree of integration need not even be an integer, leading to a class of 'long-memory' processes (on which he published contemporaneously as discussed below). Next, he defined a consistent model in his 1981 *Journal of Econometrics* paper. A model is consistent if simulation of the right-hand side variables reproduces the major properties of the variable y_t being explained. As an example, if a right-hand side variable is seasonal with period s (its spectrum contains distinct peaks at frequencies $2\pi j/s$, $j = 1, 2, \dots, s/2$), then y_t has to be seasonal. The paper noted an interesting special case, however: if two right-hand side variables are seasonal such that a combination of them is not seasonal, then y_t could be non-seasonal, leading to a consistent model.

It was this particular situation of 'cancellation of a property' that ultimately became the focus of interest and spawned an enormous literature. The definition and analysis of cointegration (initially co-integration) based on an analogy with this special case appeared in a 1987 *Econometrica* paper by Clive and Robert F. Engle, his colleague at the University of California in San Diego, which has since received more than 19,000 citations (based on Anne-Wil Harzing's *Publish or Perish*—Melbourne, 2011). Two variables were defined to be cointegrated (of order $(1, 1)$ in the simplest case) if both were $I(1)$ and there existed a linear combination that was $I(0)$. Thus, the two variables had to share a 'common trend' (that carried their integratedness), which a unique linear combination then cancelled. That combination of levels was shown to be an error-correction mechanism, but should have been called an 'equilibrium-correction mechanism' (EqCM) as it drove the system back to the long-run equilibrium trajectory defined by the combination, but did not correct when that equilibrium changed.

The beauty of their definition was that it suggested a way of econometric modelling of non-stationary series by testing for the cancellation of the common trends, taking account of the non-standard distributions

that non-stationary processes generated. Cancellation would not happen with unrelated random walks, for example, but would when the series were cointegrated, allowing discrimination between ‘nonsense’ and substantive relationships. This was duly noted by the Royal Academy of Sciences in Stockholm that in 2003 awarded Clive the Sveriges Riksbank’s Prize in Economic Sciences in Memory of Alfred Nobel ‘for methods of analyzing economic time series with common trends (cointegration)’. He shared the prize with Rob Engle, who received that award for his autoregressive conditional heteroskedastic (ARCH) model, now widely used in finance.

Clive linked cointegration with Granger causality in his 1986 paper in the *Oxford Bulletin*. He showed that if two series are cointegrated then at least one must cause the other. In his Nobel lecture, he mentioned that ‘there seems to be no special reason why the two quite different concepts should be related; it is just the way that the mathematics turned out’. In fact, the link is deep because of a property later elucidated by Søren Johansen in a paper in 1988 in the *Journal of Economic Dynamics and Control*, known as reduced rank (with more than 12,000 citations). This is the key to the prevalence of integrated–cointegrated time series in economics, and can be summarised as there being fewer decision variables than decisions. For example, many expenditure decisions depend on income and wealth. It follows that the same equilibrium-correction mechanism (EqCM) enters several equations—ensuring some Granger causality—and there are fewer EqCMs than equations. Surprisingly, such reduced rank also ensures that all the associated variables are integrated and some are cointegrated. Thus, there is an ‘endogenous’ explanation for the integrated–cointegrated nature of economic time series, and a set of statistical tools for ‘taming’ their wandering.

As a result of these and related developments, the starting point for any statistical analysis of economic time series is that they are non-stationary, usually integrated and often cointegrated, as well as possibly subject to shifts in their moments for other reasons (such as changes in technology, legislation or economic policy, social mores etc.).

Forecasting

In his Nobel lecture, Clive mentioned that his inspiration to investigate economic forecasting had come from receiving an advance copy of Box and Jenkins’s 1970 book. With John Bates he showed in *Operational*

