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INSIDE THE BLACK BOX

The Simple Truth About Quantitative Trading

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Inside the Black Box

The Simple Truth About Quantitative Trading

RISHI K NARANG

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This book is dedicated to my father and mother, Thakur and Krishna Narang, to whom I owe so much and to my wife and partner of many years, Carolyn Wong, whose love and support make a hell of a lot of things really a lot better.

Preface

An unnecessary opaqueness surrounds quantitative trading strategies (known to many as *black boxes* despite their importance to the capital markets and the sensational, widely known examples of the successes and failures. This opaqueness, which quants themselves frequently perpetuate, exacerbat an already widespread misunderstanding of quantitative trading in the broader investment communit

This book takes you on a tour through the black box, inside and out. It sheds light on the work th quants do, lifting the veil of mystery that surrounds quantitative trading and allowing those interest in doing so to evaluate quants and their strategies.

The first thing that should be made clear is that people, not machines, are responsible for most the interesting aspects of quantitative trading. Quantitative trading can be defined as the systemat implementation of trading strategies that human beings create through rigorous research. In th context, *systematic* is defined as a disciplined, methodological, and automated approach. Despite th talk of automation and systematization, *people* conduct the research and decide what the strategi will be, *people* select the universe of securities for the system to trade, and *people* choose what data procure and how to clean those data for use in a systematic context, among a great many other thing These people, the ones behind quant trading strategies, are commonly referred to as *quants* or *qua traders*.

Quants employ the scientific method in their research. Though this research is aided by technolog and involves mathematics and formulae, the research process is thoroughly dependent on huma decision making. In fact, human decisions pervade nearly every aspect of the design, implementatio and monitoring of quant trading strategies. As it turns out, quant strategies and tradition discretionary investment strategies, which rely on human decision makers to manage portfolios day day, are rather similar in what they do.

The differences between a quant strategy and a discretionary strategy can be seen in *how* th strategy is created and in *how* it is implemented. By carefully researching their strategies, quants a able to assess their ideas the same way that scientists test theories. Furthermore, by utilizing computerized, systematic implementation, quants eliminate the arbitrariness that pervades so mar discretionary trading strategies. In essence, decisions driven by emotion, indiscipline, passion, gree and fear—what many consider the key pratfalls of "playing the market"—are eliminated from th quant's investment process. They are replaced by an analytical and systematic approach that borrow from the lessons learned in so many other fields: If something needs to be done repeatedly and with great deal of discipline, computers will virtually always outshine humans. We simply aren't cut ou for repetition in the way that computers are, and there's nothing wrong with that. Computers, after al aren't cut out for creativity the way we are; without humans telling computers what to do, compute wouldn't do much of anything. The differences in how a strategy is designed and implemented play large part in the consistent, favorable risk/reward profile a well-run quant strategy enjoys relative most discretionary strategies.

To clarify the scope of this book, it is important to note that I focus on "alpha"-oriented strategi and largely ignore quantitative index traders or other implementations of "beta" strategies. *Alph*

strategies attempt to generate returns by skillfully timing the selection and/or sizing of vario portfolio holdings; *beta strategies* mimick or slightly improve on the performance of an index, such the S&P 500. Though quantitative index fund management is a large industry, it requires litt explanation. Neither do I spend much time on the field of financial engineering, which typically pla a role in creating or managing new financial products (e.g., CDOs). Nor do I address quantitati analysis, which typically supports discretionary investment decisions. Both of these are interesti subjects, but they are so different from quant trading as to be deserving of their own, separa discussions carried out by experts in those fields.

This book is divided into three parts. Part One (Chapters 1 and 2) provides a general but usef background on quantitative trading. Part Two (Chapters 3 through 9) details the contents of the bla box. Part Three (Chapters 10 through 13) provides an analysis of quant trading and techniques th may be useful in assessing quant traders and their strategies.

