My Life as a Quant

Reflections on Physics and Finance

Emanuel Derman

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To the Memory of My Parents

Ambition is a state of permanent dissatisfaction with the present.

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MODELING THE WORLD

If mathematics is the Queen of Sciences, as the great mathematician Karl Friedrich Gauss christened it in the nineteenth century, then physics is king. From the mid-seventeenth century to the end of the nineteenth, Newton's Law of Gravitation, his three Laws of Motion, and his differential calculus described with apparent perfection the mechanical motion of objects in our world and the solar system.

In 1864, two hundred years after Newton, the Scottish physicist James Clerk Maxwell formulated the compact and elegant differential equations that described with similarly astounding precision the propagation of light, X-rays, and radio waves. Maxwell's equations showed that electricity and magnetism, formerly separate phenomena, were part of the same unified electromagnetic field.

We cannot simply look at the world around us and deduce Newton's Laws or Maxwell's equations. Data on its own does not speak. These equations were triumphs of the mind, abstracted from the world in some miraculous confluence of hard thinking and deep intuition. Their success confirmed that pure thought and beautiful mathematics have the power to discover the most profound laws of the universe.

At the start of the twentieth century, the pace accelerated. Einstein, pondering the conflicts between the Newtonian and Maxwellian views of the world, proposed his Theory of Special Relativity that amended Newton's mechanics and made them consistent with Maxwell's equations. Fifteen years later Einstein trumped Newton again with his proposal of the General Theory; it corrected the Law of Gravitation and described gravity as a large-scale wave in space and time. At almost the same time, Bohr, Schrödinger, and Heisenberg, with help from the ever-prodigious Einstein, developed the quantum mechanical theory of the small-scale behavior of molecules, atoms, and subatomic particles.

It was Einstein who perfected this mental approach to discovering the laws of the universe. His method wasn't based on observation or empiricism; he tried to perceive and then enunciate the very principles that constrained the way things should work. In a 1918 speech on the principles of research given in honor of Max Planck, the discoverer of the quantum, Einstein captured the magus-like appeal of trying to see through a glass, darkly, when he said: "There is no logical path to these laws; only intuition, resting on a sympathetic understanding of experience, can reach them."

What is the purpose behind the search for scientific laws, in any field? Clearly, it's divination—foretelling the future, and controlling it. Most of the modern technologies we enjoy, rely on, detest, or fear—cell phones, electric power grids, CAT scans, and nuclear weapons, for example—have been developed by using the basic principles of quantum mechanics, electromagnetic theory, and relativity, all of which were discovered by cerebration. The classic tools of twentieth-century divination have indeed been those of physics. More recently, physicists have begun to employ the same tools in finance.

For the past twenty years, throughout Wall Street and the City of London, in most major and many minor financial institutions, small groups of ex-physicists and applied mathematicians have tried to apply their skills to securities markets. Formerly called "rocket scientists" by those who mistakenly thought that rocketry was the most advanced branch of science, they are now commonly called "quants."

Quants and their cohorts practice "financial engineering"—an awkward neologism coined to describe the jumble of activities that would better be termed *quantitative finance*. The subject is an interdisciplinary mix of physics-inspired models, mathematical techniques, and computer science, all aimed at the valuation of financial securities. The best quantitative finance brings real insight into the relation between value and uncertainty, and it approaches the quality of real science; the worst is a pseudoscientific hodgepodge of complex mathematics used with obscure justification.

Until recently, financial engineering wasn't really a subject at all—when I entered the field in 1985, it didn't have a name and was something one learned on the job at an investment bank. Now you can get a master's degree in the subject at scores of institutions—the Courant Institute at New York University, the University of Michigan at Ann Arbor, and the University of Oregon in Eugene, to name a few. Since July 2003 I have been a professor of the subject at Columbia University. Engineering schools, statistics and mathematics departments, and business schools organize these one- to two-year programs; they promise to transform students, in exchange for about $30,000 per year, into employable financial engineers. So popular are these degrees that some universities run several similar programs in distinct departments.

