151 Trading Strategies

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ZK: To my mother Mila and my children Mirabelle and Maximilien

JAS: To my parents, Claudio and Andrea, and my brother Emiliano

Abstract

We provide detailed descriptions, including over 550 mathematical formulas, for over 150 trading strategies across a host of asset classes (and trading styles). This includes stocks, options, fixed income, futures, ETFs, indexes, commodities, foreign exchange, convertibles, structured assets, volatility (as an asset class), real estate, distressed assets, cash, cryptocurrencies, miscellany (such as weather, energy, inflation), global macro, infrastructure, and tax arbitrage. Some strategies are based on machine learning algorithms (such as artificial neural networks, Bayes, k-nearest neighbors). We also give: source code for illustrating out-of-sample backtesting with explanatory notes; around 2,000 bibliographic references; and over 900 glossary, acronym and math definitions. The presentation is intended to be descriptive and pedagogical.

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Praises of *151 Trading Strategies*

"If you want to work as a trader or quant on Wall Street, you have to walk the walk and talk the talk. This unique book is a comprehensive introduction to a wide variety of tried and tested trading strategies. I highly recommend a 152nd trading strategy called buy this book!"

–**Peter Carr**, Professor and Chair of Finance and Risk Engineering Department, NYU's Tandon School of Engineering; and 2010 Financial Engineer of the Year, International Association for Quantitative Finance & Sungard

"This book is an encyclopedic guided tour of "quant" investment strategies, from the simplest ones (like trend following) to much more exotic ones using sophisticated derivative contracts. No claim is made about the profitability of these strategies: one knows all too well how much implementation details and transaction costs matter. But no quant trader can afford ignoring what's out there, as a source of inspiration or as a benchmark for new ideas."

–**Jean-Philippe Bouchaud**, Chairman and Chief Scientist, Capital Fund Management; Professor, École Normale Supérieure; Member, French Academy of Sciences; and Co-Director, CFM-Imperial Institute of Quantitative Finance

"Zura Kakushadze and Juan Andrés Serur have created a masterful encyclopedia of quantitative trading strategies. The authors offer us a rigorous but accessible treatment of the mathematical foundations of these strategies. The coverage is comprehensive, starting with simple and well-known strategies such as covered call and then moving naturally to strategies involving cryptocurrencies. The supporting material such as a detailed glossary and an extensive list of references will make this book an essential reference for financial economists and investment professionals."

–**Hossein Kazemi**, Michael & Cheryl Philipp Endowed Professor of Finance, University of Massachusetts at Amherst; and Editor-in-Chief, *The Journal of Alternative Investments*

"The successful trading of financial instruments is both a science and an art, just as the efforts of a chef reflect both gastronomic artistry and the underlying chemical and thermal processes of cooking. In *151 Trading Strategies* financial traders are provided with a compendium of sound recipes, spanning the broad range of methods that can be applied to modern investment practice. The exposition of both the mathematics and intuition of each described trade is clear and concise. Readers will appreciate the inclusion of extensive computer code so as to reduce effort needed to implement any required calculations."

–**Dan diBartolomeo**, President, Northfield Information Services; and Editor, *Journal of Asset Management*

"A real tour de force–*151 Trading Strategies* provides the most comprehensive un-

covering of popular hedge fund strategies. By revealing all the hedge funds' secret sauce, Kakushadze and Serur have now rendered everything as beta-strategies. Time to lower 'em fees!"

–**Jim Kyung-Soo Liew**, Assistant Professor of Finance, Carey Business School, Johns Hopkins University; Advisory Board Member, *The Journal of Portfolio Management*; and Co-Founder, SoKat

"This book is an impressive concentration of strategies and formulas to expand knowledge in quantitative finance; it's a must-read for anyone who wants to drastically improve his or her expertise in financial markets dynamics."