Research Quarterly (1969) that combining forecasts from different models often improves the forecast accuracy compared to forecasts from individual models. Using the idea that differential biases in forecasts could cancel when combined, they proposed forecast-weighting schemes for that purpose. This work prompted a large and still expanding literature, a useful survey of which by Allan Timmermann can be found in the *Handbook of Economic Forecasting* (Amsterdam, 2006) that Clive edited jointly with his UCSD colleagues Timmermann and Graham Elliott. Following the Bates–Granger idea, Clive received a grant to do further research on the topic and, with Paul Newbold, produced *Forecasting Economic Time Series* (New York, 1976). This was at the same time as their research on nonsense regressions, and the finding by Charles Nelson and Phillip Cooper that large econometric models often forecast less accurately than random walks seemed consistent with their view that many empirical economic relationships were spurious. An improved approach to economic forecasting was clearly required, and at first it was hoped that dealing appropriately with integrated–cointegrated time series would be a major advance. Unfortunately, the prevalence of unanticipated shifts has continued to thwart everyone’s best efforts, even though Clive repeatedly tackled the problems of forecasting and the associated issue of better specification of forecasting models.

Another forecasting topic where Clive made important contributions was the evaluation of forecasts, especially judging forecast ‘inaccuracy’ in light of a forecaster’s loss function. In research with Hashem Pesaran, they analysed how the choice of loss function influenced both parameter estimation and model evaluation. Although mechanistic forecast-error evaluation (by, say, root mean-square errors) remains dominant, such developments brought economic considerations into judging the costs of forecast errors, building on the work of Gordon Leitch and Ernest Tanner (*American Economic Review*, 1991).

Non-linearity

Another of Clive’s many areas of interest was non-linearity. He wrote a book in 1978 (with Allan Andersen) on bilinear models (*Introduction to Bilinear Time Series Models*, Göttingen: in his autobiography he noted, however, that such a model had not proved useful in economic applications). Later he co-authored two more general volumes on non-linear

models and modelling, one with Teräsvirta (*Modelling Nonlinear Economic Relationships*, Oxford, 1993), and the other with Dag Tjøstheim and Teräsvirta: the latter one he only managed to see finished in manuscript form as it appeared in print in 2010 (*Modelling Nonlinear Economic Time Series*, Oxford). These established important classes of non-linear models that have proved more relevant to economics, and as a consequence seen many empirical applications.

By using non-linear interactions, Clive considered forecasting supposedly unpredictable processes like white noise. Although linear prediction from the history of a white-noise process will be unhelpful, there can be non-linear components that reduce forecast-error variances. With Tae-Hwy Lee in 1989 (reprinted in Engle and Granger (eds.), *Long-Run Economic Relationships*, Oxford, 1991), he defined a form of non-linear cointegration, as well as investigating multi-cointegration (where stocks and flows are connected). In addition to modelling such conditional first moments, Clive also contributed to methods for modelling conditional variances. His work on generalising the ARCH model (to power-ARCH, linked to his research with Engle) may be mentioned in this context. His paper in *Annales d'économie et de statistique* (1995, with Zhuanxin Ding), is another example of Clive's interest in the observable properties of time series. This time, the high-frequency (daily) return series were the object of interest, and the authors listed a number of stylised facts that these series seemed to share. These features were defined in the time domain and concerned the marginal distribution of returns and the autocorrelations of powers of the absolute returns. One stylised fact was the slow decay of autocorrelations of the absolute-valued returns, which led Clive to consider long memory in volatility, and the connection between this phenomenon and 'breaks' in volatility. This he did with Namwon Hyung (2004, *Journal of Empirical Finance*).

Long memory

The concepts of cointegration and long-memory were developed in parallel, and Clive made use of spectral analysis when developing both. With Roselyne Joyeux (*Journal of Time Series Analysis*, 1980), Clive showed that the decay rate of the autocorrelations of some variables was slower than exponential, which is the corresponding decay rate for a stationary autoregressive model (after some initial lags)—hence the term 'long

memory'. They introduced concepts of fractional integration and fractional differencing, and showed how fractionally differenced variables could have a long-memory property. In a related *Journal of Econometrics* paper in 1980, Clive showed how a long-memory time series can arise by aggregating variables that are stationary and autocorrelated of first order, but have different autoregressive coefficients.

The greatly increased availability of financial time series at high frequencies over long time spans has made long-memory models more important in econometrics. Clive subsequently showed that when a high-frequency return time series (such as a stock return) was decomposed into the product of its sign and its absolute value, the latter was a long-memory process, but the sign (namely the direction of change) was essentially unpredictable. Consequently, models of conditional volatility indicate considerable persistence, consistent with long memory (but also with ignored shifts in the unconditional variance), whereas stock prices themselves are nearly unforecastable.

