Financial Time Series, Nobel Prize, and Ecology
Lessons Learned from the 2003 Nobel Prize in Economics

Richard A. Davis
Colorado State University
(http://www.stat.colostate.edu/~rdavis/lectures)
Jeopardy

Hosted by

Richard Trebeck
Name of the model developed by 2003 Nobel Prize winner Engle.
Nobel Prize winner whose story was depicted in the movie “A Beautiful Mind”
Who is Aldo Leopold?

Considered the father of ecology.
Who is Tim Bollerslev?

This person added the letter G to ARCH.
These Nobel Prize winners developed an innovative theory for pricing derivatives.
What is ACES?

The Alaska Consortium for Environmental Statistics.
What is long memory?

Another term to describe persistence in volatility.
Who are Rob Engle and Clive Granger?

Shared the 2003 Nobel Prize in Economics.
What is PRIMES?

The PRogram for Interdisciplinary Mathematics, Ecology and Statistics at Colorado State University.
The term Granger used to combine two nonstationary time series to form a single stationary process.
These 1997 Nobel prize winners were Partners in the hedge fund, Long-Term Capital Management, that ultimately needed a $3.65 billion bailout.
What is the Lotka-Volterra model?

A simple model for predator-prey interactions.
The process used by Black and Scholes to model asset prices.

What is geometric Brownian motion?
Who is Jan Tinbergen?

This 1969 Nobel Prize winner is known as the father of Econometrics.
Bonus
Black-Scholes’ Nobel Prize Winning Formula for Pricing Options

• Merton-Scholes won 1997 Nobel Prize (Fischer Black died in 1995).
• tells investors what value to put on a financial derivative
So revolutionary was the very idea that you could use mathematics to price derivatives that initially Black and Scholes had difficulty publishing their work. When they first tried in 1970, Chicago University's *Journal of Political Economy* and Harvard's *Review of Economics and Statistics* both rejected the paper without even bothering to have it refereed.

It was only in 1973, after some influential members of the Chicago faculty put pressure on the journal editors, that the *Journal of Political Economy* published the paper.

Industry was far less shortsighted than the ivory-towered editors at the University of Chicago and Harvard. Within six months of the publication of the Black-Scholes article, Texas Instruments had incorporated the new formula into their latest calculator, announcing the new feature with a half-page ad in *The Wall Street Journal.*

—Keith Devlin
The Formula

\[ V(s, T) = s \Phi \left( \frac{\log \frac{s}{K} + (r + 0.5\sigma^2)}{\sigma \sqrt{T}} \right) - ke^{-rT} \Phi \left( \frac{\log \frac{s}{K} + (r - 0.5\sigma^2)}{\sigma \sqrt{T}} \right) \]

= value of European call option

\[ \sigma \] = volatility
\[ r \] = risk free bond rate
\[ \Phi \] = std normal cdf.
\[ s \] = current value 50
\[ T \] = exercise date 60
\[ K \] = strike price 70
Postscript on Black-Merton-Scholes

• rejuvenated the field of stochastic differential equations
• created a new field of financial mathematics
• the rise and fall of “Long Term Capital Management” – $3.65 billion bailout by Federal Reserve et al.

“once in-a-100-year event to cause LTCM to lose even 25% of its capital.”
8 October 2003

The Royal Swedish Academy of Sciences has decided that the Bank of Sweden Prize in Economic Sciences in Memory of Alfred Nobel, 2003, is to be shared between

Robert F. Engle
New York University, USA
“for methods of analyzing economic time series with time-varying volatility (ARCH)”

and

Clive W. J. Granger
University of California at San Diego, USA
“for methods of analyzing economic time series with common trends (cointegration)”.

Robert Engle and Clive Granger
The stock market is like a small row boat on a rough sea, bouncing around as it drifts, whereas the macro economy is like a large ocean liner, very ponderous and difficult to maneuver but without such a rough journey. … I was more concerned with building models that central bankers could use for policy purposes and particularly for long run forecasting. The idea is called "cointegration" and provides ways to discover that two large boats are drifting with the same current or that two macroeconomies are moving together. You will find both of these words [ARCH and cointegration] defined in the Oxford English Dictionary in a few years time!

Forecasts vary in horizon, from a few seconds up to a few days in financial markets, compared to from one to several months for macro variables. We have to provide uncertainty intervals around the central forecasts to indicate the extent to which we are unclear about the future. The ARCH models are concerned with variations in the confidence intervals at different horizons while my methods are concerned with coordination of forecasts for several variables. The advantage that I have is that it may take a year or more to show that my forecasts were wrong, whereas Rob's could be found incorrect in about a day! ---banquet speech
Rob Engle (UC San Diego/NYU)

- modeling volatility
- high frequency (tick) data
Closing log(Price) for IBM 1/2/62-11/3/00

Closing log returns for IBM 1/2/62-11/3/00
Impact on GARCH modeling

Estimate of IBM Volatility using GARCH

absolute returns

0.0 0.05 0.10 0.15 0.20 0.25


time
Pound/Dollar Exchange Rate 10/1/81-6/28/85

Random Walk

Pound/Dollar Exchange Rate 10/1/81-6/28/85

Random Walk

returns for random walk
Impact on GARCH modeling

Estimate of Exchange Rate Volatility using GARCH

absolute returns

Application to Ecology

Example: NEE=Net Ecosystem Exchange in Harvard Forest

• About half of the CO₂ emitted by humans accumulates in the atmosphere

• Other half is absorbed by “sink” processes on land and in the oceans

\[
\text{NEE} = (\text{Rh} + \text{Ra}) - \text{GPP} \quad \text{(carbon flux)}
\]

\[
\text{GPP} = \text{Gross Primary Production (photosynthesis)}
\]

\[
\text{Rh} = \text{Heterotrophic (microbial) respiration}
\]

\[
\text{Ra} = \text{autotrophic (plant) respiration.}
\]

The NEE data from the Harvard Forest consists of hourly measurements. We will aggregate over the day and consider daily data from Jan 1, 1992 to Dec 31, 2001.
Daily NEE for Harvard Forest 1/1/92 to 12/31/2001
NEE data after transformation - remove seasonality, etc

Daily NEE (transformed) for Harvard Forest 1/1/92 to 12/31/2001
Estimating SV using GARCH(1,1) model.

Absolute values of NEE transformed) data
Lessons learned.

• look for volatility in data
• there now exist tools and techniques that are helpful for detecting and modeling volatility
• volatility may be present in many ecological and environmental data sets.
  • modeling paths of hurricanes near Hawaii
  • wind speed data
  • pricing weather derivatives