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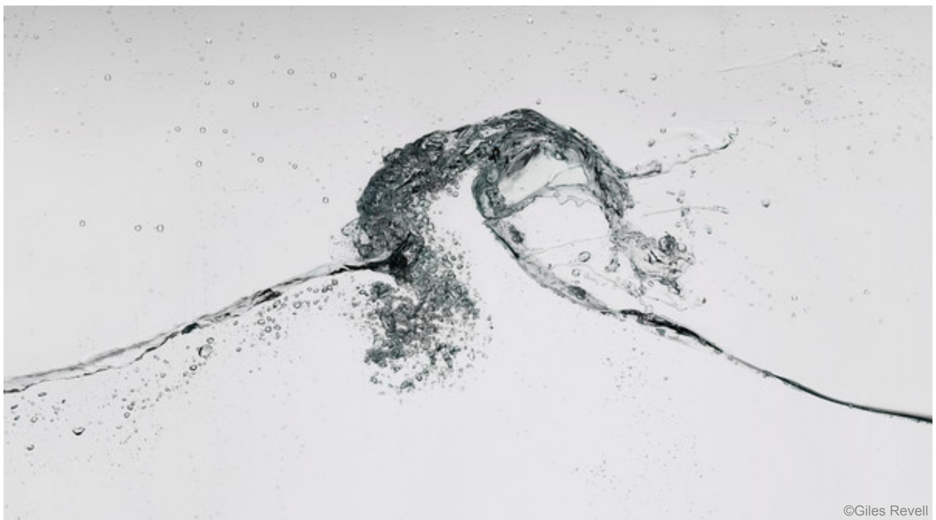
Physicists and the financial markets

By Stephen Foley

Physicists have been lured into the financial market for decades, prized for their insights and data-crunching skills. But in a time of turbulence, flash crashes and high-frequency trading, can they really spot things that others miss?



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Markets may be more like a body of water whose surface is constantly disturbed by new events and information, creating great waves whose energy is dissipated beneath the surface

Gene Stanley raises his fork, holds it out flat, a few inches above his plate of risotto. “The majority of traders still use Gaussian models and, when something outside the Gaussian happens, they have all these phrases, like ‘outliers’, but the main phrase is ‘shit happens’.”

He stares at his raised cutlery.

“Now, if we saw the forks start to levitate, it would be bizarre to say, ‘oh, shit happens’, but they do, that’s what they say. They say, ‘oh, you can’t predict everything’.”

With a chuckle, Stanley tucks back into his food.

Didier Sornette, *chair of Entrepreneurial Risks at Swiss Federal Institute of Technology Zurich*

The famous bell curve described by Carl Friedrich Gauss, the humble normal distribution that underlies so many statistical models, might explain most phenomena in a financial market but Stanley, professor of physics at Boston University, is interested in the levitating forks, the outliers, the “black swans” of Nassim Nicholas Taleb’s description.

This is the territory of econophysics, a discipline that sometimes sounds less like a collaboration between physics and economics and more like an attempted takeover of the latter by the former. By using the

‘These complex systems are not systematically predictable. They’re only predictable in some regimes’

techniques of physics – poring through vast quantities of data in order to build models from the ground up, searching for patterns and, ultimately, for laws – econophysicists such as Stanley are trying to explain things that traditional financial theories do not.

In the past five years alone, investors have had to endure a US housing market collapse, a global credit crunch and a stock market “flash crash”. That is a lot of flying cutlery.

When future historians debate the genealogy of chickens and eggs up to the credit crisis, one question will be whether rocket scientists came to finance because of its increasing complexity or whether finance became increasingly complex because of the rocket scientists.

Banks and hedge funds have lured physicists for more than two decades, from the shrinking ranks of academic science or from corporate research departments such as Bell Labs in the US. The heads of trading desks were hungry for anyone who could bring new theory to the chaos of the markets or who could model the price of complex derivatives the same way they could divine laws for the physical world.

Little wonder. Vast fortunes can accrue to the most successful of these number crunchers, the so-called “quants” who can spot the market patterns that others cannot. Renaissance Technologies, the Long Island, New York-based hedge fund created by former codebreaker Jim Simons, now manages $39bn and provides a comfortable career for those trained as physicists, mathematicians and computer scientists.