Nowadays, managers on Wall Street receive daily calls and emailed résumés from PhDs seeking jobs in finance. Physics journals publish increasing numbers of papers on financial economics. And increasingly, physicists and mathematicians working on the quantitative side of banking have been joined by PhDs and faculty members from finance departments and business schools. Two of the best graduate finance departments in the country, the Sloan School at MIT and the Haas School of the University of California at Berkeley, have each lost several of their best young finance faculty to the banking and trading worlds.

Part of the reason for the influx of physicists to other fields was the 1970s collapse of their traditional job market: academia. Thirty years earlier during World War II, the invention of radar and the construction of the atomic bomb confirmed the usefulness of physics to postwar governments. Shocked by the successful voyage of Sputnik, the Departments of Defense and Energy began to fund pure research more copiously, and physicists seeking grants to do such research weren't above playing up the spin-off benefits of their work. Physics departments in the 1960s grew and academic posts multiplied. Inspired by the subject and supported by scholarships, a wave of ardent graduate students entered the field.

The good times didn't last. By the end of the Vietnam War a deteriorating economy and a public revulsion with science in the service of war put a large dent in research funds. During the 1970s and 1980s, many theoretical physicists who had once hoped to devote their lives to fundamental research were forced to become migratory laborers if they wanted to remain in academia, taking temporary short-term positions in universities and national laboratories wherever they became available. Many of us eventually gave up the struggle to find even a low-paying semipermanent academic job and turned to other areas. We sought physics-related jobs in a variety of fields—in energy research or telecommunications, for example. Former colleagues of mine began to work on alternate power sources at the Solar Energy Research Institute in Golden, Colorado, or on the mathematics of oil retrieval at Schlumberger in Ridgefield, Connecticut. Others helped develop advanced switching systems at AT&T's Bell Laboratories in New Jersey.

Coincidentally, some of the same forces that compelled physicists to move out of academia made Wall Street begin to embrace them. The Arab oil embargo of 1973 caused fuel prices to soar and interest rates to climb; soon the fear of inflation propelled gold prices above $800 an ounce. Suddenly, financial markets seemed to become more volatile. Bonds, a traditionally conservative investment, were suddenly seen as much riskier than anyone had imagined. The old rules of thumb no longer applied. Understanding the motion of interest rates and stock prices became more important than ever for financial institutions. Risk management and hedging were the new imperative and, in the face of so much freshly perceived risk, complex new financial products that provided protection from change proliferated.

How could one describe and understand the movement of prices? Physics has always been concerned with dynamics, the way things change with time. It was the tried-and-true exemplar of successful theories and models. And physicists and engineers were jacks-of-all-trades, simultaneously skilled mathematicians, modelers, and computer programmers who prided themselves on their ability to adapt to new fields and put their knowledge into practice. Wall Street began to beckon to them. In the 1980s, so many physicists flocked to investment banks that one headhunter I know referred to them as "POWs"—physicists on Wall Street.

THE MOST SUCCESSFUL THEORY

What is it that physicists do on Wall Street? Mostly, they build models to determine the value of securities. Buried in investment banks, at hedge funds, or at financial software companies such as Bloomberg or SunGard, they tinker with old models and develop new ones. And by far the most famous and ubiquitous model in the entire financial world is the Black-Scholes options pricing model. Steve Ross, a famous financial economist, options theorist, and now a chaired professor at MIT, wrote in the *Palgrave Dictionary of Economics* that ". . . options pricing theory is the most successful theory not only in finance, but in all of economics."

The Black-Scholes model allows us to determine the fair value of a stock option. Stocks are commonplace securities, bought and sold daily, but a call option on a stock is much more arcane. If you own a one-year call option on IBM, for example, you have the right to buy one share of IBM one year from today at a predetermined price: say, $100. The value of the option on that future date when it expires will depend on the prevailing value of a share of IBM. If, for example, a share sells for $105 on that day, the option will be worth exactly $5; if a share sells for less than $100, the option will be worth nothing. In a sense, the option is a bet that the stock price will rise.

