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Quant Quarterly

NC STATE UNIVERSITY

Financial Mathematics

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Message from the Program Director

Dr. Tao Pang
Ph.D., CFA, FRM
Professor and Director

The Masters of Financial Mathematics program continued to grow in Fall 2023. We welcomed 32 new students and had the pleasure to admit a few more exceptional candidates to join us in Spring 2024.

This fall semester, Dr. Dominykas Norgilas joined the Department of Mathematics as a new faculty member of financial mathematics. Dr. Norgilas earned his PhD in Statistics from the University of Warwick in Coventry, England in 2019 and he was a visiting assistant professor at the University of Michigan before he joined NC State University. He taught FIM 528, Options and Derivatives Pricing, in Fall 2023 and he will teach FIM 548, Monte Carlo Methods for Financial Mathematics, in Spring 2024.

The Women in Finance symposium, which was held on Friday, September 15, 2023 at the McKimmon Center here at NC State, was a resounding success. Erica Isabella from McKinsey & Company, Ratika Kapoor from Bank of America, and Katherine Taylor from Freddie Mac were our guest panelists for the event. They shared their views on career opportunities for women within the field of finance and the importance of a graduate degree in quantitative finance, as could be earned through a master of financial mathematics. In attendance, were approximately 50 participants from all over the state of North Carolina. Learning about the dynamic opportunities in the field of finance has led to many participants expressing an interest in our program.

Fall 2023 was especially busy for us, as we also hosted the 7th Eastern Conference on Mathematical Finance from October 20 through October 22. Researchers and students from the U.S. and Canada were in attendance, including the University of Toronto, Florida State University, Duke University, and Princeton University. University representatives presented their research results and ideas that may have a broader bearing within the financial field and markets in the years to come.

In 2023, as a result of the strength of our program, we earned a higher ranking from QuantNet in their annual review. The results, posted in their 2024 QuantNet Ranking of Best Financial Engineering Programs, place us at #12. Risk.net had also highlighted our success among the top 25 universities, placing us at #4 in their Quant Finance Master's Guide 2023. We look forward to their latest rankings for 2024, due later this year. We always share the latest ranking results on our website.

As we enter the new year in 2024, I am confident that the Masters of Financial Mathematics program at NC State will continue to remain strong.

Sincerely yours,

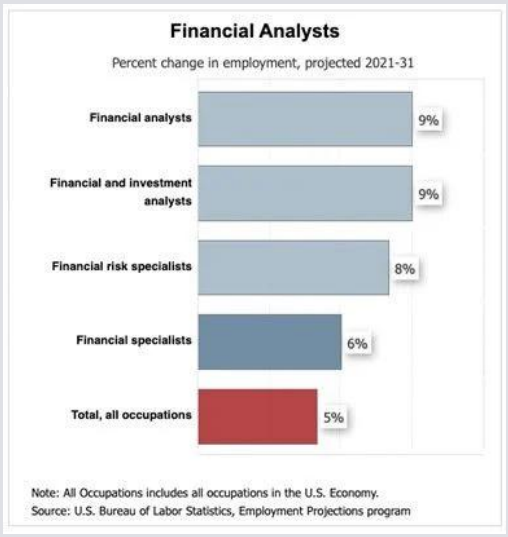
Tao Pang

Director of Career Services

Patrick Roberts
Director of Career Services

Job Outlook Report 2024

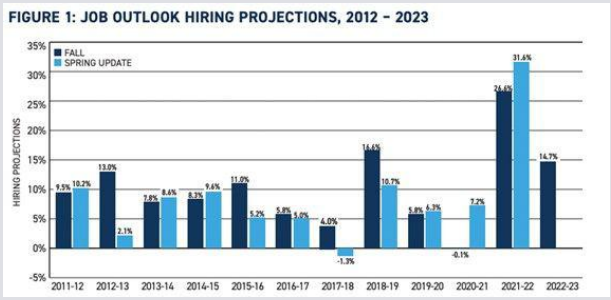
The follow report indicates the potential job outlook on the financial industry and professions closely associated with the Master of Financials Mathematics program as determined by multiple economic and research studies conducted over the past year. These resources include the United States Bureau of Labor Statistics, the National Association of Colleges and Employers, and the Collegiate Employment Research Institute. Combined, these reports provide total responses from over 1,800 employers and organization representatives.



According to the U.S. Bureau of Labor Statistics (BLS), the occupation of financial analyst is projected to grow 9% over the next 8 years through 2031 and similar projections are included for additional positions that include financial investment analysts, risk specialists and general financial specialists.