Yet for some of those who have crossed over or undertaken research collaborations with traders, there remains a belief that the insights of physics have been imperfectly applied.

“I think a lot of physicists were probably hired for the wrong reasons,” says Jean-Philippe Bouchaud, a statistical physicist and professor at Ecole Polytechnique outside Paris who, for two decades, has run one of France’s most successful hedge funds. More absorbed the financial orthodoxy than were able to change it. “They were not left enough intellectual space to criticise the Gaussian world they were asked to absorb as quickly as possible. We just had no time to say, ‘this seems fishy to me and I want to think it through’. The dogma effect of the [financial] community was very, very strong before 2008.”

Gene Stanley, *professor of physics, Boston University*

‘If you make a catastrophic mistake in finance, the worst that can happen is you are fired’

The first generation of physicists-turned-financiers had never been under the illusion that their elegant pricing models were God’s truth, says Emanuel Derman. In 1985, the particle physicist was one of the first to swap physics work at Bell Labs for a job in finance, and his memoir, *My Life as a Quant*, about his years at Goldman Sachs, is on many a Wall Street trainee’s bookshelf. In 2009, as markets melted, he co-authored *The Financial Modelers’ Manifesto*, urging the quants to sign a kind of Hippocratic oath: “I will remember that I didn’t make the world and it doesn’t satisfy my equations.”

Models are only metaphors, Derman says now, repeating the warning he has given a thousand times to his financial engineering students at Columbia University, New York. People are not like apples, dropped from Newton’s tree; by describing the financial world, one changes behaviour. Models only work until they don’t. “Don’t take your model so seriously. Rather, use your model, put it to the things you can see. Then use it to interpolate to things that you can’t measure – and hope that it more or less interpolates directly. And when the world blows up that model is going be bad and the interpolation isn’t going to work.”

Derman’s warnings are not being heeded by everyone. Physicists continue to aspire to scoop in outlier phenomenon and to divine laws that can be used to predict the future, despite the daunting complexity. They reject the notion that financial systems tend towards a theoretical equilibrium and instead go hunting for inspiration in nature. Markets may be more like a body of water whose surface is constantly disturbed by new events and information, creating great waves whose energy is dissipated beneath the surface. Or they may be like the weather or the shifting tectonic plates, whose hurricanes and earthquakes are the culmination of many tiny interactions.

Didier Sornette began studying financial market bubbles and crashes more than 20 years ago as an extension to his work predicting the crash of rockets from acoustic emissions. For the past five years he has been professor on the Chair of Entrepreneurial Risks at the Swiss Federal Institute of Technology Zurich (ETH Zurich), running what he calls the Financial Crisis Observatory. Sornette says the models being built there are able to spot bubbles before they go pop, as they signalled in real estate in 2004 and 2005, and in gold and silver in

2011. "The big difficulty in many models is that people are trying to develop predictors that work all the time, to calibrate a model on regimes where there is no predictability, so they are bound to learn from noise, from patterns which are irrelevant," he says. "These complex systems are not systematically predictable. They're only predictable in some regimes."

The Financial Crisis Observatory's work instead describes a complex system that is inherently unstable but where random events can quickly start feeding on themselves. In a bubble, it might be that even sceptical investors jump aboard, for fear of being criticised for missing out on the gains, or badly written regulation encourages buying of a particular asset. However they begin, these periods of "super exponential growth, where the growth rate grows itself" can at least be identified in real time, Sornette believes. The financial devastation that can be wreaked in these bubbles and busts is such that Sornette calls them "dragon-kings" – but he also believes they can be slain.

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Jean-Philippe Bouchaud, *co-founder, Capital Fund Management, and professor of physics at Ecole Polytechnique*

'A lot of physicists were hired for the wrong reasons … We just had no time to say, "this seems fishy to me" '

One of the biggest shortcomings of traditional economic modelling was how little attention it paid to banks. Money was just assumed to find its way from those with capital to spare, to the businesses or households looking to borrow. Except that the cascading failures of banks and other intermediaries in 2007 and 2008 threatened to bring financial activity to a halt, and can no longer be ignored. Add to that the insights of behavioural economists, who are sweeping away the fiction that everybody acts rationally in their own financial interest, and it is clear why physicists studying complex systems are highly sought after.