An option is a special case of a more general *derivative security*, a contract whose value is *derived from* the value of some other simpler *underlying* security on which it "rests." A derivative security's payoff at expiration is specified in a contract via a mathematical formula that relates the payoff to the future value of the underlying security. The formula can be simple, as is the case with the stock option just described, whose payoff is the amount by which the final stock price exceeds the value of $100, or it can be extremely complicated, with a payoff that depends on the prices of several underlying securities through detailed mathematical expressions. During the past twenty years derivative securities have become widely used in the trading of currencies, commodities, bonds, stocks, mortagages, credit, and power.

Derivatives are more intricate than unvarnished stocks or bonds. Then why do they exist? Because derivatives allow clients such as investment banks, money managers, corporations, investors, and speculators to tailor and fine-tune the risk they want to assume or avoid. An investor who simply buys a share of IBM takes on all the risk of owning it; its value waxes and wanes in direct proportion to IBM's share price. In contrast, an IBM call option provides potentially unlimited gain (as the share price rises above $100) but only limited loss (you lose nothing but the cost of the option as the stock price drops below $100). This asymmetry between upside gain and downside loss is the defining characteristic of derivatives.

You can buy or sell options retail on specialized options exchanges, or you can trade them with wholesalers, that is, the dealers. Options dealers "make markets" in options; they accomodate clients by buying options from those who want to sell them and selling options to those who want to acquire them. How, then, do dealers handle the risk they are forced to assume?

Dealers are analogous to insurance companies, who are also in the business of managing risk. Just as Allstate must allow for the possibility that your house will burn down after they sell you an insurance contract, so an options dealer must take a chance of a rise in IBM's stock price when he or she sells you a call option on IBM. Neither Allstate nor the options dealer wants to go broke if the insured-against scenario comes to pass. Because neither Allstate nor the dealer can foretell the future, they both charge a premium for taking on the risks that their clients want to avoid.

Allstate's risk strategy is to charge each client a premium such that the total sum they receive exceeds the estimated claims they will be obliged to pay for future conflagrations. An option dealer's risk strategy is different. In an ideal world, he or she would simply offset the risk that IBM's price will rise by buying an IBM option similar to the one he or she sold, from someone else and at a cheaper price, thereby making a profit. Unfortunately, this is rarely possible. So instead, the dealer *manufactures* a similar option. This is where the Black-Scholes model enters the picture.

The Black-Scholes model tells us, almost miraculously, how to manufacture an option out of the underlying stock and provides an estimate of how much it costs us to do so. According to Black and Scholes, making options is a lot like making fruit salad, and stock is a little like fruit.

Suppose you want to sell a simple fruit salad of apples and oranges. What should you charge for a one-pound can? Rationally, you should look at the market price of the raw fruit and the cost of canning and distribution, and then figure out the total cost of manufacturing the hybrid mixture from its simpler ingredients.

In 1973, Black and Scholes showed that you can manufacture an IBM option by mixing together some shares of IBM stock and cash, much as you can create the fruit salad by mixing together apples and oranges. Of course, options synthesis is somewhat more complex than making fruit salad, otherwise someone would have discovered it earlier. Whereas a fruit salad's proportions stay fixed over time (50 percent oranges and 50 percent apples, for example), an option's proportions must continually change. Options require constant adjustments to the amount of stock and cash in the mixture as the stock price changes. In fruit salad terms, you might start with 50 percent apples and 50 percent oranges, and then, as apples increase in price, move to 40 percent apples and 60 percent oranges; a similar decrease in the price of apples might dictate a move to 70 percent apples and 30 percent oranges. In a sense, you are always trying to keep the price of the mixture constant as the ingredients' prices change and time passes. The exact recipe you need to follow is generated by the Black-Scholes equation. Its solution, the Black-Scholes formula, tells you the cost of following the recipe. Before Black and Scholes, no one even guessed that you could manufacture an option out of simpler ingredients, and so there was no way to figure out its fair price.