Modelling

Clive devoted just one book specifically to the topic of empirical modelling (*Empirical Modeling in Economics*, Cambridge, 1999), even though his long-term research agenda can be seen as improving the quality of econometric model building by a better match between empirical models and the data evidence. He argued that this required careful specification of the model which was to be estimated then a thorough evaluation of its properties, mainly through forecast performance, as that was outside the control of the model builder. However, unanticipated shifts in economics make forecast accuracy a potentially unreliable guide to the 'goodness' of the underlying model—remember Apollo 13, where the catastrophically bad forecast of its arrival time at the moon sheds no light on either Newton's gravitational theory or on NASA's forecasting methods. Thus, what he called 'thick modelling', namely combining many models, seemed a more viable approach.

Clive was also interested in model selection, and in the growing literature on computer-based methods for doing so, although these developments came near the end of his career. He engaged in a Socratic discussion with Hendry as to how well automatic selection might work (*Econometric*

Theory, 2005), although Clive was never an easy person to persuade, perhaps fortunately because that led him to discover cointegration.

During the last few years, experimental economics has become quite popular. Both laboratory and field experiments have been conducted to test economic theory propositions. Clive was an early contributor to this field. With André Gabor in the 1960s, he conducted price experiments in supermarkets: prices of various products were altered and changes in sales recorded. He wrote several articles on price formation and consumers' attitudes to prices, the majority of them jointly with Gabor (in, for example, *Journal of the Royal Statistical Society, C*, 1961, and *Management Decision*, 1979).

Legacy

Clive had a huge intellectual influence on the theory and practice of econometrics and on forecasting. His concept of cointegration provided a unified framework for combining economic theories of long-run equilibrium relationships with dynamic econometric models of short-run behaviour, extending to non-stationary macroeconomic time series previous formulations of the economy as a system of simultaneous stochastic relationships proposed earlier by Nobel Laureates Ragnar Frisch and Trygve Haavelmo and implemented particularly by Klein. Cointegration models represent the short-term effects by changes in variables, whereas long-term relations become cointegrated levels, essentially the model proposed by Bradford Smith in 1926, but now sustained by viable statistical methods and general concepts. An EqCM specification also greatly reduces collinearity between the transformed variables. Offsetting these benefits, non-stationarity from shifts in equilibria can lead to large and systematic forecast errors, so 'equilibrium correction' is a more appropriate designation, as there is no correction between different equilibria.

The overall outcome of Clive's innovative ideas was one of the most successful research programmes in the history of econometrics, making many lasting contributions to that discipline. At the time of his death, he had more than 40,000 citations to his published work, a figure that has continued to rise in subsequent years to the present total of almost 70,000.

Clive was continuously fascinated by new challenges and difficult questions in econometrics, and always creative in his search for answers, from his first choice of doctoral thesis about non-stationarity onwards.

We cannot remember any occasion on which he did not have some new direction, theme, topic or approach to explore, from nonsense regressions, through cointegration, its links back to causality, long memory, non-linearity, and thick modelling, to forecasting, together with a vast range of applied studies, both outside and within economics, as well as finance. In addition to his creativity, Clive was a master of written and presentational clarity, a necessary adjunct to conveying so many ideas so quickly and having them adopted.

Clive also kept the serious analysis of economic forecasting alive in his joint research with Paul Newbold, when forecasting had become the orphan of economics, derided as ‘those who can, do economics, and those who cannot, forecast’. His influence was so pervasive that Mike Clements and Hendry accidentally used the same title for their first forecasting book as Clive and Paul had used for theirs twenty years earlier. Clive was delighted to see the massive resurgence of interest in the topic over the last twenty years, with numerous scholars and highly cited econometricians joining his quest to understand the properties of forecasts and how to improve them, reflected in a plethora of handbooks and companions to economic forecasting.