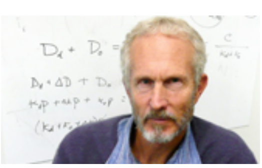
Oxford university's J Doyne Farmer first mixed physics and money at the roulette table. With fellow graduate students in California in the late 1970s, he built a computer model to try to predict the motion of the ball spinning around a roulette wheel – and even claims some success in Las Vegas. Adapting his work in chaos theory to financial markets, through a hedge fund called Prediction Company, proved most lucrative of all, and the fund was eventually acquired by UBS.

From his modest study in Oxford, he describes his latest immodest project. It is called Crisis, funded with €3.3m from the European Union, spanning 11 institutions and multiple disciplines, with Farmer as its scientific co-ordinator. "Our goal is to build a broad-based model of the key components of the economy: households, firms, banks and government," he says. The project is an attempt to do in economics what is common in physics, to build an agent-based model not from a mathematical formula or theory but from the ground up, by simulating the interactions of all the component parts. "The failure to embrace things like simulation has inhibited progress in economics," Farmer says. "Physics, meteorology, chemistry, biology, even other branches of social science have got major impetus because of serious use of computers as a simulation tool."

Crisis builds on techniques from Farmer's recent work constructing a model of a housing market, using data from the Washington, DC, area. It has pulled in census information, local economic statistics, mortgage offerings from local banks and data on both asking prices and the ultimate selling prices of all the homes that changed hands.

Like aircraft engineers testing new models in a wind tunnel, policy makers, regulators, economists and investors might one day use such a giant simulation to test theories about how their economies really work, and to run some "what ifs". Might it even tell us who "caused" the credit crisis? Will we be able, once and for all, to blame Alan Greenspan for keeping interest rates too low? Or reckless mortgage companies for lowering lending standards?

J Doyne Farmer, *co-director, complexity economics, Oxford Martin School*



'The failure to embrace things like simulation has inhibited

"It is definitely fun to do that and it is more fun the more you start to believe your model. The basic result we see is that both interest rates and lending policy have an effect. Lending policy has a bigger effect than interest rates," says Farmer.

"Ultimately, our biggest interest is in providing a tool for policy makers for when they ask questions like: what restrictions should we place on markets? How much leverage should we let home buyers have? Should we allow this type of loan? What would happen if there was a mass migration to that type of loan? Is that going to make the housing market more volatile or not? We think we can answer those questions," says Farmer.

And as anyone who has read Michael Lewis's *The Big Short* about the US housing crash knows, there is progress in economics, progress in other fields'

money to be made for those who can spot a calamity in the making. Experts from Ellington Capital Management, a mortgage securities-focused hedge fund, have been aiding the Washington, DC, market project. "This model probably has a lot of potential commercial value and it makes me a little nervous because, having been there and done that, I don't really want to get stuck on a money-making venture," says Farmer. "If you want to make money, there are plenty of people who want to throw money at you to help them make money. If you just want to do good for the world, it's a lot harder to get funded."

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If some physicists are looking upwards to the wider economy in search of complex systems to examine, they are also looking inwards to the microstructure of financial markets, where practices are changing at dizzying speeds. The advent of high-frequency trading, using computer algorithms to hop in and out of individual stocks within microseconds, has vastly increased the amount of traffic flowing through financial markets and created new patterns, often to the chagrin of regulators – and, on May 6 2010, to the shock of everyone who pays attention to the stock market. That was the day of the "flash crash", when the S&P 500 of US stocks plunged 9 per cent within minutes and then rebounded just as quickly.

The Securities and Exchange Commission's report into the incident was written by Gregg Berman, a physics PhD who had come to the regulator via Wall Street, where he had been an early developer of just the kinds of algorithmic trading strategies whose manifold, unexpected and disastrous interactions went on to trigger the market's wild ride on May 6.

