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The Blow-Up

In Wall Street's summer of scary numbers, all eyes were on the mathematically trained financial engineers known as "quants."
By Bryant Urstadt

On Wednesday, August 8, not long after the markets closed, 200 of the smartest people on Wall Street gathered in a conference room at Four World Financial Center, the 34-story headquarters of Merrill Lynch. August is usually a slow month, but the rows of chairs were full, and highly paid financial engineers were standing by the windows at the back, which looked out over black Town Cars below and the Hudson River beyond. They didn't look like Masters of the Universe; they looked like members of a chess club. They were "quants," and they had a lot to talk about, for their work was at the heart of one of the most worrisome summer markets in decades.

The conference was sponsored by the International Association of Financial Engineers (IAFE), and its title asked, "Is Subprime the Canary in the Mine?" "Subprime" borrowers are home buyers whose poor credit history means they don't qualify for market interest rates. Loans to subprime borrowers, which have become more common in recent years, typically have variable interest rates; as those rates rose, many borrowers were failing to meet their mortgage payments. Their defaults, in turn, had triggered unexpected problems in the market for financial instruments known as derivatives.

A derivative is a tradable product whose value is based on, or "derived" from, an underlying security. The classic example of a derivative is the option to buy a stock at some time in the future. In comparison, more recent derivatives are extraordinarily complex, and they had been invented by quants like the ones at the Merrill Lynch headquarters.

Things had started to go wrong in June, when the weakness in the subprime market had led to the collapse of two huge funds at the investment bank Bear Stearns, costing investors some $1.6 billion. When the quants gathered in August, the most pessimistic among them imagined that the collapse of the subprime market could lead to a shortage of credit as banks dealt with defaults. That would chill the economy, causing worldwide job losses, still more defaults, decreased spending, and withdrawals from the stock market, culminating in a global recession, or worse.

The panel was moderated by Leslie Rahl, an MIT graduate and the founder of Capital Market Risk Advisors. Her job is to advise companies on risk and help them understand the products quants invent. But understanding was in short supply in August. Some of the quants' financial products had collapsed in price, with unexpected consequences in another financial sector: the trading of equities.

The stock market had plunged in July and had been behaving erratically since. In the weeks after the conference, an organizing narrative of sorts would develop. But at the time, the economic view was dizzying. The market would drop precipitously over the course of a day, then rebound nearly to its previous level in the last 45 minutes of trading. Stranger still, stocks with strong financial reports and a good outlook were falling; these were the blue chips, which normally rose in uncertain times. Stocks with weak financials and a gray future were rising. These were normally the dogs that got dumped.

No one quite knew why, yet, but the market's odd behavior would turn out to be closely linked to the work of the quants. In addition to creating arcane financial products, quants have been pushing the frontiers of computer-driven trading systems, and not enough of those systems were working the way they were supposed to--or, to put it more precisely, the way they were supposed to work turned out to be counterproductive in volatile times like these.

Quants like the ones at the August conference were knee deep in the troubles threatening the global financial system. It all raised two very good questions: Who exactly are the quants? And what do they really do?

"Quant" is an elastic word that has meant different things at different times. Historically, the term referred to back-room technicians who used quantitative analysis to support the bankers who sold financial instruments. It came into wider use in the 1980s, when academics--pure mathematicians and physicists, mostly--began to appear in the financial world in larger numbers. Classic geeks, the newcomers were at first treated as déclassé immigrants by the financial establishment. Emanuel Derman was a theoretical physicist at Columbia University before he joined Goldman Sachs in 1985, and he remembers in his fine memoir My Life as a Quant when "it was bad taste for two consenting adults to talk math or Unix or C in the company of traders, salespeople, and bankers." But success lent the quants credibility. What was at

first a disdainful term was cheerfully embraced by those whom it was originally meant to insult. It finally came to encompass a larger group of people, including, most broadly, anyone involved in mathematical or computational finance. In this article, the word "quant" refers to any practitioner of quantitative finance, a wide-ranging discipline that includes, among other things, the pricing of financial instruments, the evaluation of risk, and the search for exploitable patterns in market data.