This discovery revolutionized modern finance. With their insight, Black and Scholes made formerly gourmet options into standard fare. Dealers could now manufacture and sell options on all sorts of underlying securities, creating the precise riskiness clients wanted without taking on the risk themselves. It was as though, in a thirsty world filled with hydrogen and oxygen, someone had finally figured out how to synthesize H_2O.

Dealers use the Black-Scholes model to manufacture (or synthesize, or financially engineer) the options they sell to their clients. They construct the option from shares of raw stock they buy in the market.

Conversely, they can deconstruct an option someone sells to them by converting it back into shares of raw stock that they then sell to the market. In this way, dealers mitigate their risk. (Since the Black-Scholes model is only a model, and since no model in finance is 100 percent correct, it is impossible for them to entirely cancel their risk.) Dealers charge a fee (the option premium) for this construction and deconstruction, just as chefs at fancy restaurants charge you not only for the raw ingredients but also for the recipes and skills they use, or as couturiers bill you for the materials and talents they employ in creating *haute couture* dresses.

LIFE AS A QUANT

The history of quants on Wall Street is the history of the ways in which practitioners and academics have refined and extended the Black-Scholes model. The last thirty years have seen it applied not just to stock options but to options on just about anything you can think of, from Treasury bonds and foreign exchange to the weather. Behind all these extensions is the same original insight: It is possible to tailor securities with the precise risk desired out of a mix of simpler ingredients using a recipe that specifies how to continually readjust their proportions. The readjustment depends on the exact way in which the ingredients' prices move.

Because bond prices don't move exactly like stock prices, the recipe for a bond option must differ from that of the classic Black-Scholes model. But this is a subtlety—when a new product is first created, a crude Black-Scholes-like model often suffices. Then, an arms race begins. As competitive pressures increase and spreads tighten, quants at different firms refine and extend their first pass at the model, adding new and more accurate descriptions of the motion of the ingredients and obtaining better recipes for the salad. Extending the model demands a grasp of financial theory, mathematics, and computing, and quants work at the intersection of these three disciplines.

The life of a practitioner quant in a trading business is quite different from that of a physicist. When, after years of physics research, I first came to work on Wall Street at the end of 1985, my new boss asked me to take a second pass at a problematic Black-Scholes-like model for bond options that he had built a year earlier. I started out slowly and carefully, working like a physicist; I read the relevant papers, learned the theory, diagnosed the problem, and began to rewrite the computer program that made the model work. After several weeks he became impatient with my lack of progress. "You know," he said a little sharply as he took me aside, "in this job you really need to know only four things: addition, subtraction, multiplication, and division—and most of the time you can get by without division!"

I took his point. Of course, the model used more advanced mathematics than arithmetic. Yet his insight was correct. The majority of options dealers make their living by manufacturing the products their clients need as efficiently as they can—that is, by providing service for a fee. For them, a simple, easy-to-understand model is more useful than a better, complicated one. Too much preoccupation with details that you cannot get right can be a hindrance when you have a large profit margin and you want to complete as many deals as possible. And often, it's hard to define exactly what constitutes a "better" model—controlled experiments in markets are rare. Though I did ultimately improve the model, the traders benefited most from the friendly user interface I programmed into it. This simple ergonomic change had a far greater impact on their business than the removal of minor inconsistencies; now they could handle many more client requests for business.

Although options theory originated in the world of stocks, it is exploited more widely in the fixed-income universe. Stocks (at least at first glance) lack mathematical detail—if you own a share of stock you are guaranteed nothing; all you really know is that its price may go up or down. In contrast, fixed-income securities such as bonds are ornate mechanisms that promise to spin off future periodic payments of interest and a final return of principal. This specification of detail makes fixed income a much more numerate business than equities, and one much more amenable to mathematical analysis. Every fixed-income security—bonds, mortgages, convertible bonds, and swaps, to name only a few—has a value that it depends on, and is therefore conveniently viewed as a derivative of the market's underlying interest rates. Interest-rate derivatives are naturally attractive products for corporations who, as part of their normal business, must borrow money by issuing bonds whose value changes when interest or exchange rates fluctuate. It is much more challenging to create realistic models of the movement of interest rates, which change in more complex ways than stock prices; interest-rate modeling has thus been the mother of invention in the theory of derivatives for the past twenty years. It is an area in which quants are ubiquitous.