It is my aspiration to explain quant trading in an intuitive manner. I describe what quants do a how they do it by drawing on the economic rationale for their strategies and the theoretical basis f their techniques. Equations are avoided, and the use of jargon is limited and explained, when requir at all. My aim is to demonstrate that what many call a black box is in fact transparent, intuitive sensible, and readily understandable. I also explore the lessons that can be learned from quant tradi about investing in general and how to evaluate quant trading strategies and their practitioners. As result, *Inside the Black Box* may be useful for a variety of participants in and commentators on t capital markets. For portfolio managers, analysts, and traders, whether quantitative or discretiona this book will help contextualize what quants do, how they do it, and why. For investors, the financi media, or anyone with a reasonable knowledge of capital markets in general, this book will engende deeper understanding of this niche.

RISHI K NARANG

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Finance or Bloomberg, unless otherwise noted.

One

The Quant Universe

CHAPTER 1

Why Does Quant Trading Matter?

Look into their minds, at what wise men do and don't.

—Marcus Aurelius, Meditations

John is a quant trader running a midsized hedge fund. He completed an undergraduate degree mathematics and computer science at a top school in the early 1990s. John immediately starte working on Wall Street trading desks, eager to capitalize on his quantitative background. After seve years on the Street in various quant-oriented roles, John decided to start his own hedge fund. Wi partners handling business and operations, John was able to create a quant strategy that recently w trading over $1.5 billion per day in equity volume. More relevant to his investors, the strategy mad money on 60 percent of days and 85 percent of months—a rather impressive accomplishment.

Despite trading billions of dollars of stock every day, there is no shouting at John's hedge fund, n orders being given over the phone, and no drama in the air; in fact, the only sign that there is an trading going on at all is the large flat-screen television in John's office that shows the strategy performance throughout the day and its trading volume. John can't give you a fantastically interestin story about why his strategy is long this stock or short that one. While he is monitoring his universe thousands of stocks for events that might require intervention, for the most part he lets the automate trading strategy do the hard work. What John monitors quite carefully, however, is the health of h strategy and the market environment's impact on it. He is aggressive about conducting research on a ongoing basis to adjust his models for changes in the market that would impact him.

Across from John sits Mark, a recently hired partner of the fund who is researching high-frequenc trading. Unlike the firm's first strategy, which only makes money on 6 out of 10 days, the high frequency efforts Mark and John are working on target a much more ambitious task: looking f smaller opportunities that can make money every day. Mark's first attempt at high-frequenc strategies already makes money nearly 95 percent the time. In fact, their target for this high-frequenc business is even loftier: They want to replicate the success of those firms whose trading strategi make money every hour, maybe even every minute, of every day. Such high-frequency strategies can accommodate large investments, because the opportunities they find are small, fleeting. Nonetheles they are highly attractive for whatever capital they can accommodate. Within their high-frequenc

trading business, John and Mark expect their strategy to generate at least 200 percent a year, possib
much more.

There are many relatively small quant trading boutiques that go about their business quietly,
John and Mark's firm does, but that have demonstrated top-notch results over reasonably long period
For example, Quantitative Investment Management of Charlottesville, Virginia, averaged over 2
percent per year for the 2002-2008 period—a track record that many discretionary managers wou
envy.[1]

On the opposite end of the spectrum from these small quant shops are the giants of quant investin
with which many investors are already quite familiar. Of the many impressive and successf
quantitative firms in this category, the one widely regarded as the best is Renaissance Technologie
Renaissance, the most famous of all quant funds, is famed for its 35 percent average yearly retur
(after exceptionally high fees), with extremely low risk, since 1990. In 2008, a year in which ma
hedge funds struggled mightily, Renaissance's flagship Medallion Fund gained approximately 8
percent.[2] I am personally familiar with the fund's track record, and it's actually gotten better as tim
has passed—despite the increased competition and potential for models to "stop working."

Not all quants are successful, however. It seems that once every decade or so, quant traders cause-
or at least are perceived to cause—markets to move dramatically because of their failures. The mo
famous case by far is, of course, Long Term Capital Management (LTCM), which nearly (but for th
intervention of Federal Reserve banking officials and a consortium of Wall Street banks) brought th
financial world to its knees. Although the world markets survived, LTCM itself was not as lucky. Th
firm, which averaged 30 percent returns after fees for four years, lost nearly 100 percent of its capit
in the debacle of August-October 1998 and left many investors both skeptical and afraid of qua
traders (although it is debatable whether this was a quant trading failure or a failure of huma
judgment in risk management, and it's questionable whether LTCM was even a quant trading firm
all).

