Sir Clive W.J. Granger Memorial Special Issue on Econometrics

Sir Clive W.J. Granger Memorial Special Issue on Econometrics: An Introduction.

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Abstract. Clive W.J. Granger made many fundamental contributions to econometrics and was awarded the Sveriges Riksbank Prize in Economic Science in Memory of Alfred Nobel in 2003 for developing cointegration. This Special Issue reviews his contributions to Granger causality, forecasting, cointegration, fractional integration, non-linearity and model selection.

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1. Overview

Clive W.J. Granger made many fundamental contributions to econometrics, and his published research has now accumulated more than 110,000 citations by other scholars, with an h-index of 93 (i.e., 93 publications each with more than 93 citations). This large number of citations to his work are a clear manifestation of his immense impact on economics, econometrics, and forecasting. In addition, we note the obvious recognition entailed for his seminal contribution to the analysis of cointegration by his award of *The Sveriges Riksbank Prize in Economic Science in Memory of Alfred Nobel* in October 2003: Hendry (2004) (see [31]) discusses the conceptual and statistical basis for his Nobel Prize.

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There is a *Festschrift* with many papers related to Clive's research (edited by Robert F. Engle and Halbert White, 1999 [7]), the Special Issue in his honor of the *Journal of Econometrics*, **135**, 2004, and the *Tribute* edited by Mark P. Taylor (2012) [42]. Clive's own collected works were published in 2 volumes by Eric Ghysels, Norman Swanson, and Mark Watson (2001) [9]. Personal details about his life and times are provided in his Nobel Prize Biography http://www.nobelprize.org/nobel_prizes/economic-sciences/laureates/2003/granger-bio.html, in his *ET Interview* by Peter C.B. Phillips, 1997, (see [38]) and in the extensive British Academy Memoir by Hendry and Timo Teräsvirta (2013) (see [32]). We have drawn on all of these as well as on several Obituaries, for the information recorded below.

This Special Issue reviews Clive Granger's contributions to the following fields, a subset of his wide and varied contributions, in an approximate historical order:

- Granger causality (David F. Hendry)

- Forecasting (Michael P. Clements)

- Cointegration (Jennifer L. Castle and David F. Hendry)

- Fractional integration (Ryoko Ito)

- Non-linearity (Timo Teräsvirta)

- Model selection (Jennifer L. Castle)

The research described by our coverage, and summarized in the next six subsections, relates to his 17 most cited publications, out of more than 300, although his more recent empirical applications remain an important contribution as well. This introduction sketches the rough time sequence of Clive's research interests, and offers a somewhat personal perspective on their links.

2. The evolution of Clive Granger's research interests

Given an initial interest at school in the practical applications of mathematics, Clive went to Nottingham University to study for a new degree course there in mathematics and economics, although after a year he switched to study for a degree in mathematics. However, he looked for an application of mathematics to economics for his PhD, and chose to research the properties of economic time series, which would be a life-long preoccupation, presciently investigating *Testing for Non-stationarity*. We now know that most macroeconomic time series are non-stationary, but when Clive commenced his research, most empirical studies and almost all econometric analyses assumed stationary distributions and used methods of statistical inference that relied on that assumption. Moreover, many large econometric models seemed badly mis-specified dynamically, and produced less accurate forecasts than atheoretic time-series devices. As A.A. Milne (1926) (see [37]) expressed such a state of affairs in *Winnie-the-Pooh*:

> Here is Edward Bear, coming downstairs now, bump, bump, bump, on the back of his head, behind Christopher Robin. It is, as far as he knows, the only way of coming downstairs, but sometimes he feels there really must be another way, if only he could stop bumping for a moment and think of it.

Clive 'stopped bumping', and began to search for an improved approach.

2.1. Granger causality

Following his PhD in 1959, Clive took up a Harkness Fellowship at Princeton University for a year, where he and Michio Hatanaka wrote Granger (1964) (see [10]), since becoming a Citation Classic, and leading to the application of spectral analysis to stock-market prices in Granger and Oscar Morgenstern (1963) [25]. Moreover, in Granger (1966) (see [11]) he noted that many economic time series have most of their spectral mass at the lowest frequencies in the spectrum, consistent with their having a unit-root non-stationarity, relating back to his doctoral thesis and forward to his interest in 'nonsense regressions'. His study of spectral analysis also led to research on cross-spectra and from there to his

famous paper on causality, Granger (1969) [12], since known as **Granger causality**, and the topic of the second paper in this special issue by David F. Hendry.

