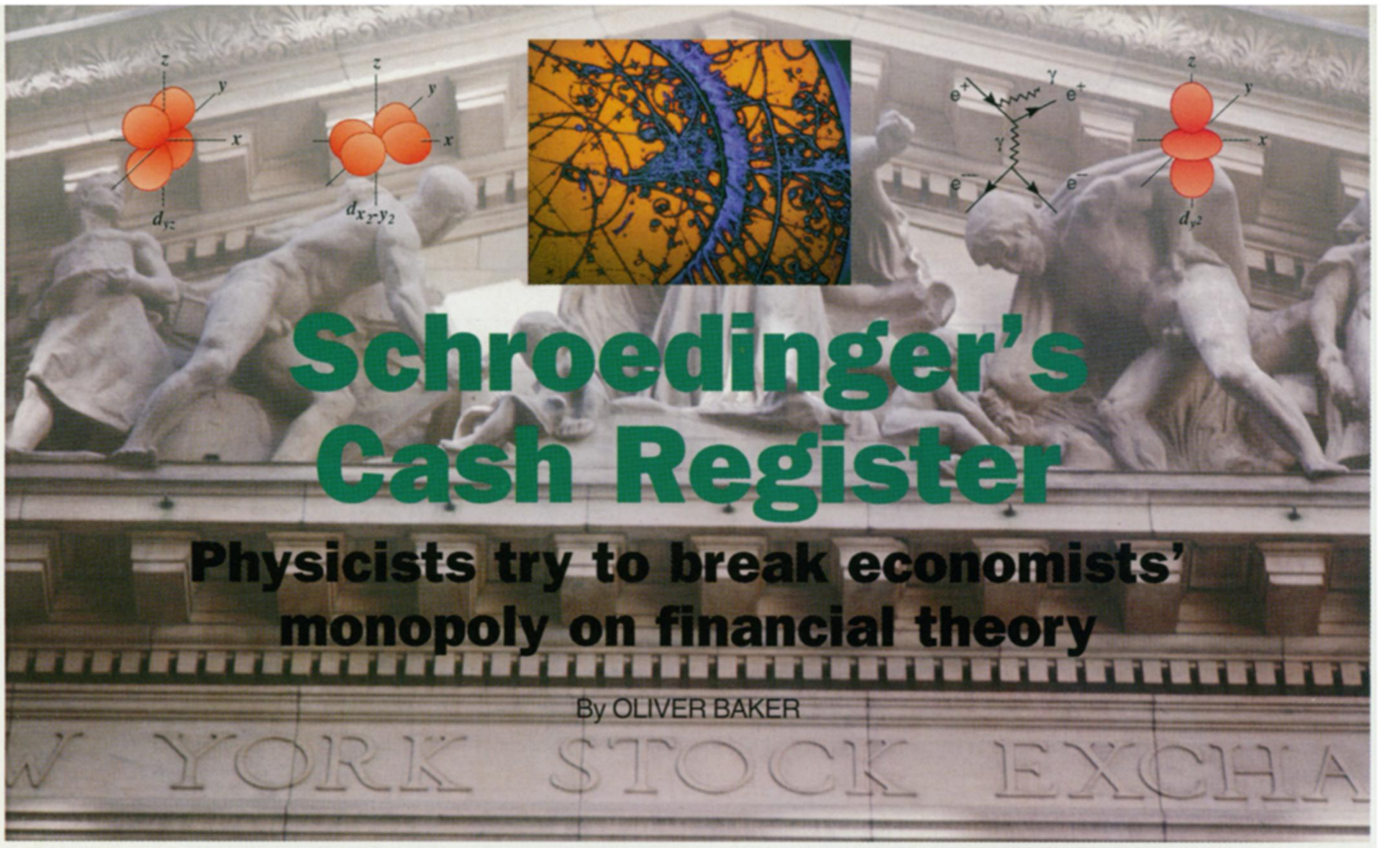


Schroedinger's Cash Register

Physicists try to break economists' monopoly on financial theory

By OLIVER BAKER

How is the stock market like the nucleus of an atom? To an economist, the question sounds like a joke. It's no laughing matter, however, for physicists seeking to plant their flag in the field of economics.

In the past few years, these trespassers have borrowed from quantum mechanics, string theory, and other accomplishments of physics in an attempt to divine undiscovered laws of finance. They're already tallying what they say are important gains.