–**Daniele Bernardi**, CEO, DIAMAN Capital; and Chairman of the Board, *INVESTORS' Magazine Italia*

Author Biographies

Zura Kakushadze received his Ph.D. in theoretical physics from Cornell University, USA at 23, was a Postdoctoral Fellow at Harvard University, USA and an Assistant Professor at C.N. Yang Institute for Theoretical Physics at Stony Brook University, USA. He received an Alfred P. Sloan Foundation Fellowship in 2001. After expanding into quantitative finance, he was a Director at RBC Capital Markets, Managing Director at WorldQuant, Executive Vice President and substantial shareholder at Revere Data (now part of FactSet), and Adjunct Professor at the University of Connecticut, USA. Currently he is the President and CEO of Quantigic® Solutions and a Full Professor at Free University of Tbilisi, Georgia. He has over 17 years of hands-on experience in quantitative trading and finance, 130+ publications in physics, finance, cancer research and other fields, 3,400+ citations and h-index 30+, 170,000+ downloads on SSRN, and over a quarter million followers on LinkedIn.

Juan Andrés Serur holds a Master's Degree in Finance from the University of CEMA, Argentina. With more than 6 years of experience in trading in the stock market, he currently works as a quantitative analyst and strategist in an Argentine quantitative asset management firm and as a financial consultant for large corporations. In addition, he serves as the Academic Secretary of the Master of Finance Program at the University of CEMA, where he teaches undergraduate and postgraduate computational finance courses as an Assistant Professor. In 2016 he won the First Prize in an Argentine Capital Markets Simulation Challenge for Universities and Professional Institutions.

Preface (by Zura Kakushadze)

The purpose of this "post-factum" Preface is to give some history, which sheds light on why we (the authors) have decided to make this book, which has been published in hardcover (and as an e-book),[4] into a freely downloadable PDF e-book on SSRN.

In December of 2015 I posted the paper "101 Formulaic Alphas" on SSRN [Kakushadze, 2016], which provides explicit formulas (that are also computer source code) for 101 real-life formulaic quantitative trading alphas. That paper was a hit – in hindsight, perhaps unsurprisingly, considering how secretive quant trading is.

So, at some point down the road, a light bulb went on in my head and I got this seemingly "crazy" idea to write a paper entitled "101 Trading Strategies", except that this time these 101 strategies would be spread across all asset classes (as opposed to equities (StatArb) quant trading alphas as in "101 Formulaic Alphas"). I did not envision this as a book, just as a paper, maybe 100+ pages long, 1 page per strategy on average, plus overhead (introduction, references, etc.), something publishable in a journal (at least online). I also thought it would be both fun and efficient to get around 10-12 coauthors together, each would contribute about 10 strategies in one or two asset classes according to their fields of expertise, so the project would go faster. So, I pinged my contacts by email and posted several posts in the LinkedIn feed and groups saying that I was looking for collaborators for this project. I got a rather decent number of responses, some evidently were not serious, but some were.

However, once I outlined in more detail what I had in mind for this project – I had a written plan – apparently people realized that this would not be a cakewalk, and most disappeared. As it turned out, the only person who was truly serious about this project was Juan Andrés Serur, a young professor from Buenos Aires, Argentina, whom I had never even met in person. There were a lot of challenges along the way (including that Juan had never worked on a project of this magnitude and was learning on the job, so to speak). But at the end we got through it. Except that we did not have just 100+ pages with 101 strategies but over 350 pages with around 160-170 strategies (depending on how one counts). This was not publishable in any journal, by any stretch. This project basically had taken on a life of its own and turned into... a book. So, we discussed it and decided to publish it as such.

Publishing a quant trading/finance book such as "151 Trading Strategies" is not a very rewarding business (at least financially), for several reasons. First, the target audience is rather limited because of the highly technical nature of the material. In my original exploratory call with them, the publisher mentioned that books like this sell around 1,000 copies total. This was consistent with what I was told by someone who is well-known in the field and had published 5 quant trading/finance books over the years, which had sold around 5,000 copies altogether. Second, if the book is published by a major publisher, the authors get dismal royalties, usually in the 8-12% range, which can go to around 20% if the book sells better than

[4] Z. Kakushadze and J.A. Serur. *151 Trading Strategies.* Cham, Switzerland: Palgrave Macmillan, an imprint of Springer Nature, 1st Edition (2018), XX, 480 pp; ISBN 978-3-030-02791-9.