In contrast, quants have been a rarer presence in the equity world. There, most investors are concerned with which stock to buy, a problem on which the advanced mathematics of derivatives can shed little light. Fixed income and equities have fundamentally different foci. When you walk around a frenetic fixed-income trading floor, you hear people shouting out numbers—yields and spreads—over the hoot-and-holler; on a busy equities floor, you mostly hear people shouting company names. Fixed-income trading requires a better grasp of technology and quantitative methods than equities trading. A trader friend of mine summed it up succinctly when, after I commented to him that the fixed-income traders I knew seemed smarter than the equity traders, he replied that "that's because there's no competitive edge to being smart in the equities business."

I don't mean to suggest that all quants work on the Black-Scholes model. Increasingly, some of them work on statistical arbitrage, the attempt to seek order and predictability in the patterns of past stock price movements and then exploit them—that is, to divine the future from the past. Hedge funds, private pools of capital that seek out subtle price discrepancies in odd and unexplored corners of markets, have become major employers of quants during the past five years, and continue to hire them to do "stat-arb."

Risk management is also in mode, and for good reason. A decade ago, in 1994, a sudden unexpected rise in global interest rates caused severe losses on many proprietary bond trading desks whose bets turned sour. This led banks to enlarge their previously rudimentary risk management efforts, and caused regulators of the securities industry to focus on risk limitation. Many quants now work within each investment bank's centralized-risk group, whose job it is to aggregate all the firm's positions and so estimate quantitatively the current risk and probable future losses. But probabilities are necessarily extracted from past events; they provide notoriously poor estimates of the likelihood of future catastrophes. Market crashes are not randomly occurring lightning bolts; they are the consequence of the madness of crowds who are busy avoiding the last mania as they participate in what will turn out to be the current one. Despite the losses of 1994, many firms again lost vast sums on their speculations during the worldwide withdrawal of credit following Russia's 1998 bond default. More and more, therefore, the market for quants is in risk monitoring and management.

THINKERS VERSUS DOERS

I didn't fully realize that the word *quant* had negative overtones until I leafed through a dictionary of finance terms several years ago and saw the entry "quant—often pejorative." Often is right. When I first came to work at Goldman, Sachs and Co. in 1985, I instantly noticed the shame involved in being numerate. Sometimes, talking in a crowded elevator to another quant, you might start to say something about the "duration" or "convexity" of a bond. These are relatively low-tech bond-math terms that describe the sensitivity of a bond's price to changes in interest rates. If the colleague you were talking to had been at the firm a little longer than you, then he—most quants are male—would shift uncomfortably and try to change the subject. "Futures dropped more than a handle today!" he might say, imitating the confident vernacular of a genuine bond trader. Soon, you began to realize, it was bad taste for two consenting adults to talk math or UNIX or C in the company of traders, salespeople, and bankers. People around you averted their gaze. There was something terminally awful about being outed.

Even in the mid-1990s geeks were fair game. One afternoon a colleague and I were standing on either side of one of the narrow aisles between the banks of trading desks on the floor when one of the chief traders walked between us, his head momentarily between ours. At that instant he winced, clutched his head with both hands as though in excruciating pain, and exclaimed, "Aaarrggh-hhh! The force field! It's too intense! Let me out of the way!" In the same vein, I lost count of the number of times some junior traders heading for lunch entered the elevator to see a group of quants standing there and then reflexively uttered some variant of "Uh-oh! Isn't there some rule against all of you getting in the elevator at once?"