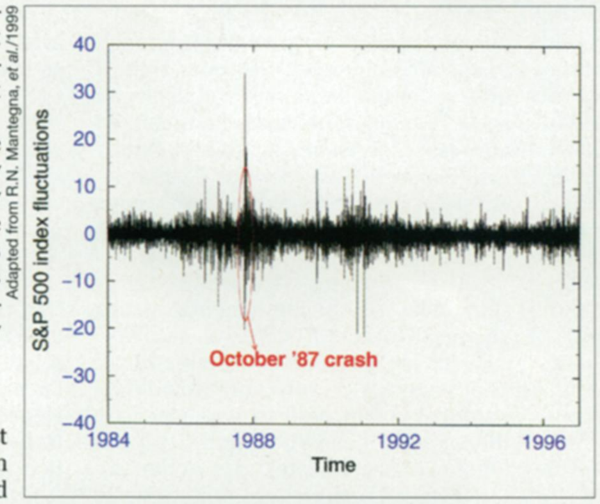
Inside the halls of economics, the whoops of physicists outside barely stir the air. Economists occasionally gaze out the windows, but are unimpressed by what they see. Is the new physics of finance a fool's errand—as most economists contend—or a rising stock that they will soon be buying into?

Boston University physicist H. Eugene Stanley specializes in the behavior of molecules and particles en masse—a discipline that, he says, provides an ideal background for approaching problems in economics.

"Economics is a pure subject in statistical mechanics," says Stanley. "It's not the case that one needs to master the field of economics to study this."

Physics training, he says, gives a person powerful mathematical tools, computer savvy, a facility in manipulating large sets of data, and an intuition for modeling and simplification. Such skills, he says, could bring new order into economics. Geophysics, astrophysics, and biophysics testify to the success of physicists at fertilizing new fields.

Financial firms on Wall Street put out welcome mats for physicists over a decade ago. People with physics Ph.D.s hold about half of the so-called quantitative analyst positions at such institutions, says Wall Street headhunter Robert



Fluctuations over time in Standard & Poor's index of 500 U.S. stocks (S&P 500), expressed in standard deviations. Analysts use this index to monitor broad trends in the value of U.S. stocks.

Long of the Denison Group in New York City. "And they significantly outnumber economists," he adds.

Wall Street physics has been mostly a proprietary pursuit of new spins on old methods for concocting abstract financial instruments, of which stock options are among the simplest examples. In the margins, a few physicist-financiers are working on so-called black box trading schemes (see sidebar).

Now, the embrace of physics and finance is reaching into academics. Physicists at universities are taking up finance, and nonacademic physicists in finance are pursuing basic research. Together they published about 50 economics papers this year in journals of physics.

Participants in the movement say that research in finance is growing faster than in any other area of physics. They point to a meeting this summer in Dublin entitled "Applications of Physics in Financial Analysis," which drew about 200 physicists. Many describe the phenomenon as the birth of a new field: econophysics.

Most economists aren't aware of the physicists' efforts, and those who are informed tend to dismiss them. Jonathan Berk, a financial economist at the University of California, Berkeley, read the first one or two financial articles in physics journals that his graduate students brought him. These sated his curiosity permanently, he says.

Berk says that he doesn't read physics articles anymore and his colleagues don't, either. "No one references this work," he says.

It wouldn't be surprising if some of the ideas published by physicists in recent years were to turn economists a queasy shade of yellow.

To explain interest rates and fluctuations of stock market prices, these theories draw analogies to earthquakes, turbulence, sand piles, fractals, radioactivity, energy states in nuclei, and the composition of elementary particles.

Some of these theories make propositions that strike Andrew Lo as patently absurd. An econometrist at the Massachusetts Institute of Technology, he cites papers proposing that prices can be negative or can incorporate so-called imaginary numbers, based on the square root of negative one.

Many econophysicists acknowledge the presence in their field of an unusual amount of work that they call ungrounded, misguided, or in some cases downright crazy. Pioneer econophysicist Jean-Philippe Bouchaud, whose company, Science & Finance, in Levallois, France, provides consultation to banks, says that many physicists have not invested sufficient time to learn about finance. Too many, he says, are dabbling in economics "as just an easy way to do some research."

Yet the work of others, Bouchaud contends, deserves economists' full attention. Econophysicists have the right skills to eke information from the fluctuating prices seen in stock market records. Furthermore, Bouchaud says, they've been mining their insights from a wealth of new data that has become available with the proliferation of computers.

Bouchaud cites a study done last year by Stanley and his collaborators. The team analyzed a 2-year price record of 1,000 stocks traded on the New York Stock Exchange, the American Stock Exchange, and the National Association of Securities Dealers Automated Quotation (NASDAQ). Taking quotations spaced 5 minutes apart, the researchers compiled a data set of 40 million prices, the largest pool of market data that had ever been analyzed, they say. They described their findings in just two pages of the May 2, 1998 European Physical Journal B.