expected. At \$60-\$70 for a hardcover, your book has to sell 100,000+ copies for you to make any decent money so it is a least somewhat commensurate with the time you spend on writing the book – this book took about 9 months to write, not including the time I spent on it before drafting started (conceiving it, looking for coauthors, etc.) or the time spent dealing with the publisher, advertising it, etc. Third, this particular publisher does not publish paperbacks as a matter of some policy I do not comprehend, and when the price is set around \$60-\$70 for a hardcover, the pool of potential buyers is dramatically reduced compared with a \$20-\$30 price point a paperback would have. Fourth, there are plenty of people working in quant trading/finance who can easily afford \$60-\$70, but many of these people – not to offend anyone – would rather download a pirated PDF copy from the internet... Fifth, the publisher's business model appears to be immune to the fact that they cannot make much money from hardcover sales. Instead, their business model appears to hinge on e-book downloads through their existing (institutional) subscriptions: a subscriber, who pays a subscription fee, can freely download any book from the publisher's portfolio. So, the success of a book is measured by e-book downloads by subscribers, not by hardcover sales, and the authors do not get paid per download, they only get paid a very symbolic (mildly put) flat fee irrespective of the number of such downloads. The bottom line is that there is no money to be made in this business for the authors. We were well-aware of this from the get-go. We did not publish this book for money – originally, it was going to be a paper.

What is worse though is that, unlike in the olden days when editors would read every word of your manuscript and mark it up so it could be improved, etc., nowadays there appears to be little to no editorial support. We wrote the manuscript in LaTeX (as there are over 550 elevated equations in the book, not counting inline math), we created the index ourselves (which is a major pain and very time-consuming, if done right; in fact, it is probably the single worst part of writing a book), and proofread the manuscript several times to the point where upon the final proofreading right before printing we found only 5 minor typos attributable to our original manuscript. The bottom line is that we spent a lot of time perfecting our manuscript and it was very much print-ready. However, things got really messy on the publisher's end.

The nightmare started with the book cover. The publisher ask me if I had any concrete ideas for how I wanted the cover designed, and if I had a specific cover image in mind and to feel free to send along some images from Getty and Alamy (the image providers the publisher uses). I was taken aback. They keep almost all the profits and they ask me for the cover design? If we have to design our own cover, then we might as self-well publish and keep most royalties. I told them to design the cover professionally, as this was their responsibility. Their so-called "designs" they forwarded were highly unimpressive (just really super-minimalist – mildly put). So, I ended up designing the cover myself, including picking the cover image from the library of thousands of available images, placing the title and author names on the cover, etc. Their "design team" used my cover design and the only "substantial" change they made was changing the color of the title fonts to (in my

humble opinion) suboptimal white – the publisher said they could not accommodate the color I suggested. So, imagine how appalled and taken aback I was when in the ready-to-publish final book version, on the copyright page, they put some name for the cover design credit, and did not even mention mine. They said the cover design "is theirs", apparently referring to their "design team". This was just factually false. But we did not wish to appear "difficult" or "unaccommodating", so we let this go.

However, the nightmare continued with author biographies on an inside flap of the dust jacket. They asked us to provide our headshots. We did. At least three times they produced the author biographies with one of the headshots sizably larger than the other, even though we provided identically sized headshots. Worse yet, they claimed that the headshots on the dust jacket were the same size when they clearly were not. So, again, not to appear "difficult" or "unaccommodating", having wasted an inordinate amount of time on this, we let them leave our headshots out of the inside flap as their "design team" either could not or would not get them right.

Little did we know that this was only the tip of the iceberg. When we finally (and belatedly) received the proofs from the publisher, we found over 100 typos introduced by the publisher's typesetters in most incomprehensible ways. Worse yet, the one inadvertent grammar typo we did have in our original manuscript (along with four other, more subtle, non-grammar typos) was not fixed. It was painfully evident that they did not proofread the manuscript very carefully – them creating 100+ unfathomable typos speaks volumes. So, we spent countless additional hours fixing their typos, and it took more than one round of revisions for them to get it right. In hindsight, this should come as no surprise: as many other publishers, they apparently outsource typesetting, copyediting, cover design, etc., to a developing country, and I highly doubt that, e.g., the English proficiency on the other end of this outsourcing process is top-notch. It is the all-familiar and prevalent sad story: English-language books are produced by people whose first language is not English.