Another similar occupation listed through BLS is Operations Research Analysts which can include both data science and mathematical modeling. This occupational area is projected to grow 29% through 2031. Both areas are projected to grow much faster than the average for all occupations in the United States.

The National Association of Colleges and Employers released their annual Job Outlook 2023 survey results and found that employers plan to hire 14% more new graduates from the Class of 2023 than they did from the Class of 2022. In addition, 50% of employers planned to increase hiring in 2023. Within the field of finance, 71% of employers indicated their projected hiring in 2023 will increase.



Finally, the Collegiate Employment Research Institute released their annual report entitled College Hiring Outlook 2023. This report indicates that of employers within financial services, 86% plan to hire the same number as last year among master's level candidates. Another positive indicator is that employers seeking data analytics, statistics and applied mathematics candidates are in high demand at over 16% seeking to fill positions.

Overall, the outlook for hiring in 2024 is very positive for Financial Mathematics students and there are a wide variety of opportunities available.

For additional information and to discuss your current career goals, contact Career Services Director, Mr. Patrick Roberts at probert2@ncsu.edu.

Farewell to NC State and the FM Program

Ritu Sharma
Class of 2023 and Former FM Ambassador

As thrilled as I was to get accepted into the top 4 globally ranked program in Quantitative Finance, I knew this program was going to push my limits, hone my skills and prepare me for my professional challenges. It was not easy to switch gears from a comfortable corporate life back to the student phase, but as I graduate, I can surely say the decision was worth it all.

Mine was a journey of a techie engineer, experienced in solving all problems of the trading floor aspiring to be a FinTechie Quant. It was amazing to see how the courses were closely aligned to the latest skills required in the job market. Industry professionals, seasoned on Wall Street taught us Fixed Income. The freedom to choose electives helped me fill in the gaps in my profile. One of my favorite electives was Credit Risk Management – a perfect blend of Financial concepts, taught by an industry expert and helped me explore my interest in mathematical modeling and statistics.

During the 3 semesters, I also got the opportunity to serve as an ambassador of the FM program. I led a team of 3 graduate students and worked on a project exploring applications of Extreme Value Theory in estimating Value at Risk (VaR). This experience was a memorable one. Apart from up-skilling myself technically, I became a better leader as well. Guidance from the Director, Dr. Pang, Program Specialist, Ms. Uy and Career Services Director, Mr. Roberts played a key role in polishing my soft skills. Overall, I have grown professionally and personally.

As I graduate, and prepare to embark on my professional journey as a Quant, I would like to extend my heartfelt gratitude to the NC State and FM Program throughout.

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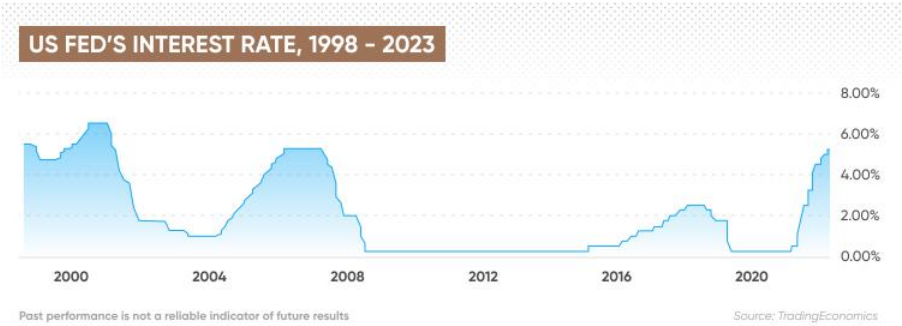
Sharath Balthu

Higher for Longer: Unveiling the Impact of Interest Rates

Interest keeps the economy moving by encouraging people to borrow, to lend, and to spend. As interest rates are a significant factor of the income you can earn by lending money, of bond pricing and of the amount you will have to pay to borrow money, it is important that one understand how prevailing interest rates change: primarily by the force of supply and demand, which is also affected by inflation and monetary policy.

The Fed in September made a statement of Higher for Longer on Interest rates. This government entity influences the interest rate to control inflation. By increasing the federal funds rate, the Federal Reserve is effectively attempting to shrink the supply of money available for making purchases. The Federal Reserve has set a goal of reducing the current inflation rate of 9% to a more manageable 2% and is determined to raise interest rates as needed to achieve this target. We're currently experiencing the all-time high federal funds rate in the last two decades, that is 5.5%.



