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Econophysics: Making Money before Doomsday

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Lost Money

In these days of frustrating markets, it is consoling to ponder the very weak—arguably nonexistent—relationship between intelligence and stock-picking. Isaac Newton, the greatest scientist of all, notoriously sold early in the South Sea Bubble of 1720 after doubling his investment and remarking, somewhat smugly, that he could "calculate the motions of the heavenly bodies but not the madness of people." But he was tempted back in again a few months later when he saw the market continue to climb exponentially. He bought at the top of what was probably the worst stock-market crash on record, losing a fortune of £20,000.[1]

It Could Be the End of the World

The challenge of modeling the madness of crowds has been taken up by many disciplines in science and by even more pseudo-sciences over the intervening centuries. Physicists, though, have only started to study this phenomenon but are quickly catching up, judging by some notable successes and worrying predictions. Didier Sornette, one of the leaders in the emerging discipline of econophysics, claims to detect log-periodic oscillations decorating a super-exponential trend in key long-term demographic, economic and financial series that, when extrapolated, explode to infinity in about the year 2050.[2] In short, he predicts the end of the world in or about the year 2050. Remarkably, this date coincides with Newton's conclusion from studying the Bible, when he settled on the year 2050 as the starting date for the everlasting reign of the Saints of the Most High.[3]

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1) *Kindleberger, C.P. (1996) Manias, Panics, and Crashes: A History of Financial Crises. Wiley.*

2) *Sornette, D. (2003) Why Stock Markets Crash: Critical Events in Complex Financial Systems. Princeton University Press*

3) *Robinson, A.B. (1991) Introduction to Observations upon the Prophecies of Daniel and the Apocalypse of St John by Sir Isaac Newton (London, 1733). The Oregon Institute of Science and Medicine, Oregon, US.*

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Econophysics

Sornette is part of a movement of physicists modeling 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 H. Eugene Stanley, but can be dated from 1991 when a leading physics journal, Physica A, began publishing papers on this topic. A sub-group of these econophysicists specialize in studying capital markets (a sub-discipline 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 centers of excellence in phynance have sprung up about Stanley, Sorin Solomon, Rosario Mantegna and Doyne Farmer (all of whom maintain excellent Web sites). 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 models to exploit the perceived opportunities.

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In The Beginning, There Is Data

Econophysicists, in contrast to financial economists, begin with data—huge quantities of data. Their studies into financial markets typically analyze 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). These empirical regularities or stylized facts 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 characterize 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 the former is played out in excruciatingly slow slow-motion.

Agent modeling

So what is common to all the different capital markets over any time period and characterizes the trading process? John Maynard Keynes, no mean investor himself, described it well: "The actual, private object of the most skilled investment today 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.[4]" So the game of professional investment is a "battle of wits to anticipate the basis of conventional valuation a few months hence…For it is, so to speak, a game of Snap, of Old Maid, of Musical Chairs. …" Physicists take this metaphor rather literally and have modeled markets as a game played by similar players ('agents') that can only be won by a minority of the players ('minority game').

This sort of modeling invites parallels with the Boltzmann-Maxwell reduction of thermodynamics to elementary mechanics, modeling thermodynamic properties as the simple aggregate of many simple collisions between many similar billiard-ball molecules. And just as Boltzmann was lead to the surprising Second Law of Thermodynamics—the irreversibility of time—when contemplating the aggregate of these time-reversible collisions, the

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4) Keynes, J.M. (1936) The General Theory of Employment, Interest and Money. MacMillan & Cambridge University Press.

econophysicists are reporting some surprising consequences of agent modeling in minority games.

First, such agent models can replicate many of the 'stylized facts' above that characterize asset price evolution. Second, they suggest that (as J. P. 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.[5]

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 such 2^{2^m} mapping. 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, $2^{2^{12}} >> 10^{1200} >> 10^{1000}.10^{10}$ 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 emphasizes some strategies more than 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.

More speculative agent models are reporting that trend following rules induce trends but with an oscillatory feature, which favors different trend, following rules and, surprisingly, not all value strategies push market values closer to fundamental value.

Self-Organized Criticality

Agent modeling 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 stock market 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-organize and perhaps make a sudden transition to a new state or phase (e.g., evolution, epidemics, earthquakes, ferromagnetism, weather, ecology, ruptures). He attempts to forecast these points of 'self-organized 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 stock market indices and demographic, economic and other time series to detect a trend and make predictions. True, this is making a rather heroic generalization 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.[6] Inevitably, not all Sornette's forecasts have proved correct, but, unlike Chicken Little, he can claim some notable successes—in January 1990

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Sornette forecast that the Nikkei would rise 50 percent by the end of the year (it rose just over 49 percent) and he also forecast the NASDAQ would crash in April 2000. Maybe the sky is falling.

The econophysicist's approach in general, and Sornette's in particular, see speculative markets as just another instance of a much more general phenomenon—game-playing or some complex natural phenomenon. This fresh perspective already

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5) *Farmer, J.D. (1999) Physicists attempt to scale the ivory towers of finance. Computing in Science & Engineering, Nov./Dec, 26-39.*

6) *Osborne, M.F.M. (1977) The Stock Market and Finance from a Physicist's Viewpoint. Crossgar Press, Minneapolis.*

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adds value. Their empirical emphasis has squeezed some universal regularities out of the process of price evolution that have helped characterize the process of speculation. Some econophysicists, such as Bertrand Roehner, have taken to collect data on such related markets as regional wheat prices over previous centuries and on prices of collectables such as rare books, coins, stamps and baseball cards.[7] Sornette and others claim data on many natural catastrophes are relevant to predicting stock market crashes or bubbles—being just a different manifestation of the same underlying phenomenon. More data, and more novel ways to analyze it, must accelerate the growth of our knowledge of the perplexing behavior of assets.

Doomsday 2050

We are perhaps nowadays 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 to use knowledge of doomsday to increase their material wealth.

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EMPIRICAL REGULARITIES DETECTED IN RETURNS ON CAPITAL ASSETS [8]

(1) Return series are non-stationary. Past returns are really not a guide to future returns and all those stationary models (e.g., the ARMA and ARCH models) will eventually fail.

(2) There is little or no correlation between successive returns.

(3) Returns come from a heavy-tailed distribution, where the variance exists but the kurtosis (4th moment) does not. Further, even when volatility clustering is removed, the declustered residuals still exhibit heavy tails (although somewhat less heavy than the original returns). Volatility tends to cluster in time, and the decay from high bouts of volatility tends to follow a characteristic power-law.

(4) Others, for example:
   a. The correlation of the current return to future volatility is negative, decaying to zero as time increases.
   b. The correlation between volume traded and volatility is high.
   c. There is an asymmetry between large positive and negative movement, with the latter more frequent.

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7) Roehner, B.M. (2002) Patterns of Speculation: A Study in Observational Econophysics. Cambridge University Press.

8) Cont, R. (2001) Empirical properties of asset returns: stylized facts and statistical issues. Quantitative Finance, Vol 1, 223-236.