Finally, the book was online. However, the nightmare continued. There is an appendix in the book with computer source code and a lengthy discussion. This appendix was just another chapter in the book and was not supposed to be a part of the free preview of the book, which we expressly discussed and agreed on with the publisher in writing to be limited to the first two chapters. Yet, they included the appendix in the back matter of the book, which is freely downloadable from the publisher's website along with the front matter. When I pointed this out to the publisher, their reply was that, for them to redo the files, it would delay the release of the book accordingly (and, based on prior history, that meant weeks, if not longer). This was already after multiple delays on the publisher's end. So, once again, not to appear "difficult" or "unaccommodating", we let this go and the appendix stayed in the freely-downloadable back matter. Speaking of which, while in our original manuscript all references were in one place, at the end, in the published version the references were cited at the end of each chapter. However, the publisher – for the reasons we do not comprehend – also kept the full list of references in the freely-downloadable back matter. While in the modular (where all chapters, front matter

and back matter have separate PDF files) electronic e-book version this is not a big deal, they actually also included these duplicate references in the back matter in the printed version, which substantially (and artificially) increased its number of pages.

But there is more. One would imagine that their production team would do some basic quality control post-production. Months later we found out that the Kindle version on Amazon was all messed up, with equations not displaying properly, etc. The publisher claimed that they provided correct files to Amazon and that the problem was on Amazon's end. It took them several weeks to fix this issue, and the fix was a "hack": they replaced the Kindle version with the so-called "replica" version, which is just a replica of the PDF. Anyone can easily create a "replica" version from a PDF using Kindle Create – this does not take a leading publisher. Furthermore, the Kindle preview version displays material substantially outside of the preview material we agreed on. But then again, who cares about the authors?

Nor did the publisher seem to care much about the apparent pirated versions of the book PDF appearing on various websites. Basically, it was unclear what, if anything, the publisher was doing for the book. Their entire marketing effort was apparently limited to whopping two tweets they sent when the book was published. Essentially all the marketing efforts came from me promoting the book on LinkedIn (where I have over quarter million followers) by posting links to the preview version then-available on SSRN and the full version/hardcover on the publisher's websites.

Perhaps most unfathomably, not only did the publisher apparently did not do much to protect the book from pirated copies being available on the internet, or to promote the book, they outright refused to refute a factually false and defamatory "review" an anonymous purchaser placed on Amazon. E.g., that review falsely claims that "there is only a tiny paragraph (no more than 10 lines), very general, on each strategy and then close to 10 pages of book references after each strategy." This is factually false: there are not "10 pages of book references after each strategy". There are references after each chapter (not strategy or section) pursuant to the publisher's own formatting (see above). The review also falsely claims that "A 10 line description of a very general strategy, no math, no backrest, no optimization." Again, this is factually false: as the reader can readily see, the book has over 550 elevated equations (not counting lots of math embedded in the text), the source code for backtesting in Appendix A, strategies involving optimization, 900+ glossary terms, acronyms and math definitions, etc. Furthermore, simpler strategies have concise (but precise) descriptions, while others span pages, not "10 lines", contrary to what the review falsely claims. The review also complains about the number of references in the book. The book description on Amazon (as well as the publisher's websites) expressly states that there are around 2,000 bibliographic references in the book, one of whose aims is to serve as a reference guide into (and essentially an encyclopedia of) trading strategies (which is also stated in the Editorial Reviews of the book). Therefore, the anonymous reviewer was well aware of this before purchasing the book. The review further falsely claims: "And then, as if it were not enough, at the end of the book the author recaps all the references

one more time." The review is expressly attacking "the author" of the book, even though, as mentioned above, the specific formatting of the references (whereby the references pertinent to each chapter are included after each chapter, and all references are also included in the back matter, which is freely downloadable from the publisher's website) was performed by the publisher, not by the authors. Our original manuscript has references only at the end. Again, as mentioned above, why the publisher duplicated the references both after the chapters and in the back matter is not something we understand, and it is not something we did or had control over, contrary to the anonymous reviewer's factually false and defamatory statements.

When we discovered the aforesaid factually false and defamatory review on Amazon, we contacted the publisher and asked them, at the minimum to put a comment on the review refuting its factually false statements, and also to contact Amazon to remove the review (as under Amazon's policies, defamatory reviews are not allowed). To our bewilderment, the publisher suggested that we use our contacts to generate positive reviews on Amazon to counteract that negative review. Incredible, isn't it?