Traders and quants are genuinely different species. Traders pride themselves on being tough and forthright while quants are more circumspect and reticent. These differences in personality are reflections of deeper cultural preferences. Traders are paid to act. All day long they watch screens, assimilate economic information, page frantically through spreadsheets, run programs written by quants, enter trades, talk to salespeople and brokers, and punch keys. It's hard to have an extended conversation with a trader during the business day; it takes an hour of standing around to have five minutes of punctuated repartee. Part of what traders do has a video game quality. In consequence, they learn to be opinionated, visceral, fast-thinking, and decisive, though not always right. They thrive on interruption.

Quants do not. Like academics trained in research, they prefer to do one thing from beginning to end, deeply and well. This is a luxury that is difficult to enjoy in the multitasking world of business, where you have to do many things simultaneously. When I moved to Wall Street, the hardest attitude adjustment for me was to learn to carry out multiple assignments in parallel, to interrupt one urgent and still incomplete task with another more pressing one, to complete that, and then pop the stack.

Traders and quants think differently, too. Good traders must be perpetually aware of the threat of change and what it will do to the value of their positions. Stock options in particular, because of their intrinsic asymmetry, magnify stock price changes and therefore suffer or benefit dramatically from even small moves. Quants think less about future change and more about current value. According to financial theory, at any instant the so-called fair value of a security is an average over the range of all its possible future values. Fair value and change are therefore two sides of the same coin; the more ways in which a security can lose value from a future market move, the less it should rationally be worth today, and hence the mantra: more risk, more return. This difference between the quant's view of value as an average versus the trader's need to worry about any change makes this kind of professional cross-communication difficult.

Tour de France cyclists don't need to know how to solve Newton's Laws in order to bank around a curve. Indeed, thinking too much about physics while cycling may prove a hindrance. Similarly, options traders need not be expert quants; they can leave the details of the recipe for manufacturing options to others as long as they have the patience to thoroughly understand how to use it and when to trust it, for no model is perfect. One trader I know used to say, "You can't give a person a Black-Scholes calculator and turn him into a trader," and this is true; it takes study, understanding, intuition, and a grasp of the limits of the model in order to trade wisely. You cannot just follow formulas, no matter how precise they appear to be.

A good quant must be a mixture, too—part trader, part salesperson, part programmer, and part mathematician. Many quants would like to cross over to become traders, but they face the formidable obstacles of scholarly backgrounds, introspective personalities, and hybrid skills.

One of the theories about what makes an animal nonkosher is that it transcends categories. In the book of Genesis, the creation categorizes animals by both their species and location, referring to "birds of the sky" and "fish of the sea." Occupying both categories is what makes some animals nonkosher. Shrimp, for example, live in the sea but aren't fish and don't swim. Ostriches are birds, but do not fly in the sky. Both are nonkosher. Similarly, cloth made from a mixture of linen (a plant) and wool (an animal product) is also proscribed. Those who were brought up keeping kosher can feel nauseated at the thought of eating category-violating food.

Quants are the nonkosher category violators of Wall Street, half-breed players who make pure traders or undiluted information technology managers uncomfortable. Quants are amateurs with no clear professional role model. While traders and programmers in investment banks have distinct ladders to climb and clearly marked rungs to ascend, the quant professional ladder is short and often ends in midair.

Nevertheless, in the twenty-first century, as universities have initiated financial engineering programs and financial institutions have embraced risk management, being a quant has slowly become a more legitimate profession. The overheated tech-stock market of the late 1990s cast a warm, reflected glow on geeks of all types, as did the droves of hedge funds trying to use mathematical models to squeeze dollars out of subtleties. The guts to lose a lot of money carries its own aura. D.E. Shaw & Co., a New York trading house that was rumored to be making substantial profits doing "black box" computerized statistical arbitrage before their billion-dollar losses in 1998, and Long Term Capital Management, the quant-driven Connecticut hedge fund that ultimately needed a multibillion-dollar bailout, have both contributed to this more glamorous view of quantization. And indeed, many of the Long Term Capital protagonists are back in business again at new firms. The capacity to wreak destruction with your models provides the ultimate respectability.