A quant sees the financial world through a mathematical lens. This does not necessarily describe the average Wall Street salesperson or trader, whose success is often based as much on intuition and, maybe more important, connections and personal charisma as on any understanding of a topic like stochastic calculus. To give some idea of how far the quant mind is from that of the typical financier, stochastic calculus--a branch of mathematics dealing with randomness--is sometimes derided by quants as "folk math." The quant, unlike his slicker counterpart, seeks to understand and profit from the markets on a purely numerical basis. Or as Herbert Blank, a quant who devises algorithms for evaluating the financial health of companies, says, "If you think you can find out what you need to know by going to see the management of a company, then I have nothing to say to you."

If quants in one guise or another have been around for a while, they have also made trouble before. The hedge fund Long-Term Capital Management, which collapsed in August 1998, boasted some of the founders of the field among its directors and officers. Nonetheless, in recent years, quants' numbers and influence have grown. Over-the-counter derivatives, such as the ones at the heart of the subprime crisis, have become more popular, fueling a boom in lending by making loans easier to trade. The value of over-the-counter derivatives, one shorthand measure of activity in the market, went from $298 trillion in December 2005 to $415 trillion a year later, according to statistics kept by the Bank for International Settlements. By some measures, the money invested in two of the most common types of quant funds has grown 60 percent in the last two years (including both expanding assets and new investments), and the funds have generated some of the highest returns in the financial industry.

They're also among the industry's most mysterious organizations. Firms that keep their methods secret are known as "black boxes," and the quant-driven hedge funds are as black as any. It is not unusual for billions of dollars to be invested in such firms with little revealed except the results. Previous results, though, can be a powerful incentive for giving money to someone who won't tell you what he's going to do with it. A case in point is James Simons's Renaissance Technologies, which has earned an average of more than 30 percent a year since its founding in 1988. Like other quant funds, it is ferociously secretive. Still, so many investors have trusted Simons that the two funds under his management now total more than $30 billion. In 2006 alone, he earned $1.7 billion running the fund.

The press often refers to Simons as the world's leading quant. A world-class mathematician with a PhD from the University of California, Berkeley, he spent years in academia, making significant contributions to mathematics. He worked primarily in geometry and in a subfield called differential geometry, where his most prominent contribution was the Chern-Simons theory, a topological description of quantum field behavior that has been useful to string theorists. Many of his employees have backgrounds in physics, astronomy, and mathematics.

The quants of Renaissance Technologies are unusual in that many might have enjoyed significant careers in academia. But quants of a less exalted sort are becoming ubiquitous at financial institutions. There are quants at investment banks, developing new loan structures. There are quants at hedge funds, crunching years of market data to develop trading algorithms that computers execute in milliseconds. And there are more and more quants at pension funds, trying to understand and value the tools created by the banking quants, and trying to evaluate the methods of the investing quants.

"We used to send our graduates mainly to the big banks," says Andrew Lo, the director of MIT's Laboratory for Financial Engineering, where many quants are trained. "Now they're going everywhere, to pension funds, insurance companies, and companies that aren't finance companies at all." MIT's lab was founded in 1992, one of a host of academic programs in the discipline that have sprung up on campuses around the United States and abroad; a new institute at the University of Oxford is one of the most recent additions. "Financial markets and investment processes are becoming more quant across the board," says Lo.

To understand who they were and what they were doing, I spoke with current and former quants, on and off the record. Many would speak happily and at length. Others spoke guardedly or anonymously--especially those using proprietary analysis and algorithms to conduct trades. I read memoirs of quants--a recently expanding genre--and dipped into an introductory textbook for quants, Paul Wilmott Introduces Quantitative Finance, a 722-page condensation of the author's 1,500-page, three-volume anvil of a book, Paul Wilmott on Quantitative Finance. And I went to a quant drinking party, which convened in the basement of a pub next to Grand Central Station. The name of that event proves, as much as anything, that the quants have geek in their veins: it was the August meeting of the New York chapter of the

Quantitative Work Alliance for Applied Finance, Education, and Wisdom, or QWAFAFEW.

