The sky is falling!

Shane Whelan overviews how the emerging science of econophysics is forecasting poorer UK actuaries by the end of the year, and forecasting the end of the world in about 2050.

Isaac Newton predicted the world would end around 2050. Didier Sornette, a leader in the emerging discipline of econophysics, concurs, detecting a singularity in many long-term demographic, economic, and financial series at about the same date.

This is where agreement between the two physicists ends. Newton came to his conclusion from studying the Bible, putting 2050 as the starting date for the everlasting reign of the Saints of the Most High; Sornette bases his on log-periodic oscillations decorating a super-exponential trend that, when extrapolated, forecast these key series to explode to infinity at about 2050.

So what?

That we are close to the end is not, of course, news to readers of this magazine. Nick Bostrom ('The disturbing doomsday argument' *The Actuary*, March 2001) prepared us by demonstrating that the probability of the human race becoming extinct in the near future is rather higher than many suspect. What is novel in the latest version, aside from pinning down the date, is that the same technique can be used to make money in the meantime.

The method has already produced some notable predictive successes: in January 1990, Sornette forecast that the Nikkei would rise 50% by the end of the year (it rose just over 49%) and he forecast the NASDAQ would crash in April 2000. Older actuaries, expecting an end earlier than 2050, can take little solace from another of Sornette's predictions. Older and therefore better endowed actuaries can expect to receive a significant dent in their balance sheet in the near term:

> '…the analysis points to the end of the bubble for the UK housing market no later than the end of the year [2004], with either a crash or a strong change of direction.'

Empirical regularities detected in returns on capital assets

- Return series are non-stationary. Past returns are really not a guide to future returns and all those stationary models (eg the ARMA and ARCH models) will eventually fail.
- There is little or no correlation between successive returns.
- Returns come from a heavy-tailed distribution, where the variance exists but the kurtosis (4th moment) does not. Volatility tends to cluster in time, and the decay from high bouts of volatility tends to follow a characteristic power-law.
- Others, for example:
  - the correlation of the current return to future volatility is negative, decaying to zero as time increases;
  - the correlation between volume traded and volatility is high;
  - there is an asymmetry between large positive and negative movement, with the latter more frequent.

Shane Whelan is an actuary in the Department of Statistics at the University of Dublin

If it sounds like a quack…

This all sounds like commonplace quackery. Yet there is nothing commonplace in the modelling approach that leads to these forecasts. Sornette is part of a movement of physicists modelling economic systems using techniques and concepts developed in studying the out-of-equilibrium dynamics of complex systems. The movement was named 'econophysics' in 1997 by Eugene Stanley, but can be dated from 1991 when a leading physics journal, *Physica A*, began publishing papers on this topic. A subgroup of these econophysicists specialise in studying capital markets (a subdiscipline that has come to be called 'phynance', which has maintained its own dedicated journal from 2001, *Quantitative Finance*) and along with Sornette and his research team, other centres of excellence in phynance have sprung up about Stanley, Sorin Solomon, Rosario Mantegna, and Doyne Farmer. Some have even given the research a commercial edge with companies such as the Olsen Group, Science & Finance, and the Prediction Company developing practical trading or risk control. Outside of Peter Richmond and his growing team at Trinity College Dublin and David Lamper and his colleagues at Oxford, the movement has not yet gained much of a following on these islands.

In the beginning there was data

Econophysicists, in contrast to financial economists, begin with data. Their studies into financial markets typically analyse several million price changes – capturing, say, every price change every minute over the last couple of decades, or every bargain on every equity over a couple of years. Several empirical regularities in the price formation process are now documented that shed light on the way speculative prices evolve (see box to the left). These empirical regularities are observed in markets as diverse as commodity markets, currency markets, cash, bond, equity, and property markets and seem to be present no matter how frequently or infrequently prices are sampled. That is, the same patterns observed in asset price returns measured over every ten minutes appear when returns are measured in months.

The empirical regularities can be used to characterise the evolution of asset prices or, equivalently, the returns from capital assets. We know that active trading leads to these patterns in all capital markets and so the detail of the dealing structure must be irrelevant. Further, the same regularities are observed irrespective of the time interval between prices, so the institutional structure of the traders must also be irrelevant. Taking a short leap, we might conclude that, as the resultant patterns are the same, the forces giving rise to the patterns must also be very similar. That is, pension funds investing in equities over decades are participating in essentially the same game as intra-day traders acting on minute movements of the dollar–yen market – the principal difference being that the former is played out in excruciatingly slow slow-motion.