2.2. Forecasting

In turn, that last idea led Clive to consider testing whether or not dropping a subset of variables from a model affected its forecasts, fostering his interest in forecasting already piqued by his work on combining forecasts from two models to improve forecast accuracy compared to forecasts from those individual models in John Bates and Granger (1969) (see [3]). Clive's major contributions to **forecasting** are the subject of the third paper in this special issue by Michael P. Clements. In his Nobel Prize Autobiography http://nobelprize.org/nobel_prizes/economic-sciences/laureates/2003/granger-bio.html, he amusingly noted that a teacher at his primary school told his mother he 'would never become successful', and remarks that this 'illustrates the difficulties of long-run forecasting on inadequate data'. At the time Clive first started researching forecasting, it was an orphan in economics somewhat disparaged by the epithet 'those who can do; those who cannot forecast'. His energetic contributions attracted others to a serious study of the properties of forecasts, how to make them, evaluate them, and improve them, such that it is now a fully integrated aspect of econometric research. The role of forecasting in evaluating econometric models has been a recurring theme in his research, despite the dangers inherent in any forecasting enterprise, well reflected in this quote from Douglas Adams (2002), [1]:

> "Oddly, the computer industry—which is the primary engine of our incredible pace of change—turns out to be rather bad at predicting the future. There are two things in particular that it failed to see: one was the coming of the Internet; the other was the end of the twentieth century."

2.3. Cointegration

Clive had been promoted to full professor at Nottingham University in 1965, but moved permanently to the University of California at San Diego in 1974, where he attracted an exceptional group researching primarily time-series econometrics. The analysis of economic time series dates back to the foundations of our discipline as a science, and has always been a fraught subject as Judy Klein (1997) (see [35]) records. For example, the invention of moving averages in 1797 by the Bank of England was as a method for concealing the perilous state of its bullion reserves—an early instance of creative accounting. Stanley Jevons (1884) (see [34]) was among the first to investigate weekly financial time series over 1825–1860, including on bankruptcies, currency circulation and discount rates, so even high frequency financial econometrics is not new. Towards the end of the nineteenth century, 'peculiar' correlations were being found including the infamous 'urban myth' of the high correlation between the number of storks nesting in Stockholm and the number of babies born there. Udny Yule ([44],[45]) provided the first analytical insights into what he

called respectively spurious and nonsense correlations, the latter for the case of integrated data.

Hendry recollects first meeting Clive in 1975 at a conference in Minnesota, reported in Chris Sims (1977) (see [41]), who described the comments in Hendry (1977) [29] on Granger and Paul Newbold (1977) [26] as 'ascerbic'. We disagreed about the importance and nature of nonsense regressions, and how they might, or need not, affect statistical analysis. Building on the brilliant paper by Denis Sargan (1964) (see [40]), who introduced what are now called equilibrium-correction mechanisms, Hendry suggested there was no problem linking time-series variables with unit roots, a claim essentially denied by Clive, who set about refuting it, leading to the development of **cointegration** analysis as he later recounted in http://www.nobelprize.org/nobel_prizes/economic-sciences/laureates/2003/granger-lecture.html.

Cointegration is discussed in the fourth paper by Jennifer L. Castle and David F. Hendry. Thus, it was in the process of failing to refute the possibility that unit-root variables could be legitimately linked that Clive invented the concept of cointegration, formalised in another famous paper, Engle and Granger (1987) (see [6]), although he had already connected cointegration with Granger causality in Granger (1986) (see [14]), tying together two of his central research interests. Doing so extended to non-stationary time series Nobel Laureate Trygve Haavelmo's (1944) (see [28]) approach to modelling stochastic simultaneous equations systems, and spawning an academic industry. Our other links to Clive's research occurred during his several visits to Oxford University, where we both had extensive discussions with him on many aspects of econometrics, and Castle also met with him at the third meeting of Nobel Prizewinners in Economics in Lindau, Lake Constance.

2.4. Fractional integration

Nevertheless, Clive was well aware that economic time series were more complicated than just having unit roots, so pushed his research into both long memory and non-linearity. The first was addressed in his work with Roselyne Joyeux (1980) (see [22]), relating **fractional integration** and fractional differencing for processes where the autocorrelation function decays at a much slower rate than that of a linear autoregressive-moving average. Such variables have a 'long-memory' property, although ideas of self-similarity were known before that. His research on fractional integration is the subject of the fourth paper in this special issue by Ryoko Ito. Moreover, Ingolf Dittmann and Granger (2002) (see [4]) considered nonlinear transformations of fractionally integrated processes, leading into the next paper.

2.5. Non-linearity

Clive's first publication on **non-linearity** was with Allan Andersen in (1978) (see [19]). That early work on bi-linear models was an important stimulus to Robert F. Engle (1982) [5] in creating the Autoregressive Conditional Heteroscedasticity (ARCH) model, for which Rob shared the Nobel award with Clive in 2003. However, the later research reported in Granger and Teräsvirta (1993) [27], and Teräsvirta, Dag Tjøstheim and Granger (2011) [43], proved more influential because the forms of non-linear models considered were more

relevant to economics. Initially, most of Clive's research on non-linearity was for I(0) processes, and he only briefly considered non-linear models for I(1) data in Granger (1996) [16]. Nevertheless, he also investigated the link to possibly time-varying models in Granger and Hahn Lee (1991) [24], and Granger (2008) [18]. The fifth paper by Timo Teräsvirta describes these contributions.