Though derivatives were simpler once, they were never very simple. The breakthrough in the valuation of derivatives in general, and options in particular, was the model and formula know as Black-Scholes, first proposed by Fischer Black and Myron Scholes in the 1970s and formalized by Robert Merton in 1973. (Merton, like so many of the best quants, came not out of Wall Street but out of academia, earning a PhD in economics from MIT in 1970.)

In quantitative finance, the formal expression of Black-Scholes by Robert Merton is so important that everything that followed has been called a "footnote." The Black-Scholes model assumes that a stock's price changes partly for predictable reasons and partly because of random events; the random element is called the stock's "volatility." The idea can be represented mathematically by a simple equation:

St is the value of the stock, and dSt is the change in stock price. The symbol µStdt represents the stock's predictable change and its volatility. (View the results of Black-Scholes model using this interactive calculator.) That final, kabbalistic combination of letters, dWt, is the mathematical expression for randomness, known as either Brownian motion or the Wiener process. (Chemically, Brownian motion is the random movement of particles in solution, identified by the botanist Robert Brown in 1828 and mathematically described by the great MIT mathematician Norbert Wiener. Black-Scholes shares some qualities with heat and diffusion equations, which describe everyday events like the flow of heat and the dispersion of populations. That some physical processes seem relevant to finance has inspired all kinds of far-out work, such as efforts to bend general relativity to a theory of finance.) Black-Scholes prices an option according to the amount of randomness in a stock's price; the greater the randomness, the higher the stock could climb, and thus the more expensive the option.

Quants have since refined Black-Scholes, and with the increasing power of computers, they have developed other, more processing-intensive methods of valuing derivatives. In Monte Carlo simulations, for instance, powerful computers model the performance of a stock millions of times and then average the results. Where Black-Scholes, as a mathematical shortcut, assigns a constant value to a stock's volatility, Monte Carlo simulations vary the volatility itself. In theory, this provides a better approximation of price fluctuations in the real world. And quants have devised yet more arcane methods of derivatives pricing. Some particularly complicated models track other economic factors--like the stock market as a whole, or even larger macroeconomic factors--in addition to a stock's price.

Running such computationally intensive simulations has become a lot easier in the last decade. Gregg Berman, a former experimental astrophysicist who left the academy for the world of finance in 1993, is one of what he calls "a plethora of PhDs" at RiskMetrics, a firm that provides models, tools, and data to the majority of important banks, brokerages, and hedge funds. (Among other things, the company tries to predict how a derivative will behave in a variety of market conditions--how it might respond, for instance, to weakening exchange rates or increased interest rates.) When Berman started in the business, he says, "full-blown simulations [of the Monte Carlo type] were rare." Now that computers can be so easily linked, however, Berman might put as many as 1,000 processors to work at once to run "simulations within simulations," which might measure risk on a product like a mortgage-backed security.

The net result of this improved ability to assign values to increasingly complex derivatives was an explosion in their variety. That meant there was a derivative to suit every investor's appetite for risk. In consequence, investors were increasingly willing to put more money into derivatives.

Recently, one of the most popular of these new instruments has been collateralized debt obligations, or CDOs. Crucially for our story, CDOs are also the product most closely associated with the summer's subprime mess. The CDO has been called a "derivative of a derivative," and to further confuse things, there are CDOs of CDOs, and even CDOs of CDOs of CDOs. A CDO combines both high- and low-risk securities that might derive their cash flow from mortgages, car loans, or more esoteric sources like movie revenues or airplane leases. Investors in a CDO can buy the rights to different levels of income and associated risk, called "tranches." Generally, the most risky tranche of a CDO pays the most income. Created by quants and priced by quants, CDOs have become a popular way for hedge funds, pension funds, insurance companies, and other investors to buy pieces of high-risk but high-profit sectors like subprime loans. According to the Securities Industry and Financial Markets Association, annual issues of CDOs worldwide nearly doubled between 2005 and 2006, going from $249.3 billion to $488.6 billion.