Agent modelling

So what is common to all the capital markets over any time period and characterises the trading process? John Maynard Keynes, no mean investor himself, described it well:

> 'The actual, private object of the most skilled investment to-day is to "beat the gun", as the Americans so well express it, to outwit the crowd and to pass the bad, or depreciating, half-crown to the other fellow.'

So the game of professional investment 'is, so to speak, a game of snap, of old maid, of musical chairs…'. Physicists take this metaphor rather literally and have modelled markets as a game played by similar players ('agents') that can only be won by a minority of the players ('minority game').

First, such agent models can replicate many of the 'stylised facts' above that characterise asset price evolution. Second, they suggest that (as JP Morgan memorably remarked when asked what the market will do) the market will fluctuate – the equilibrium they reach is dynamic as the price is expected to change even in the absence of new information. Third, when markets reach what looks like a dynamic equilibrium, there remain exploitable patterns.

This latter argument is wonderfully general. Let us say all agents record the last m changes in price as simply up (1) or down (0). Now a trading strategy is a mapping from the set of all m-tuples of 1 or 0 into the indicator set 1 (meaning next trade is a buy as expect upward movement) or 0 (meaning next trade is a sell as expect downward movement). There are 2^m elements in the domain, and each element can be mapped to either a 1 or 0. Accordingly, there are 2^{2^m} such mappings. Each agent selects from a pool of n strategies and, say, there are A agents in total. So there are somewhat less than $n.A$ strategies actually being played while the total universe of strategies is of the order of 2^{2^m}. Now, for any plausible numbers assigned to m, n, and A, we find that 2^{2^m} is several orders of magnitude greater than $n.A$. For instance, with $m = 12$, $2^{2^m} >> 10^{1,200} >> 10^{1,000}.10^{10}$, which is significantly greater than the current best estimate of the number of elementary particles in the universe times the number of humans alive at the moment.

Hence, the actual number of strategies being played is a negligible proportion of the total number of all strategies. Finally, put in operation some evolutionary mechanism that ensures the population of successful agents prosper while the unsuccessful ones perish, and we find that the evolutionary mechanism emphasises some strategies more then others, leading to small biases in the original population being magnified in the surviving population. These biases create patterns in the future evolution of the price, induced by the not-so-random surviving trading strategies.

Self-organised criticality

Agent modelling is just one approach the econophysicists have brought to a new level of sophistication. It could not, though, forecast the end of the world. Sornette takes another approach. Rather than drawing parallels between the stockmarket and games, he finds parallels with many natural phenomena – specifically those phenomena with a

large number of interacting parts with feedback, which typically can self-organise and perhaps make a sudden transition to a new state or phase (eg evolution, epidemics, earthquakes, magnetism, weather, ecology, ruptures). He attempts to forecast these points of 'self-organised criticality'. In attempting to estimate the point of rupture of pressure tanks in rockets, he claims to have detected some tell-tale signs of the approaching rupture – log-periodic oscillations about an underlying trend – that throws the trend into sharper relief, thus allowing it to be extrapolated.

Sornette has applied this approach to stockmarket indices and demographic, economic, and other time series to detect a trend and make predictions. True, this is making a rather heroic generalisation but, as pointed out by Maury Osborne (who, with Louis Bachelier and Benoit Mandelbrot, is one of the great forerunners of the econophysics movement), speculation in science is always in the best tradition of chicken little. Inevitably, not all Sornette's forecasts have proved correct but, unlike chicken little, he can claim some notable successes.

Doomsday 2050

Due in no small part to the cultural legacy of Newton's other studies, we are perhaps now more disposed to Sornette's rationale for Doomsday in 2050 than to Newton's. But both physicists will be right if the world as we know it ends in or around 2050 – if anyone then cares. And, arguably, both could claim to be right for the right reasons: Newton would doubtlessly have expected no more from the final generations than for them to use knowledge of Doomsday to increase their material wealth. ❑