To be clear, having over a quarter million followers on LinkedIn and putting lots of content out there on social media, I have had my share of haters. And one thing I have learned is that there is some truth to the common expression "haters make us famous". When you write a paper or a book or anything else you stick your neck out with, it comes with the territory: some will love it, some will hate it, and some will not care. I write things for the "some-will-love-it" demographic and I do not care about the rest. However, there is a big difference between someone expressing a negative opinion about what you have written – this is perfectly acceptable, we live in a free country with freedom of speech – and someone making factually false and defamatory statements, which is not acceptable. And when you write a book and grant the publisher all kinds of rights for the book, it falls onto the publisher to protect its integrity and reputation, as the publisher owns the rights to the book.

There is a lesson to be learned from all this. That a large publisher will do little to nothing to protect the integrity and reputation of the book or its authors (especially if it involves a potential headache with Amazon) or to promote the book. So, as an author, you do all the hard work, and your publisher just takes over your sweat-and-blood creation, makes money from it, while you do all the work promoting the book, with little to no support from the publisher, including protecting the book from, e.g., being pirated on the internet, defamed, etc. Is this fair? Absolutely not!

So, we have terminated the publishing agreement and are making our work free for everyone to download and benefit from the knowledge we have compiled in this now-free e-book. We hope you enjoy it and thanks for reading our book and our story, which hopefully will also be useful to other authors contemplating publishing a book. Consider this. Without real editorial support, when you have to design the book cover, deal with a large number of typos introduced by the typesetters, etc., is publishing with a big-name publisher all that different from "vanity publishing"?

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1 Introduction and Summary

A trading strategy can be defined as a set of instructions to achieve certain asset holdings by some predefined times $t_1, t_2, \ldots$, which holdings can (but need not) be null at one or more of these times. In many cases, the main objective of a trading strategy is to make a profit, i.e., to generate a positive return on its investment. However, some viable trading strategies are not always outright profitable as stand-alone strategies. E.g., a hedging strategy can be a part of a bigger plan, which itself can but need not be a trading strategy. Thus, an airline hedging against rising fuel costs with commodity futures is a trading strategy, which is a risk-management step in executing the airline's business strategy of generating profits through its services.

In the case of trading strategies that are intended to be outright profitable as stand-alone strategies, one may argue that the phrase "buy low, sell high" captures their essence. However this viewpoint is somewhat superfluous and, while it applies to trading strategies that buy and sell a single asset (e.g., a single stock), it would exclude a whole host of viable strategies that do not work quite like that. E.g., a trading strategy that uses a hedging sub-strategy for risk management may not always "buy low, sell high" when it comes to a particular asset in its portfolio. This is because hedging risk – or, essentially, transferring some risk to other market participants – is not free, and often a trader will pay a premium for hedging some risks in a trading strategy to achieve its objectives. Another example would be the so-called statistical arbitrage, wherein the trading portfolio can consist of, e.g., thousands of stocks and profitability is typically not achieved by buying low and selling high each stock or even any discernable groups of stocks, but statistically, across all stocks, with some trades making money and some losing it. It gets complicated quickly.

The purpose of these notes is to collect a variety of trading strategies in the context of finance (as opposed to trading baseball cards, classic cars, etc.) across essentially all (or at least most frequently encountered) asset classes. Here we deliberately use the term "asset class" somewhat loosely and include what can be referred to as "asset sub-classes". Thus, a narrower definition would include stocks, bonds, cash, currencies, real estate, commodities and infrastructure. However, this definition would be too narrow for our purposes here. We also consider: derivatives such as options and futures; exchange-traded funds (ETFs); indexes (which are usually traded through vehicles such as ETFs and futures); volatility, which can be treated as an asset class (and traded via, among other things, exchange-traded notes); structured assets (such as collateralized debt obligations and mortgage-backed securities); convertible bonds (which represent a hybrid between bonds and stocks); distressed assets (which are not a separate asset class per se, but the corresponding trading strategies are rather distinct); cryptocurrencies; miscellaneous assets such as weather and energy (derivatives); and also trading strategies such as tax arbitrage and global macro (which use some assets mentioned above as tradables). Some strategies are relatively simple and can be described in words, while many (in fact, most) require a much more detailed mathematical description, which we provide formulaically.