The quants who devise such derivatives work more or less in public view. They're obscured mainly by the complexity of their work. But our knowledge of the quants who design trading strategies is additionally occluded by the secrecy of the big fund operators like Renaissance Technologies. I did manage to speak with some current traders, who gave me a general idea of their approach, and with some ex-traders, who were slightly more specific.

One common method that quants use to identify market opportunities is pairs trading. Pairs trading involves trying to find securities that rise in tandem, or that tend to go in opposite directions. If that relationship falters--if, say, the values of two stocks that travel together suddenly diverge--it's likely to indicate that one stock is undervalued or overvalued. Which stock is which is irrelevant: a trader who simultaneously bets that one will go up and the other one down will probably make money. It's a strategy that lends itself to the use of computers, which can sort through huge numbers of price correlations over many years of stored data--although the final decision to speculate on the relative pricing of paired stocks generally rests with a fund's managers.

Quants have also been pursuing a strategy known as "capital structure arbitrage," which seeks to exploit inefficient pricing of a company's bonds versus its stocks. Again, computers do the searching, looking for instances where, for one reason or another, the securities are slightly misaligned.

In a similar technique, Max Kogler, a principal at the newly launched MM Capital in New York, uses computers to look for inconsistencies in value between the option on an index fund and the options on the stocks that compose that index. Kogler has a master's from the University of Cambridge in pure mathematics with a focus on statistics. He says his algorithms look for "baskets of options that are not doing what they're supposed to be doing." When his computers find such a basket, he and his partners discuss whether or not to buy.

Kogler runs his algorithms on "one Linux box." "Part of the allure of our algorithm," he said in an e-mail, "is that it cuts down computational requirements dramatically. Nonetheless, you'll want to have a speedy machine with pretty decent clock speed and a couple of parallel CPUs."

In what's called nondiscretionary trading, computers both find the inefficiencies and execute the trades. The Aite Group, a financial-services research firm, estimates that roughly 38 percent of all equities may be traded automatically, a number it expects to increase to 53 percent in three years.

Computers also underlie another developing frontier, high-frequency trading, which is a fantastically exaggerated form of day trading. The computer looks for patterns and inefficiencies over minutes or seconds rather than hours or days. An algorithm, for instance, might look for patterns in trading while the Japanese are at lunch, or in the moments before an important announcement. There is a massive amount of such data to crunch. Olsen Financial Technologies, a Zürich-based firm that offers data for sale, says it collects as many as a million price updates per day.

One trader I spoke with at a $10 billion hedge fund based in New York said that his computer executed 1,000 to 1,500 trades daily (although he noted that they were not what he called "intra-day" trades). His inch-thick employment contract precluded my using his name, but he did talk a little bit about his approach. "Our system has a touch of genetic theory and a touch of physics," he said. By genetic theory, he meant that his computer generates algorithms randomly, in the same way that genes randomly mutate. He then tests the algorithms against historical data to see if they work. He loves the challenge of cracking the behavior of something as complex as a market; as he put it, "It's like I'm trying to compute the universe." Like most quants, the trader professed disdain for the "sixth sense" of the traditional trader, as well as for old-fashioned analysts who spent time interviewing executives and evaluating a company's "story."

High-frequency trading is likely to become more common as the New York Stock Exchange gets closer and closer to a fully automated system. Already, 1,500 trades a day is conservative; the computers of some high-frequency traders execute hundreds of thousands of trades every day.