Not only have quants been widely panned because of LTCM, but they have also been blame
(probably unfairly) for the crash of 1987 and (quite fairly) for the eponymous quant liquidation
2007, the latter having severely impacted many quant shops. Even some of the largest names in qua
trading suffered through August 2007's quant liquidation. For instance, Goldman Sachs' largel
quantitative Global Alpha Fund was down an estimated 40 percent in 2007 after posting a 6 perce
loss in 2006.[3] In less than a week during August 2007, many quant traders lost between 10 and 4
percent in a few days, though some of them rebounded strongly for the remainder of the month.

Spectacular success and failure aside, there is no doubt that quants cast an enormous shadow on th
trading marketplace virtually every trading day. Across U.S. equity markets, a significant, and rapidl
growing, proportion of all trading is done through algorithmic execution, one footprint of qua
strategies. (*Algorithmic execution* is the use of computer software to manage and "work" an investor
buy and sell orders in electronic markets.) Although this automated execution technology is not th
exclusive domain of quant strategies—any trade that needs to be done, whether by an index fund or
discretionary macro trader, can be worked using execution algorithms—certainly a substantial portio
of all algorithmic trades are done by quants. Furthermore, quants were both the inventors of, an
primary innovators of, algorithmic trading engines. A mere five such quant traders account for about
billion shares of volume *per day*, in aggregate, in the United States alone. It is worth noting that n

one of these is well known to the broader investing public. The TABB Group, a research and advisor firm focused exclusively on the capital markets, estimates that, in 2008, approximately 58 percent all buy-side orders were algorithmically traded. TABB also estimates that this figure has grown som 37 percent per year, compounded, since 2005. More directly, the Aite Group published a study in earl 2009 indicating that more than 60 percent of all US equity transactions are attributable to short ter quant traders.[4] These statistics hold true in non-U.S. markets as well. Black-box trading accounted f 45 percent of the volume on the European Xetra electronic order-matching system in the first quart of 2008, which is 36 percent more than it represented a year earlier.[5]

The large presence of quants is not limited to equities. In futures and foreign exchange markets, th domain of commodity trading advisors (CTAs), there is a significant presence of quants. The Barcla Group, proprietor of the most comprehensive commercially available database of CTAs and CT performance, estimates that well over 85 percent of the assets under management among all CTAs ar managed by quantitative trading firms. Although a great many of the largest and most establishe CTAs (and hedge funds generally) do not report their assets under management or performanc statistics to any database, a substantial portion of these firms are actually quants also, and it is like that the "real" figure is still over 75 percent. As of the end of the third quarter of 2008, the amount quantitative futures money under management, including only the firms that report to Barclay, wa $227.0 billion.

It is clear that the magnitude of quant trading among hedge funds is substantial. Hedge funds a private investment pools that are accessible only to sophisticated, wealthy individual or institution clients. They can pursue virtually any investment mandate one can dream up, and they are allowed keep a portion of the profits they generate for their clients. But this is only one of several arenas which quant trading is widespread. Proprietary trading desks at the various banks, boutiqu proprietary trading firms, and various "multistrategy" hedge fund managers who utilize quantitativ trading for a portion of their overall business each contribute to a much larger estimate of the size the quant trading universe.

With such size and extremes of success and failure, it is not surprising that quants take their shar of headlines in the financial press. And though most press coverage of quants seems to be marked negative, this is not always the case. In fact, not only have many quant funds been praised for the steady returns (a hallmark of their disciplined implementation process), but some experts have eve argued that the existence of successful quant strategies improves the marketplace for all investor regardless of their style. For instance, Reto Francioni (chief executive of Deutsche Boerse AG, whic runs the Frankfurt Stock Exchange) said in a speech that algorithmic trading "benefits all mark participants through positive effects on liquidity." Francioni went on to reference a recent academ study showing "a positive causal relationship between algo trading and liquidity."[6] Indeed, this almost guaranteed to be true. Quant traders, using execution algorithms (hence, "algo trading" typically slice their orders into many small pieces to improve both the cost and efficiency of th execution process. As mentioned before, although originally developed by quant funds, thes algorithms have been adopted by the broader investment community. By placing many small order other investors who might have different views or needs can also get their own executions improved.