It is important to bear in mind that, unlike the laws of nature (physics), which (apparently) are set in stone and do not change in time, financial markets are man-made and change essentially continuously, and at times quite dramatically. One of the consequences of this transiency is that trading strategies that may have worked well for some time, may die, sometimes quite abruptly. E.g., when the New York Stock Exchange (NYSE) started switching away from its human-operated "specialist" system to electronic trading beginning late 2006,[5] many statistical arbitrage strategies that were profitable for years prior to that, pretty much died overnight as volatility increased and what used to do the trick before no longer did. Eventually the market was flooded with high frequency trading (HFT)[6] strategies further diminishing profit margins of many "good old" trading strategies and killing them.

However, technological advances gave rise to new types of trading, including ubiquitous trading strategies based on data mining and machine learning, which seek to identify – typically quite ephemeral – signals or trends by analyzing large volumes of diverse types of data. Many of these trading signals are so faint that they cannot be traded on their own, so one combines thousands, in fact, tens or even hundreds of thousands if not millions of such signals with nontrivial weights to amplify and enhance the overall signal such that it becomes tradable on its own and profitable after trading costs and slippage, including that inflicted by HFT.[7]

Considering the intrinsically ephemeral nature of the financial markets and trading strategies designed to make a profit therefrom, the purpose of these notes is *not* to convey to the reader how to make money using any trading strategy but simply to provide information on and give some flavor of what kind of trading strategies people have considered across a broad cross-section of asset classes and trading styles. In light of the foregoing, we make the following DISCLAIMER: *Any information or opinions provided herein are for informational purposes only and are not intended, and shall not be construed, as an investment, legal, tax or any other such advice, or an offer, solicitation, recommendation or endorsement of any trading strategy, security, product or service.* For further legal disclaimers, see Appendix B hereof.

We hope these notes will be useful to academics, practitioners, students and aspiring researchers/traders for years to come. These notes intentionally – not to duplicate prior literature and to avoid this manuscript spanning thousands of pages – do not contain any numeric simulations, backtests, empirical studies, etc. However, we do provide an eclectic cornucopia of references, including those with detailed empirical analyses. Our purpose here is to describe, in many cases in sizable detail, various trading strategies. Also, Appendix A provides source code for illustrating out-of-sample backtesting (see Appendix B for legalese).[8] So, we hope you enjoy!

[5] NYSE first started with its "Hybrid Market" (see, e.g., [Hendershott and Moulton, 2011]). However, the writing had been on the wall for the ultimate demise of the specialist system for quite some time. For a timeline, see, e.g., [Pisani, 2010].

[6] See, e.g., [Aldridge, 2013], [Lewis, 2014].

[7] See, e.g., [Kakushadze and Tulchinsky, 2016], [Kakushadze and Yu, 2017b].

[8] The code in Appendix A is not written to be "fancy" or optimized for speed or otherwise.

Acronyms

ABS: asset-backed security.

ADDV: average daily dollar volume.

ANN: artificial neural network.

ATM: at-the-money.

B/P: book-to-price.

BA: banker's acceptance.

BICS: Bloomberg Industry Classification System.

bps: basis point.

BTC: Bitcoin.

Btu: British thermal unit.

CA: commodity allocation percentage.

CBOE: Chicago Board Options Exchange.

CD: certificate of deposit.

CDD: cooling-degree-days.

CDO: collateralized debt obligation.

CDS: credit default swap.

CFTC: U.S. Commodity Futures Trading Commission.

CI: core inflation.

CIRP: Covered Interest Rate Parity.

CME: Chicago Mercantile Exchange.

COT: Commitments of Traders.

CPI: Consumer Price Index.

CPS: cents-per-share.

CTA: commodity trading advisor.

DJIA: Dow Jones Industrial Average.

EMA: exponential moving average.

EMSD: exponential moving standard deviation.

ETF: exchange-traded fund.

ETH: Ethereum.

ETN: exchange-traded note.

EUR: euro.

FOMC: Federal Open Market Committee.

FX: foreign exchange.

GDP: Gross Domestic Product.

GICS: Global Industry Classification Standard.

HDD: heating-degree-days.

HFT: high frequency trading.

HI: headline inflation.

HMD: healthy-minus-distressed.

HML: High minus Low.

HP: hedging pressure; Hodrick-Prescott.

IBS: internal bar strength.

ITM: in-the-money.

JPY: Japanese Yen.

LETF: leveraged (inverse) ETF.

LIBOR: London Interbank Offer Rate.