Honours

Clive received many honours for his important research contributions. He was elected to a Fellowship of the Econometric Society in 1972, and in 2002 became a distinguished Fellow of the American Economic Association and a Corresponding Fellow of the British Academy. He was also a Fellow of the American Academy of Arts and Sciences, and an Honorary Fellow of the International Institute of Forecasters, as well as a foreign member of the Finnish Society of Sciences and Letters. He held Honorary Degrees from the University of Nottingham, Universidad Carlos III de Madrid, Stockholm School of Economics, Universities of Loughborough and Aarhus, and Aristotle University. His Festschrift, entitled *Cointegration, Causality, and Forecasting* (Oxford, 1999), was co-edited by Robert F. Engle and Halbert White. In 2001 his collected papers were published in two volumes as *Essays in Econometrics* (Cambridge).

When he and Engle were jointly awarded their Prize in Economic Sciences in Memory of Alfred Nobel in 2003, Clive was visiting the University of Canterbury in New Zealand. One October morning at 3 a.m.

local time, he was woken up by a telephone call beginning with the words: 'This is Professor Gunnar Öquist from the Royal Academy of Sciences in Stockholm. I have some very important news for you, Professor Granger.' After that call, Clive's day and, in fact, the rest of the whole Southern spring became quite different from what he may have originally planned.

He was knighted in 2005, and in the next year the University of Nottingham renamed the building housing its economics and geography departments the Sir Clive Granger Building and created the Granger Centre for Time Series Econometrics. He was delighted in 2004 to be voted one of the 100 Welsh Heroes. Clive became an Honorary Fellow of Trinity College, and greatly enjoyed that privilege because it reminded him of his happy childhood years in Cambridge. He was a member of the Advisory Board of the *Journal of Applied Econometrics* for many years, and helped younger authors in numerous ways, including his joint editorship with Grayham E. Mizon of the Oxford University Press *Advanced Texts in Econometrics*.

Secrets of success

There is no doubt that Clive was an exceptionally successful person. In his Nobel Autobiography he explained his recipe for success: 'Do not start too high on the ladder, move to a good but not top university, work hard, have a few good ideas, choose good collaborators (I had over eighty in my career), attract some excellent students, wait twenty years or so, and then retire.' That statement, however, leaves a few questions open. For example, how to develop all those good ideas, many of which generated an entire literature? A few guesses may be made. Clive read widely. We both remember from visits to San Diego that every Wednesday afternoon he used to walk to the Science Library (before it was moved to the general library) to read articles in journals outside his field. These included physics and engineering journals, as well as those statistics journals that economics libraries typically do not carry, and was a way of gathering interesting information and getting food for thought.

His ideas have in turn been applied by many non-economists, in biology, engineering, and the environment especially on river flooding and deforestation, climate change, palaeobiology and palaeoclimatology, as well as business science, political science, sociology, and marketing.

In an address at the Stockholm School of Economics in December 2003 after receiving the Economics Prize, he jokingly mentioned that because he had retired (he did that earlier that year), he did not have to worry about publishing papers any more and was thus able to take on more difficult topics. Indeed, during the last years of his life, Clive turned to broad topics such as forecasting economic crises and the economics of peace. He was, among other things, considering an economic turbulence indicator that would warn about approaching crises, but did not have time to finish this work. He was proud of his work on the future of the Amazon rainforests, and mentioned that in both his Nobel lecture and his autobiography (*The Dynamics of Deforestation and Economic Growth in the Brazilian Amazon*, Cambridge, 2002, with four collaborators). He did not manage to present his thoughts on the economics of peace in public before he died, except for an informal lecture at UCSD.

Clive also liked to interact with people and was generous with his time and sharing ideas with others. His story about how he started the work leading to defining cointegration is a case in point. Obviously, choosing good collaborators becomes easier when you both have good ideas and are willing to share them with others.

Clive was a sociable person and liked to organise various on-campus activities. He was the driving force behind the weekly Econometrics lunch at UCSD, as became obvious through a natural experiment. When Clive was there, the lunch was a regular weekly event. When he was visiting somewhere, the lunches became less regular, starting to wither away. This continued until Clive returned, upon which order was restored. His home was always open to visitors, and a large number of econometricians and friends over the years had a chance to enjoy the warm hospitality of Clive and his wife Patricia Lady Granger. However, Clive took short 'power' naps every afternoon, during which he posted a 'do not disturb' notice on his office door—and meant it—although his door would be open to all otherwise.