Quants typically make markets more efficient for other participants by providing liquidity whe other traders' needs cause a temporary imbalance in the supply and demand for a security. Thes imbalances are known as "inefficiencies," after the economic concept of "efficient markets." Tru

inefficiencies (such as an index's price being different from the weighted basket of the constituents
the same index) represent rare, fleeting opportunities for riskless profit. But riskless profit,
arbitrage, is not the only—or even primary—way in which quants improve efficiency. The ma
inefficiencies quants eliminate (and, thereby, profit from) are not absolute and unassailable but rath
probabilistic and requiring risk taking.

A classic example of this is a strategy called *statistical arbitrage*, and a classic statistical arbitra
example is a *pairs trade*. Imagine two stocks with similar market capitalizations from the sa
industry and with similar business models and financial status. For whatever reason, Company A
included in a major market index, an index that many large index funds are tracking. Meanwhil
Company B is not included in any major index. It is likely that Company A's stock will subsequentl
outperform shares of Company B simply due to a greater demand for the shares of Company A fro
index funds, which are compelled to buy this new constituent in order to track the index. Th
outperformance will in turn cause a higher P/E multiple on Company A than on Company B, which
a subtle kind of inefficiency. After all, nothing in the fundamentals has changed—only the nature
supply and demand for the common shares. Statistical arbitrageurs may step in to sell shares
Company A and buy shares of Company B, thereby preventing the divergence between these tw
fundamentally similar companies from getting out of hand while improving efficiency in mark
pricing.

This is not to say that quants are the only players who attempt to profit by removing mark
inefficiencies. Indeed, it is likely that any alpha-oriented trader is seeking similar sorts of dislocatio
as sources of profit. And of course, there are times, such as August 2007, when quants actually cau
the markets to be *less* efficient. Nonetheless, especially in smaller, less liquid, and more neglecte
stocks, statistical arbitrage players are often major providers of market liquidity and help establi
efficient price discovery for all market participants.

So, what can we learn from a quant's approach to markets? The three answers that follow represe
important lessons that quants can teach us—lessons that can be applied by any investment manager.

THE BENEFIT OF DEEP THOUGHT

According to James Simons, the founder of the legendary Renaissance Technologies, one of th
greatest advantages quants bring to the investment process is their systematic approach to proble
solving. As Dr. Simons puts it, "The advantage scientists bring into the game is less the
mathematical or computational skills than their ability to think scientifically."[7]

The first reason it is useful to study quants is that they are forced to think deeply about ma
aspects of their strategy that are taken for granted by nonquant investors. Why does this happe
Computers are obviously powerful tools, but without absolutely precise instruction, they can achie
nothing. So, to make a computer implement a "black-box trading strategy" requires an enormo
amount of effort on the part of the developer. You can't tell a computer to "find cheap stocks." Yo
have to specify what *find* means, what *cheap* means, and what *stocks* are. For example, *finding* mig
involve searching a database with information about stocks and then ranking the stocks within
market sector (based on some classification of stocks into sectors). *Cheap* might mean P/E ratio

though one must specify both the metric of cheapness and what level will be considered cheap. A such, the quant can build his system so that cheapness is indicated by a 10 P/E or by those P/Es th rank in the bottom decile of those in their sector. And *stocks*, the universe of the model, might be a U.S. stocks, all global stocks, all large cap stocks in Europe, or whatever other group the quant wan to trade.

All this defining leads to a lot of deep thought about exactly what one's strategy is, how implement it, and so on. In the preceding example, the quant doesn't have to choose to rank stoc within their sectors. Instead, stocks can be compared to their industry peers, to the market overall, to any other reasonable group. But the point is that the quant is encouraged to be intentional abo these decisions by virtue of the fact that the computer will not fill in any of these blanks on its own.

The benefit of this should be self-evident. Deep thought about a strategy is usually a good thin Even better, this kind of detailed and rigorous working out of how to divide and conquer the proble of conceptualizing, defining, and implementing an investment strategy is useful to quants an discretionary traders alike. These benefits largely accrue from thoroughness, which is generally he to be a key ingredient to investment or trading success. By contrast, many (though certainly not al discretionary traders, because they are not forced to be so precise in the specification of their strateg and its implementation, seem to take a great many decisions in an *ad hoc* manner. I have been countless meetings with discretionary traders who, when I asked them how they decided on the siz of their positions, responded with variations on the theme of, "Whatever seemed reasonable." This by no means a damnation of discretionary investment styles. I merely point out that precision an deep thought about many details, in addition to the bigger-picture aspects of a strategy, can be a goo thing, and this lesson can be learned from quants.