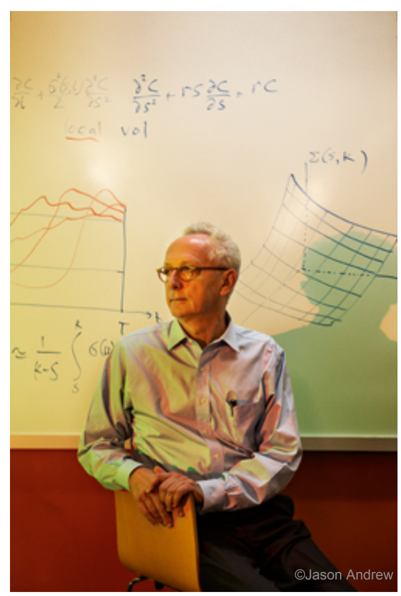
Don't take your model so seriously. Rather, use your model, put it to the things you can see

- Emanuel Derman

Predicting the likely impact of your trading activity on the market remains one of the frontiers of research and experimentation, as well as a key to staying ahead of the high-frequency traders. Just like in the old days of face-to-face trading on the stock exchange floor, when revealing you wanted to sell a big chunk of shares immediately prompted everyone else to lower their offers, algorithmic traders are acutely sensitive to the presence in the market of a big buyer or seller.

Bouchaud's hedge fund, Capital Fund Management, with access to its proprietary trading data, has written about the patterns governing trading impact and providing new insight into how hedge funds and asset managers ought to break up their orders so as to get the best price. "One of the most remarkable discoveries of very recent years is that there seems to be a pretty universal, pretty scientific law describing price impact, which is how do market prices move when people trade?" he says.

"When you trade out of the position, you are going to impact the market and perhaps induce an avalanche of trade in the same direction and, hence, the crash. Understanding impact is also something that's important to understand systemic risks, to understand feedback."



Emanuel Derman, professor of professional practice, Columbia University, and author of 'My Life as a Quant'

The accelerating speed of trading is opening up other tantalising opportunities for physics – and not just of the statistical model-building kind. High-frequency traders compete for advantage at the microsecond level and have sought out every opportunity for jumping ahead of their competitors. They have paid to put their computer servers inside stock exchange buildings to cut the length of optical cable that messages must flow through. They have incorporated parts of their algorithms directly on to microchips, to cut computing times. Almost every trade in every major stock in today's markets is a race with a photo finish.

Into this battle comes the National Physics Laboratory (NPL) in London, keeper of Greenwich Mean Time with an accuracy to within 1 second in 138 million years. It is pitching NPLTime, promising to pipe the exact time via dedicated lines from its servers in Docklands, so companies don't have to rely on GPS or internet time, which, it says, risks interference from solar flares or nefarious "jamming" and "spoofing" by competitors.

Leon Lobo, head of business development for time and frequency at NPL, debuting the service this summer, predicted high-frequency traders will use it to measure, test and improve their systems for the great race, while exchanges will want it to provide accurate time stamps for every incoming message or outgoing trade – so there will be no fighting.

It may be that the high-water mark for physicists transferring to Wall Street has passed. If it is big data sets that attract them, like children to a sandbox, these are hardly exclusive to finance in an era of cloud-connected internet-enabled information overload.

Yet Wall Street continues to appreciate physicists' facility – and imagination – with numbers, says Gene Stanley, and there is both intellectual challenge to be had and money to be made from finance. He has former students, and no doubt future collaborators, climbing the ranks at Goldman Sachs. His son, too, parlayed a physics degree from MIT into a job at the bank that pays a multiple of his professor's salary.

Over dinner near Boston University, Stanley is rueful. The financial crisis was foundation-shaking, and brought renewed interest in econophysics and in interdisciplinary approaches to understanding a complex world. But how much can it possibly change finance? "If I was forced to retire every time I made a mistake, I would be very, very careful," he says. "If you make a catastrophic mistake in finance, the worst that can happen is you are fired. But people there have saved enough money they can retire at almost any age after 35."

In other words, traders can shrug and say "shit happens". If the Gaussian distribution predicts 99 per cent of what happens, that may be plenty good enough for them. For the rest of us, not so much.

Stephen Foley is the FT's US investment correspondent. To comment, please email magazineletters@ft.com