Linked with high-frequency trading is the developing science of event processing, in which the computer reads, interprets, and acts upon the news. A trade in response to an FDA announcement, for example, could be made in milliseconds. Capitalizing on this trend, Reuters recently introduced a service called Reuters NewsScope Archive, which tags Reuters-issued articles with digital IDs so that an article can be downloaded, analyzed for useful information, and acted upon almost instantly.

All this works great, until it doesn't. "Everything falls apart when you're dealing with an outlier event," says the trader at the $10 billion fund, using a statistician's term for those events that exist at the farthest reaches of probability. "It's easy to misjudge your results when you're successful. Those one-in-a-hundred events can easily happen twice a year."

The events of August were outliers, and they were of the quants' own making. (Some dispute that verdict: see "On Quants.") To begin with, quants were indirectly responsible for the boom in housing loans offered to shaky candidates.

Derivatives allow banks to trade their mortgages like bubble-gum cards, and the separation of the holder

of a loan from the writer of a loan tended to create an overgenerous breed of loan officer. The banks, in turn, were attracted by the enormous market for derivatives like CDOs. That market was fueled by hedge funds' appetite for products that were a little riskier and would thus produce a higher return. And the quants who specialized in risk assessment abetted the decision to buy CDOs, because they assumed that the credit market would enjoy nine or so years of relatively benign volatility.

It was a perfectly rational assumption; it just happened to be wrong. Matthew Rothman, a senior analyst in quantitative strategies at Lehman Brothers, called the summer a time of "significant abnormal performance"; according to his calculations, it was the strangest in 45 years. James Simons's Renaissance Technologies fund slid 8.7 percent in the first week of August, and in a letter to his investors, he called it a "most unusual period." As Andrew Lo put it, "Unfortunately, life has gotten very interesting." The Wall Street Journal called it an "August ambush."

The damage quickly spread beyond the market for low-quality debt instruments. It was almost as if the financial world had become a market for nothing so much as standard deviations, the mathematical term for the spread of values straying from a mean. In fact, the summer might be described as a time when too many investors had purchased standard deviations that were too high for their means.

Among the lessons that August taught is that there may be a finite number of viable investing strategies--a suspicion borne out by the oddly synchronous decline of many quant funds this summer, including Simons's Renaissance Technologies. August's bizarre market behavior, according to Rothman and others, was probably the product of some large hedge funds' seeking cash to meet their debt obligations, as the value of their CDOs declined, by selling those securities that were easiest to shed, chiefly stocks. (And which funds? In another example of the secrecy of fund managers, no one really seems to know, or wants to say.)

According to most of those to whom I spoke, something like the following occurred this summer. Quants had, in the ordinary nature of their jobs, "shorted" many stocks. Shorting is an arrangement whereby an investor borrows a stock from a broker, guaranteeing the loan with collateral assets placed in what is called a margin account. The investor straightaway sells the borrowed stock; if the stock then declines in value, the investor buys it back and pockets the difference in price when he returns the stock to the broker. But if the stock unexpectedly increases in value, even for a little while, the investor must either place additional collateral in the margin account to cover the difference or buy back the shorted stock and return it to the broker.

CDOs had functioned as the collateral on the quants' short positions. When the subprime crunch squeezed the financial markets, the value of those CDOs declined, forcing quants to increase the collateral in margin accounts, buy back the shorted stocks, or both. But in either case, in order to supplement their shrinking collateral, quant funds were forced to sell strong blue-chip stocks, whose prices consequently fell. At the same time, as quants bought back shorted stocks, the prices of those stocks increased, demanding the posting of yet more collateral to margin accounts at the very time that the value of CDOs was suffering. That the quants were, apparently, long on the same strong stocks and short on the same weak stocks was a result of a number of strategies, pairs trading among them.