2.6. Model selection

Although one could reasonably interpret Clive's over-arching research agenda to be that of improving empirical econometric analysis by a better match between models and data than he found when he was a student, Granger (1999) (see [17]) is his only book explicitly on how to do so. However, many of his publications, including Granger (1993) [15], Granger, Maxwell King, and White (1995) [23] and his discourse in Granger and Hendry (2005) [20], address the general issue of **model selection** when choosing between alternative formulations including proposals in Granger and Yongil Jeon (2004) (see [21]) for 'thick modelling'. The sixth paper by Jennifer L. Castle concerns that area of Clive's work.

3. A final note

Clive was also proud of his empirical work on the future of the Amazon rainforests, recorded in Granger, Eustáquio Reis, Diana Weinhold, and Sven Wunder (2002) (see [2]), and he mentioned that research both in his Nobel Prize lecture and his autobiography. However, it was but the tip of a large iceberg of Clive's earlier empirical work including his studies of commodities and options in Granger (1975) [13], Andre Gabor and Granger (1977) [8], and Walter Labys and Granger (1970) [36].

It would be misleading to call this section a conclusion, as it is merely another step down the long road of assessing Clive Granger's many contributions: the long-term impacts of one of the most successful individual research programs in econometrics go far beyond the formulation of Granger causality and cointegration for which he is best known. Sir Clive W.J. Granger bequeathed to future econometricians a solid foundation in many areas of research, yet left open plenty of new avenues to explore. Clive has in fact published on most of the concepts in Dennis Robertson's (1952) *Non-econometrician's Lament*, [39].[†] His research is distinguished by a stream of creative new ideas pertinent to many aspects of quantitative economics. His basic attitude is well expressed by the countryman of the second author, namely David Hume [33], paraphrased by us from its original statement about philosophy to economics:

> "Take in hand any volume of *economics*; let us ask, 'Does it contain any abstract reasoning concerning quantity or number?' No. 'Does it contain any experimental reasoning concerning matter of fact and existence'. No. Commit it then to the flames: for it can contain nothing but sophistry and illusion."

[†]Also accessible in Hendry (1983), see [30].

Hendry and Teräsvirta (2013) (see [32], on which we have drawn extensively for this overview) also discuss Clive as a person, his personal life and non-academic interests, noting that 'with more than 80 doctoral students, much of his time was devoted to research'. Clive was born in Swansea to English parents, and much to his surprise, became number 67 on the list of 'Welsh Heroes': that's 3 places higher than King Arthur of the Round Table fame, but about 50 places below Catherine Zeta-Jones! Despite his success, many honours and his huge influence on the development of time-series econometrics, they also noted that Clive remained fully approachable, and was always willing to spend time helping colleagues, especially younger ones. He was well aware of how much he had achieved, but was still able to appreciate the contributions of other researchers.

At a personal level, the second author enjoyed numerous discussions with Clive about econometrics in all its shapes, forms and varieties, from our first meetings in the mid 1970s. Our friendship was built around a common desire to improve the quality of econometric model building, especially by a better match to the empirical evidence. Hendry visited UCSD sufficiently often to be almost an honorary San Diegan, and spent uncountable hours in discussions with Clive on beach walks, in his tiny office (but never between 1–2 pm!), at 'Quaker' lunches in the Department with Hal White, Rob Engle and their many visitors, in dim sum and Mexican restaurants, at his lovely house kindly hosted by Pat,

as well as at the many conferences we both attended. Yet Clive fitted those interactions in around hundreds of others, with his own and other doctoral students, colleagues and his many dozens of international collaborators.

Although we were not 'econometrics knights' at the time, colleagues did refer to us as 'jousting'. Not that our relationship was that of one-upmanship, except perhaps on the tennis court, where Clive definitely played to win. Despite our overlapping interests and the hours we spent discussing econometrics together in many wonderful locations, we only ever published one joint paper, but suitably that was in a Socratic style with Clive firing questions at Hendry about automatic model selection, who sought to answer them. Our last major discussion sessions took place in Wellington New Zealand, during the 'Phillips Curve 50th Anniversary' conference in 2008, and on the long flight we shared to Singapore for Peter Phillips' Festschrift conference at SMU. Clive was never an easy person to persuade, fortunately for us all because that led him to discover cointegration, so discussions merely reduced his scepticism about model selection rather than converted him to being an advocate.

Clive was continuously fascinated by the challenges and questions facing econometrics, and constantly innovative in his search for answers, from his first choice of doctoral thesis about non-stationarity onwards. Hendry 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 range of applied studies, both outside and within economics as well as finance. In addition to his astonishing creativity and innovative ideas, Clive was a master of written and presentational clarity, a necessary adjunct to conveying so many ideas so quickly.

Our photograph at the second author's *Festschrift* shows Clive at the front smiling happily, as ever pleased to be with fellow econometricians.

Acknowledgements

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