Clive followed his own advice about attracting excellent students. He did that by building a reputation of being an excellent supervisor, giving students new ideas to work with, having regular weekly meetings with them, and making sure that they would finish on time. He singly or jointly supervised many successful doctorates. As for the students, a part of their recipe for success could simply have been: 'Become Clive's graduate student.' Clive's past students currently occupy chairs at a host of the world's distinguished universities.

Conference organisers in turn used Clive as an extra attraction. It happened more and more often that he was either the first or the last speaker of the meeting he was invited to: the first to give the conference a flying start, and the last to guarantee a worthy ending and discourage participants from leaving early.

Personal interests and activities

Although Clive's recipe for success mentioned hard work, he had time for plenty of activities outside work. He was an active sportsman, swimming and bodysurfing in the Pacific, and playing tennis competitively until his knees told him to stop. He greatly enjoyed walking: visitors to UCSD well remember the walks down the steep hill to the beach beneath the campus and up again before going to lunch. Clive also liked to watch sports. He used to attend home games of the San Diego indoor soccer team until the team folded, and followed the fortunes of the local baseball team. Over a morning coffee at the campus, he would have comments on the previous night's Los Angeles Lakers basketball or Los Angeles Kings ice hockey game he had watched on television.

One of Clive's main cultural interests was the arts. For a visitor to UCSD sharing this interest and planning a visit to another US university or city, it was a good idea to ask Clive what were the most worthwhile art museums or exhibitions at the destination. He was always knowledgeable about what was on offer and where and, more generally, keenly followed what was going on in the world of arts. Clive's favourite among the art museums was the Frick Collection in New York, and he was a frequent visitor to important visual arts events closer to home at the Los Angeles museums. Of the ancient cultures, he was most intrigued by Etruscan art and artefacts. He was also an avid reader of novels, and was interested in learning what others were reading or had recently read.

Clive liked to travel and visited a large number of countries during his career. New Zealand was one of his favourites, and in his later years he used to spend the Southern Hemisphere spring in Christchurch at the University of Canterbury, something he particularly enjoyed. He was also a frequent visitor to Scandinavian countries, giving courses and seminars in each of them. Norges Bank (the Central Bank of Norway) used to organise special 'Clive Granger Days', having Clive as the main speaker and building the rest of the programme around him. He made longer vis-

its to Aarhus and to Finland. Reciprocally, many colleagues and students from Scandinavia visited UCSD over the years. Clive was also conscious of his roots, and had close ties to his home country, where he was often invited for extended stays, workshops and conferences.

Clive's intellectual legacy is vast, and its long term impact will be profound and enduring. His contributions make one of the most successful research programmes in econometrics, going far beyond the formulation of cointegration for which he received his Nobel Prize and subsequent knighthood. To paraphrase Isaac Newton, Sir Clive Granger is one of the giants on whose shoulders later generations of econometricians can safely stand to see far further across the great ocean of unexplored ideas that still lies before us. Despite his success and huge impact on the development of time series econometrics, Clive remained the same, an unassuming gentleman and generous person, who viewed himself as an equal among equals, conscious of his achievements, but always ready to appreciate the work of his colleagues as well. He is survived by his wife Patricia, their children Mark and Claire, and a grandson Luke.

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TIMO TERÄSVIRTA

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Note. We are indebted to a number of individuals for their information and help. First and foremost, Patricia Lady Granger filled in many of the details of Clive's background and family. We have also drawn on reviews, obituaries and memoirs written with, or by, ourselves, Hashem Pesaran and Peter C. B. Phillips, as well as 'The Nobel Memorial Prize for Clive W. J. Granger', *Scandinavian Journal of Economics*, 106: 187–213, by Hendry, and the 1997 *Econometric Theory* interview of Clive by Phillips. Alex May of the *Oxford Dictionary of National Biography* helped the first author extensively in writing their entry for Clive. Three special issues of journals have appeared in his memory: *European Journal of Pure and Applied Mathematics*, *Journal of Financial Econometrics*, both in 2010, and *Applied Financial Economics* in 2011, emphasising the breadth of his work in both theoretical and applied econometrics. An issue of *Journal of Econometrics* will also appear in his memory.