THE MEASUREMENT AND MISMEASUREMENT OF RISK

As mentioned earlier in this chapter, the history of LTCM is a lesson in the dangers of mismeasurin risk. Quants are naturally predisposed toward conducting all sorts of measurements, including of ris exposure. This activity itself has potential benefits and downsides. On the plus side, there is a certa intentionality of risk taking that a well-conceived quant strategy encourages. Rather than acceptin accidental risks, the disciplined quant attempts to isolate exactly what his edge is and focus his ris taking on those areas that isolate this edge. To root out these risks, the quant must first have an idea what these risk are and how measure them. For example, most quant equity traders, recognizing th they do not have sufficient capabilities in forecasting the direction of the market itself, measure the exposure to the market (using their net dollar or beta exposure, commonly) and actively seek to lim this exposure to a trivially small level by balancing their long portfolios against their short portfolio On the other hand, there are very valid concerns about false precision, measurement error, an incorrect sets of assumptions that can plague attempts to measure risk and manage it quantitatively.

All the blowups we have mentioned, and most of those we haven't, stem in one way or another fro this overreliance on flawed risk measurement techniques. In the case of LTCM, for exampl historical data showed that certain scenarios were likely, others unlikely, and still others had simpl never occurred. At that time, most market participants did not expect that a country of Russia

importance, with a substantial supply of nuclear weapons and materials, would go bankrupt. Nothi
like this had ever happened before. Nevertheless, Russia indeed defaulted on its debt in the summer
1998, sending the world's markets into a frenzy and rendering useless any measurement of risk. Th
naïve overreliance on quantitative measures of risk, in this case, led to the near-collapse of t
financial markets in the autumn of 1998. But for a rescue orchestrated by the U.S. government a
agreed on by most of the powerhouse banks on Wall Street, we would have seen a very different pa
unfold for the capital markets and all aspects of financial life.

Indeed, the credit debacle that began to overwhelm markets in 2007 and 2008, too, was like
avoidable. Banks relied on credit risk models that simply were unable to capture the risks correct
and in many cases seem to have done so knowingly, because it enabled them greedily to pursu
outsized short-term profits (and, of course, bonuses for themselves). It should be said that most
these mismeasurements could have been avoided, or at least the resulting problems mitigated, by t
application of better judgment on the part of the practitioners who relied on them. Just as one cann
justifiably blame weather-forecasting models for the way that New Orleans was impacted b
Hurricane Katrina in 2005, it would not make sense to blame quantitative risk models for the failur
of those who created and use them. Traders can benefit from engaging in the exercise of understandi
and measuring risk, so long as they are not seduced into taking ill-advised actions as a result.

DISCIPLINED IMPLEMENTATION

Perhaps the most obvious lesson we can learn from quants comes from the discipline inherent to the
approach. Upon designing and rigorously testing a strategy that makes economic sense and seems
"work," a properly run quant shop simply tends to let the models run without unnecessary, arbitra
interference. In many areas of life, from sports to science, the human ability to extrapolate, infe
assume, create, and learn from the past is beneficial in the planning stages of an activity. B
execution of the resulting plan is also critical, and it is here that humans frequently are found to b
lacking. A significant driver of failure is a lack of discipline.

Many successful traders subscribe to the old trading adage, "Cut losers and ride winners." Howeve
discretionary investors often find it very difficult to realize losses, whereas they are quick to reali
gains. This is a well-documented behavioral bias known as the *disposition effect*.[8] Computer
however, are not subject to this bias. As a result, a trader who subscribes to the aforementioned adag
can easily program his trading system to behave in accordance with it every time. This is not becau
the systematic trader is somehow a better person than the discretionary trader, but rather because th
systematic trader is able to make this "rational" decision at a time when there is no pressure, thereb
obviating the need to exercise discipline at a time when most people would find it extraordinari
challenging. Discretionary investors can learn something about discipline from those who make
their business.

SUMMARY