How Interest Rates Affect the U.S. Stock and Bond Markets

Stock prices always had inverse relationship with interest rates. When interest rates rise, this also makes it more expensive for companies to raise capital. If a company is seen as cutting back on its growth or is less profitable, either through higher debt expenses or less revenue, the estimated amount of future cash flows will drop. All else being equal, this will lower the price of the company's stock.

Whereas this is a perfect opportunity for investors who are looking to reduce volatility in their portfolio and have stable cashflows through Fixed Income. The yields on short term bonds are high due to rise in benchmark treasury rates. When interest rates are high, cash flows from Mortgage-Backed Securities become more consistent because prepayments decrease, and the duration of the investments increases. This creates a favorable environment for individuals seeking to invest in Passthroughs and CMOs.

How will it affect a common man?

When central banks or financial institutions raise interest rates, it often leads to higher borrowing costs for consumers. Because higher interest rates mean higher borrowing costs, people will eventually start spending less. The demand for goods and services will then drop, which will cause inflation to fall. People looking to finance major purchases like homes, cars, or education may face increased monthly payments, making these expenses more burdensome.

Grim forecasts from economists had predicted that as the Federal Reserve jacked up its benchmark rate even higher, consumers and businesses would curb spending, companies would slash jobs and unemployment would spike as high as 7% or more — twice its level when the Fed began tightening credit.

Conclusion

The current state of the U.S. economy resembles a delicate balancing act. Historically, elevated inflation led to interest rate hikes and subsequent severe recessions, causing imbalances in the economy. However, this time, the Biden Administration is orchestrating a rare and challenging "soft landing." They are successfully curbing inflation without pushing the economy into a deep recession and the decline in the financial markets. This outcome stands in stark contrast to the inflation spikes of the 1970s and early 1980s. As we navigate this economic tightrope, we can only anticipate the elegant finale of a soft landing, ushering in a promising future.

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Gabe Barber

Serving as a Quantitative Analyst

The main job function of a quantitative analyst involves studying market data to develop and implement strategies that help businesses make decisions and grow. This analysis and strategy development requires extensive mathematical, statistical, and computer science knowledge. For good reason, quants are highly desired by hedge funds, banks, insurance companies, and a variety of other financial and non-financial institutions. Whether they are working on predictive models to forecast exposures, perfecting trading algorithms, building software to streamline operations, or solving any of the countless problems in the financial world, quants are hard at work crunching numbers and building models to solve problems.

Regardless of the extensive knowledge required of a quant, successful industry professionals will testify that the best quants are the ones that never stop learning. Inevitably, professionals that devote themselves to a lifelong journey of learning gain the opportunity to share their bank of knowledge in the form of being a mentor. With this in mind, preparing for a fruitful career in quantitative analytics does not end at mastering mathematical theory and coding techniques. Investing in yourself to cultivate a service oriented mindset for the purpose of protecting and growing the financial community and its stakeholders is also of utmost importance. Having this foresight will ensure for years of the financial community flourishing and solving problems that were previously unsolvable.

One of the most effective ways of establishing this mindset is emphasizing the significance of productive relationships. As a student and aspiring quant with a demanding schedule, it is important to combat fatiguing and isolating study patterns by being intentional about building relationships with fellow students and professors. Sharing the excitement and difficulties of the program is important, and finding ways to leverage each other's knowledge to sharpen technical skills is a great way to enhance the collaborative and productive spirit necessary to thrive. As an intern or new professional seeking employment, identifying managers, mentors, and colleagues with desirable qualities such as compassion, dedication, and competence will give you a model and resource to refer to.

Ideally, work for a quant is a state of flow induced by complex challenges that are begging to be solved. However, these challenges can often feel overwhelming and frustrating. Whether quants are drowning in the details required to complete a task or doing backstrokes, they are often glued to their computer screens and have tunnel vision caused by deadlines and short term goals. To avoid shedding relational, ethical, and service-oriented responsibilities, it is important to remember the bigger picture. Remember that the work you are doing helps an organization to provide financial support to its customers. The work you are doing enables institutions to collaborate and maintain financial security and integrity that prevents failures like the 2008 crisis. Regardless of your employer's line of business, you are ultimately responsible for contributing to financial decisions that allow our economy to thrive. Working for an institution that has well defined values and gives back to the community can help reconnect you with the bigger picture as well.

Quants are required to be creative problem solvers and have in-depth knowledge of many technical aspects in several areas. While it is necessary to enhance these skills, an aspiring quant should also be proactive in developing a humble mindset to serve others within the field. Whether it is mentoring, fulfilling customers' needs, or protecting the economy, serving others as a quant is important and a meaningful dedication of your knowledge and time. This service mindset will pay dividends for years to come by maintaining a culture that prevents unethical activities and promotes growth and prosperity among the financial community.