After calculating the swing in price that occurred over each 5-minute interval for all 1,000 stocks, Stanley and colleagues constructed a graph called a histogram. Sorting price changes by size, they counted how many fell into each group and graphed that number against the size of the price change.

While the histogram exhibits the shape of a bell, it's not the bell curve most people know, which describes the random variations most visible in nature. The so-called tails to the left and right of the histogram's hump are fatter than the ones on a conventional bell curve, or normal distribution. This result means that extreme events—big price swings up or down—are far more likely than a simplistic statistical approach predicts.

Stanley's team is not the only one to observe these tail statistics. At the Dublin econophysics conference, researchers presented similar findings from analyses of other assemblages of stocks, different stock markets, currency exchanges, and interest-rate markets. In sum, says Bouchaud, "all markets look pretty much alike."

These analyses together, he says, point to an underlying, mathematical structure to market behavior. While exact numbers may differ from one market to another, Bouchaud says, essential features do not.

Beyond the innate fascination of this conclusion, these studies also have immediate practical significance to finance, according to Bouchaud. The shape of the tails matters in particular, he says, to the way trading institutions calculate risk.

"All the software I know to be used professionally is completely wrong in the tails," he says. "This will have to change."

Stanley shares his view, saying, "Physicists have completely revolutionized how you calculate risk."

Traders will want to pay attention to the lessons emerging from these studies, says Bouchaud. By assuming that conventional bell-curve statistics apply, investors have unwittingly stacked the deck against themselves.

Bouchaud and a colleague have devised a method to calculate financial risk that incorporates the recent findings about price fluctuations. Their scheme exploits the claim of Stanley and other econophysicists that a simple formula describes the shape of the histogram's tails. If a piece of commercial software could make practical use of such calculations—and should the physicists' formula prove right—it would be the first such product able to account accurately for extreme swings in price, says Mark B. Garman, chairman of Financial Engineering Associates in Berkeley, Calif., which manufactures business software.

However, few economists know the work. Those who do say the physicists' findings amount, at best, to nothing new. According to Blake LeBaron, an economist at Brandeis University in Waltham, Mass., researchers have known since 1963 that tails are fat, and they have known the fine points of the tail shape for some time, too.

"High-frequency data is [already] an enormous area in finance," says LeBaron. "There are conferences run around it."

Rather than finding a universal law, LeBaron contends, what econophysicists have uncovered is of limited interest and little practical use. The fat-tailed bell curve, he says, is not what statisticians call stable. Its shape differs if researchers sample prices every 5 months versus every 5 minutes.

For sampling intervals between 1 minute and 2 weeks, the tails remain reasonably fixed. The limit of 2 weeks, however, severely restricts the formula's utility, he says.

"To an economist, these tails would be very interesting if they held up out to long range," says LeBaron, "but they don't." He adds that economists care more about what an asset might be worth in a few months than in a few minutes.

Garman differs, however. Banks may shift financial strategies once or more within a day, he says, and they want software that calculates risk for 8 or 24 hours ahead.

Physicists' black boxes: Money machines?

Within the dark recesses of proprietary financial research on and off Wall Street, an unreckoned but purportedly small number of stock analysts are building what they call black boxes. These computerized systems monitor current and past prices of a stock or asset, consult currency exchange rates or other factors that might serve as financial indicators, and spit out decisions from moment to moment about whether an investor should buy or sell.

An ever-evolving formula instructs some black boxes as to which indicators to consult and how to factor them into the decisions. The boxes themselves may devise these formulas. Many boxes evaluate stocks using programming that mirrors how brain-cell networks operate. The computers effectively teach themselves as they go along how to forecast swings in price.

The goal of black box research is narrow, to sell high and buy low, and its ethos may be summed up as "whatever works." Researchers have a strong disincentive to publish any innovations that would be useful for turning profits, since if everybody knew of them—prevailing economic theory says—they would cease to work. In these ways, the black box efforts differ from most of the physics research that has been newly dubbed econophysics.