Another related explanation for the August downturn was that the quants' models simply ceased to reflect reality as market conditions abruptly changed. After all, a trading algorithm is only as good as its model. Unfortunately for quants, the life span of an algorithm is getting shorter. Before he was at RiskMetrics, Gregg Berman created commodity-trading systems at the Mint Investment Management Group. In the mid-1990s, he says, a good algorithm might trade successfully for three or four years. But the half-life of an algorithm's viability, he says, has been coming down, as more quants join the markets, as computers get faster and able to crunch more data, and as more data becomes available. Berman thinks two or three months might be the limit now, and he expects it to drop.

For Richard Bookstaber, a quant who has managed hedge funds and risk for companies like Salomon Brothers and Morgan Stanley, the August downturn proved that concerns he'd long harbored were well founded. Bookstaber was on the panel sponsored by the IAFE; in fact, he is everywhere these days. His book A Demon of Our Own Design, which appeared in April, was eight years in the making, and it made some very prescient predictions.

Bookstaber is a quiet, thoughtful man, with sharp brown eyes and an attentive look. He studied with Merton in the 1970s at MIT, where he got his doctorate in economics. Today, he is very worried about the tools and the methods of the quants. In particular, he frets about complexity and what he calls "tight coupling," an engineer's term for systems in which small errors can compound quickly, as they do in nuclear plants. The quants' tools, he feels, have became so complicated that they have escaped their creators. "We have gotten to the point where even professionals may not understand the instruments," he says. This, to Bookstaber, was perfectly demonstrated this summer, when the subprime troubles touched

off a reactionary wave of selling in equities that would nominally seem unrelated, or, as Wall Street puts it, "uncorrelated."

"Nobody knew that what happened in the subprime market could affect what was going on in the quant equity funds," he says. "There's too much complexity, too much derivative innovation. These are the brightest people in the business. If it could happen to them, it could happen to anyone. No one could have predicted the linkage."

Linkage is one of Bookstaber's favorite topics. He believes that quants' instruments have "linked markets together that wouldn't normally be linked," and that such linkages are dangerous because they are unforeseen.

Berman and others I spoke to agreed with many of Bookstaber's concerns. "The products are getting an order of magnitude more complex," says Berman. "Things change slightly, and get correlated where they weren't correlated before." Or, as he put it a little less gnomically, "You can't make it without understanding it, but you can buy it."

Beneath all this beats the great hope of the quants: namely, that the financial world can be understood through math. They have tried to discover the underlying structures of financial markets, much as academics have unlocked the mysteries of the physical world. The more quants learn, however, the farther away a unified theory of finance seems. Human behavior, as manifested in the financial markets, simply resists quantification, at least for now.

Emanuel Derman remembers dreaming of such a unified financial theory in the early 1990s, a little after he had made the leap from the university to the Street. But those dreams, he says, are dead. Quantitative finance "superficially resembles physics," he says, "but the efficacy is very different. In physics, you can do things to 10 significant figures and get the right answer. In finance, you're lucky if you can tell up from down."

So up was down and down was up this summer, and Bookstaber and others hope it is a warning that will be heeded, rather than the beginning of a major systemic crisis.

And was subprime the canary in the mine? It was a question the panelists and the audience who showed up at Four World Financial Center last August are only beginning to answer. Leslie Rahl, for instance, cautiously told me in a follow-up e-mail that it is "looking more and more like the answer is yes." Many signs have suggested so, from job losses to a continuing credit drought to a weakening dollar, but that history has not yet been written.

As a prelude to the panel discussion, Rahl asked the audience to predict whether credit spreads would shrink or widen in the coming months. She was talking about the difference between the price of a treasury bond and the price of a riskier corporate bond, a standard Wall Street gauge for the health of the economy. A widening credit spread is generally seen as a sign of uncertainty, and a narrow spread as a sign of optimism.

"How many think spreads will widen?" she asked.

The hands of about half the smartest people on Wall Street shot up.

"And how many think they'll narrow?"

The other half--equally smart--raised their hands.

"Well," she said. "That's what makes a market."

If they didn't know, nobody could.

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