Bhanuteja Bolisetti

Visualizing Option Strategies in Python

Introduction

An option is a derivative, a contract that gives the buyer the right, but not the obligation, to buy or sell the underlying asset by a certain date (expiration date) at a specified price (strike price). There are two types of options: calls and puts. Traders can construct option strategies ranging from buying or selling a single option to very complex ones that involve multiple simultaneous option positions. Option payoff diagrams are profit and loss charts that show the risk/reward profile of an option or combination of options. As option probability can be complex to understand, payoff diagrams give an insight into the risk/reward for the trading strategy.

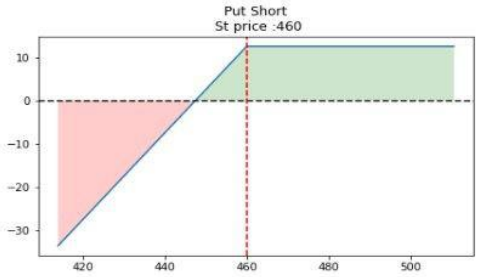
Opstrat Package

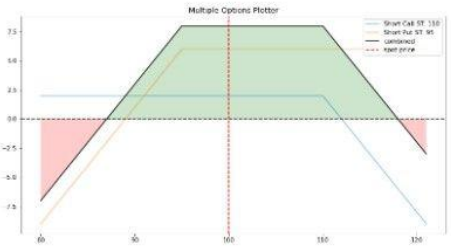
Opstrat is a python package which can be used for visualizing options, without the need of complex coding. The package provides functions for constructing payoff diagrams for single options as well as complex strategies involving multiple positions. The package is also compatible with yahoo finance package and can be used to generate option payoff diagrams fetching data from yahoo finance API.

Plotting Customized single plot

The payoff diagram for a single option can be plotted using the ***single_plotter()*** function.

```
op.single_plotter(spot=460, strike=460, op_type='p',  tr_type='s', op_pr=12.5)
```





Plotting for Multiple Options strategy

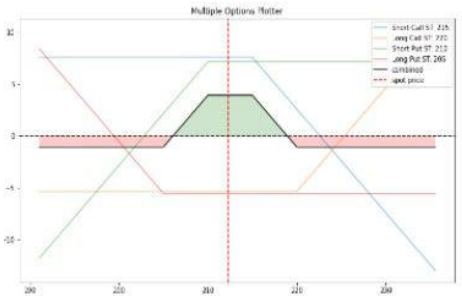
Example 1: Short Strangle

A short strangle is an options trading strategy that involves (a) selling of a slightly out-of-the-money put; and, (b) a slightly out-of-the-money call of the same underlying stock and expiration date

```
op_1 = {'op_type':'c','strike':110,'tr_type':'s','op_pr':2}
op_2 = {'op_type':'p','strike':95,'tr_type':'s','op_pr':6}
op.multi_plotter(spot=100, op_list=[op_1,op_2])
```

Example 2 : Iron Condor (Option strategy with 4 options)

An iron condor is an options strategy consisting of two puts (one long and one short) and two calls (one long and one short), and four strike prices, all with the same expiration date.



The optional argument, spot range limits the range of spot values covered in the plot. The default spot range in +/-20%. If the underlying asset is less volatile and the strike price of options are within a small range, a smaller spot range like 5% can be considered. For highly volatile underlying asset, higher spot range can be used.

```
op_list=[op1, op2, op3, op4]
op.multi_plotter(spot=212.26,spot_range=10, op_list=op_list)
```

Plotting Real Options using Yahoo Finance API

We can plot the option-payoff by providing the option ticker and other parameters(option type, transaction type and strike price) into the ***yf_plotter*** function.

Example : Call Option Buyer Payoff of Microsoft Inc.

The following code will generate the payoff diagram for Microsoft Inc. call option buyer, who buys call option at strike price $325. ***MSFT*** is the stock ticker for Microsoft Inc.

```
op_list=[{'tr_type':'b', 'op_type':'c', 'strike':325}]
op.yf_plotter('msft', spot_range=10, op_list=op_list)
```

Michael Chan

Balancing Creativity and Systemic Thinking: A Journey Through STEM

Transitioning from a qualitative economics undergraduate background to the demanding world of NCSU's financial mathematics program was, for me, akin to stepping from one realm into another. The shift from discussing geopolitcs and macroeconomics to diving headfirst into Stochastic Calculus and the Black-Scholes model brought with it a profound change in the way I approached learning and life itself. This experience is an adjustment that has not been without its challenges, as the structured thinking of STEM disciplines infiltrated my personal life, revealing a potential downside to prolonged immersion in quantitative fields. This dilemma was poignantly illustrated by a book I encountered during this academic journey.