THE SACRED AND PROFANE

There is an almost religious quality to the pursuit of physics that stems from its transcendent qualities. How *does* a planet know that it must obey Newton's Laws, or an electron perceive that it must move according to the principles of quantum electrodynamics? Do tiny internal homunculi program internal nanocomputers to spit out the electron's next position? It's hard not to have a sense of wonder when you see that principles, imagination, and a little mathematics—in a word, the mind—can divine the the behavior of the universe. Short of genuine enlightenment, nothing but art comes closer to God.

When I was a graduate student at Columbia in the 1970s, physics was the great attractor for the aspiring scientists of the world. Bearing witness to this was the large box of documents kept near the entrance to the physics department library. We referred to it as the "crank file." The box contained the unsolicited typewritten letters, manuscripts, and appeals that poured steadily into the mailbox of the department's chairman. Eccentric though the documents were, they made fascinating reading. There were eager speculations on the nature of space and time, elaborately detailed papers refuting relativity and quantum mechanics, grandiose claims to have unified them, and farfetched meditations that combined physics with more metaphysical topics. I remember one note that tried to deduce the existence of God from the approximate equality of the solid angles subtended by the sun and the moon when observed from the earth, a remarkable circumstance without which there would be no solar eclipses.

None of these papers had much chance of getting past a journal referee. Few of the writers had much hope of even getting into graduate school. They may not have wanted to. The letters were mostly a *cri de cœur* from isolated and solitary physicist manqués all over the world.

Most of my classmates laughed at the naiveté of the letter writers, but as I skimmed through the crank file I found it hard to feel superior. Instead, peering into the box of manuscripts, I always saw my pale reflection. Out there, beyond academia and industry, were people like us, similarly in thrall to the same sense of mystery and power that lay behind the attempt to understand and master the universe with only imagination and symbols. They were cranks, those letter writers, but they were also genuine amateurs, lovers of the field interested in wisdom and magic rather than money.

There are amateurs in the financial modeling world, too, but they often come in more mercenary flavors, and why not? Because I used to run a group called Quantitative Strategies at Goldman Sachs for many years, after a while almost any letter from the outside world addressed to the "Quantitative Something-or-Other" at Goldman found its way to me. Once every few months I received a note from someone isolated and far away who thought he or she had made some great breakthrough in financial theory. Often, they would explain, it was a breakthrough whose exact details they were unwilling to divulge without being given a contract promising them a share of the future profits they were certain its use would guarantee. I sympathized with them. They, too, believed in the power of imagination.

Theoretical physicists are accustomed to the success of mathematics in formulating the laws of the universe and elaborating their consequences. The universe does indeed seem to run like some splendid Swiss clockwork: We can predict the orbits of planets and the frequency of light emitted by atoms to eight or ten decimal places. But when a physicist first pages through a graduate economics or finance textbook, he or she begins to feel aghast. The mathematics of economics is so much more formal than the mathematics of physics textbooks—much of it reads like Euclid or set theory, replete with axioms, theorems, and lemmas. You would think that all this formality would produce precision. And yet, compared with physics, economics has so little explanatory or predictive power. Everything looks suspect; questions abound.

When physicists pursue the laws of the universe, it seems selfless. But watching quants pursue sacred laws for the profane production of profit, I sometimes find myself thinking disturbingly of worshippers at a black mass. What does it signify to use the methods of physics and the language of mathematics to model the economic world? Is it justifiable to treat the economy and its markets as a complex machine? How can traders put their faith in this stuff? Isn't value determined by people? And how can people be described by equations and predetermined rules? Isn't this endeavor the misguided consequence of some sort of physics envy, an inappropriate attempt to model messy human systems with the wrong paradigm? Is social science, as the economic historian Robert Skidelsky once observed, merely a compendium of flawed thinking disguised as scientific understanding? If mathematics is the Queen of Sciences, is quantitative finance a science at all? And finally, are quants scientists or cranks?

This book is an account of my experiences as a scientist, quant, and, on occasion, a fellow traveler of cranks.