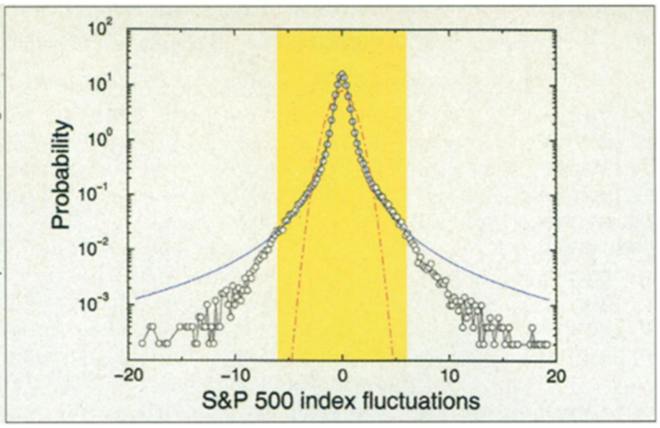
Physicists, nevertheless, number among those pursuing black boxes. A new book by Thomas A. Bass, entitled *The Predictors* (1999, Henry Holt), chronicles the adventures of two such physicists: J. Doyne Farmer and Norman Packard. They formed the Prediction Company in Santa Fe, N.M., which operates under contract with the United Bank of Switzerland.

Farmer, also of the Santa Fe (N.M.) Institute, told Science News that since the days documented in *The Predictors,* he has begun to turn his attention to more academic financial questions. This move reflects the direction of his own curiosity, he says. The profits that he and coworkers have made with black boxes, Farmer contends, are "highly statistically significant."

Most financial analysts, however, are skeptical. —*O.B.*

Physicists have also invaded another patch of economic turf—one that aims to understand price fluctuations from the ground up. Multiagent modeling, as this research is called, throws together psychological motives, rational strategies, and social dynamics in order to identify what elements control how stock prices evolve. On the computer, virtual traders—or agents—buy, sell, and swap information, causing imaginary stock prices to rise and fall.

While economists make up the vast majority of researchers working on such models, econophysicists have established a niche of their own by making models much simpler than most economists now choose to consider. Some of the stripped-down scenarios don't even involve stocks.



Histogram showing the probability of different-size relative changes in the S&P 500, expressed in standard deviations, on a minute-by-minute basis from 1984 through 1989. The tails flanking the central hump are fatter than those of a normal, or bell, curve (red; its familiar shape is distorted by the logarithmic y-axis) and thinner than those of another stable distribution (blue).

The simplicity of such models could yield rewards in several ways, say their developers. In paring down markets to their most basic facets, the models offer to clarify what makes prices behave the way they do.

Some also enable econophysicists to forecast aspects of how prices or other outputs will behave. Sophisticated mathematics have produced formulas that can predict trends in the fluctuations before researchers run a model.

The formulas are general, so they apply to many configurations of the model—whether the virtual agents rely on 20 trading strategies or only 2.

LeBaron says that with a few exceptions, only the econophysicists' models have yielded such formulas. Most of LeBaron's economist colleagues pay the physicists' models little mind, he says, because they consider them trivially simple—a judgment LeBaron often shares. However, because of the mathematical insight that some econophysicists have into their models, LeBaron says that he takes care to stay up-to-date on the latest.

In contrast to the econophysicists, "economists are more worried about getting the economic details right," LeBaron says. If there are tractable formulas with application to real markets, LeBaron says, economists—with their more elaborate models—are not liable to discover them on their own.

"Probably if anyone is going to bump into them," LeBaron says, "I have a hunch it's going to be the econophysicists."

Even if they do find such formulas, he says, that achievement will not be enough in itself to predict the behavior of actual markets. In describing real trading, the numbers that one would plug into a formula—such as how many strategies an agent has and how long a memory—are not obvious. Figuring out what these numbers should be will require models such as the ones that economists are working on, he says.

In fact, LeBaron has already initiated collaborations with a few physicists—work that has led to two articles.

Given the potential payoff, J. Doyne Farmer of the Santa Fe (N.M.) Institute says he wants to see more economists and econophysicists exchanging ideas. A trained physicist who has worked in finance for 7 years, he perceives some obstacles to this goal, however.

The newcomers to economics offend their hosts in a number of ways, Farmer says. Besides having a cultural tolerance toward audacious analogies, econophysicists have exuded a hubris that puts economists off, and at times they have operated in ignorance of basic facts of finance.

Farmer contends that the proper way to judge a field, however, is by its best work, not its worst. Many economists, he fears, have dismissed econophysics summarily, overlooking both what it has accomplished so far and the clear promise he believes it holds. On the other hand, he regards the few recent collaborative papers as encouraging.

Berk, who believes breakthroughs in economics will demand some insightful simplifications, acknowledges that physicists have skills in this regard. They could conceivably use these talents to reap dividends in his field, he grudgingly admits. "But as my undergraduate training in physics taught me," Berk says. "Let's see some evidence."

Econophysics will have to improve its credit rating before Berk and most other economists take it seriously. They haven't bought into the new field on its initial public offering. □