M&A: mergers and acquisitions.

MA: moving average.

ML: machine learning.

MBS: mortgage-backed security.

MBtu: 1,000 Btu.

MKT: market (excess) return.

MMBtu: 1,000,000 Btu.

MOM: Carhart's momentum factor.

MSA: metropolitan statistical area.

MTM: mark-to-market.

Mwh: Megawatt hour.

NYSE: New York Stock Exchange.

OAS: option adjusted spread.

OTM: out-of-the-money.

P&L: profit(s) and loss(es).

P2P: peer-to-peer.

PCA: principal component analysis.

REIT: real estate investment trust.

ReLU: rectified linear unit.

REPO/repo: repurchase agreement.

RMSE: root mean square error.

RSI: relative strength index.

S&P: Standard and Poor's.

SIC: Standard Industrial Classification.

SMA: simple moving average.

SMB: Small minus Big.

SGD: stochastic gradient descent.

SS: sum of squares.

StatArb: statistical arbitrage.

STRIPS: Separate Trading of Registered Interest and Principal of Securities.

SUE: standardized unexpected earnings.

SVM: support vector machine.

TTM: time-to-maturity.

TIPS: Treasury Inflation-Protected Securities.

UIRP: Uncovered Interest Rate Parity.

USD: U.S. dollar.

VAR: vector autoregressive model.

VWAP: volume-weighted average price.

YoY: year-on-year.

Some Math Notations

iff if and only if.

max (min) maximum (minimum).

floor(x) the largest integer less than or equal x.

ceiling(x) the smallest integer greater than or equal x.

$(x)^+$ $\max(x, 0)$.

sign(x) sign of x, defined as: $+1$ if $x > 0$; -1 if $x < 0$; 0 if $x = 0$.

$|x|$ absolute value of x if x is a real number.

rank(x_i) rank of x_i when N values x_i ($i = 1, \ldots, N$) are sorted in the ascending order.

$\exp(x)$ or e^x natural exponent of x.

$\ln(x)$ natural log of x.

$\sum_{i=1}^{N} x_i$ sum of N values x_i ($i = 1, \ldots, N$).

$\prod_{i=1}^{N} x_i$ product of N values x_i ($i = 1, \ldots, N$).

$A|_{B=b}$ (or $A|_b$) the value of A when some quantity B it implicitly depends on (usually evident from the context) takes value b.

$f(x) \to \min$ (max) minimizing (maximizing) $f(x)$ w.r.t. x (where x can, e.g., be an N-vector x_i, $i = 1, \ldots, N$).

$\text{argmax}_z\ f(z)$ the value of z for which $f(z)$ is maximized.

$\partial f/\partial x$ the first partial derivative of the function f (which may depend on variables other than x) w.r.t. x.

$\partial^2 f/\partial x^2$ the second partial derivative of the function f (which may depend on variables other than x) w.r.t. x.

$G : A \mapsto B$ G is a map from set A to set B.

$A \subset B$ set A is a subset of set B.

$\{i|f(i) = a\}$ the set of values of i such that the condition $f(i) = a$ is satisfied.

$\min(i : f(i) > a)$ the minimum value of i such that the condition $f(i) > a$ is satisfied.

$i \in J$ i is an element of set J.

$|J|$ the number of elements of J if J is a finite set.

δ_{AB} (or $\delta_{A,B}$) 1 if $A = B$; otherwise, 0 (Kronecker delta).

$\text{diag}(x_i)$ diagonal $N \times N$ matrix with x_i $(i = 1, \ldots, N)$ on its diagonal.

A^T transpose of matrix A.

A^{-1} inverse of matrix A.

$E_t(A)$ expected value of A at time t.

$dX(t)$ an infinitesimal increment of a continuous process $X(t)$.

dt an infinitesimal increment of time t.

$P(A|B)$ conditional probability of A occurring assuming B is true.

Explanatory Comments for Index

In the index entries, plural in many (but not all) cases is reduced to singular (so, e.g., "commodity" also includes "commodities"). Parentheses contain acronyms or definitions, and in some (but not all) cases both versions are present in the main text. Most (but not all) index entries with commas, i.e., "*noun, adjective*", correspond to text entries such that the precise string "*adjective noun*" is not directly present in the text, but is present indirectly (e.g., as "*adjective (...) noun*") or contextually.

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