One book, read outside the confines of the classroom, struck a chord with me – "When Breath Becomes Air" by Paul Kalanithi. This deeply personal memoir not only recounts the author's life as both a neurosurgeon and a terminal cancer patient but also delves into his contemplations on morality as he grapples with the prospect of impending death. Dr. Kalanithi's poignant words, "Science may provide the most useful way to organize empirical, reproducible data, but its power to do so is predicated on its inability to grasp the most central aspects of human life: hope, fear, love, hate, beauty, envy, honor, weakness, striving, suffering, virtue," echo throughout his journey.

As Dr. Kalanithi transitioned from a caregiver to a care receiver, from a practioner of statistics to becoming a statistic himself, he came to a profound realization: the human experience defies simple quantification and scientific analysis. There are aspects of life that transcend data and logic, embracing the realms of hope, love, and suffering. It's an insight that resonated with me, as I found myself unintentionally carrying over the systemaic thinking cultivated in my quantitative field into the realm of personal decision-making.

While logic and science undoubtedly offer invaluable tools for problem-solving, there is an important, often overlooked dimension of humanity that requires attention. Emotions play a pivotal role in our decision-making processes, and ignoring them can lead to an overly analytical, and at times, unhealthy approach to life. When every personal choice becomes an exercise in finding the "correct" answer rather than what feels right, it transforms one's existence into a perpetual test, a life driven solely by data and calculations. Is that truly the life we wish to lead?

In a world where STEM fields increasingly dominate and shape our understanding of the universe, it is essential to strike a balance between systematic thinking and the creativity that stems from the human experience. As I navigate my own path through quantitative analysis, I am acutely aware that while precision and data-driven decisions have their place, so too does the need to honor the intangible, intricate, and often unpredictable aspects of being human. Our pursuit of knowledge should not smother our creativity, but rather, it should be an integral part of our journey towards a more holistic understanding of the world and ourselves.

Aditya Chauhan

Unveiling the Power of Financial Mathematics: My Path to Quantitative Excellence

As I embarked on my journey into the world of financial mathematics at North Carolina State University, it was more than just a career choice; it was a fusion of passion, curiosity, and the desire to make a meaningful impact in the field of quantitative research. This article is a reflection on my career aspirations, the projects I have undertaken, and the experiences that have shaped my journey so far.

A Quantitative Odyssey

From an early age, I was captivated by the world of numbers and the magic they held in unraveling the complexities of our surroundings. This fascination led me to pursue a bachelor's in aerospace engineering at the University of Nottingham, UK. While engineering was intellectually stimulating, my heart yearned for a field where mathematics could be applied to solve real-world problems, and that is when I set my sights on financial mathematics. Choosing to pursue a master's in financial mathematics at NC State was a pivotal decision in my journey. The program's reputation for academic rigor, emphasis on quantitative analysis, and access to cutting-edge resources made the program an ideal choice.

Academic Pursuits

My academic journey at NC State has been nothing short of transformative. The curriculum, including modules on Applied Time Series, Statistical Inference, Options and Derivative Pricing, and Machine Learning in Finance, has equipped me with the knowledge and skills necessary for quantitative research. With a GPA of 3.7 in my undergraduate degree, I have set high standards for myself, striving for excellence in every aspect of my academic journey. The decision to pursue the Chartered Financial Analyst (CFA) Level 1 designation was a conscious one, driven by my desire to deepen my understanding of financial markets and further enhance my quantitative skillset.

Quantitative Prowess in Action

One of the highlights of my journey at NC State has been the opportunity to engage in practical, data-driven research projects that have broadened my horizons and demonstrated the real-world applicability of quantitative analysis. In the Portfolio Trading Competition, I participated in a program-wide trading challenge, tasked with achieving the highest ROI on an investment of $1 million. This project exemplified the fusion of theoretical knowledge with practical decision-making. The continuous updates, technical analysis, and stock pitch reports reflected my ability to apply quantitative reasoning to optimize investment outcomes.

My work on Loss Severity Modeling of Single-Family Residential Mortgage Loans was a deep dive into the world of data analytics and predictive modeling. This project involved the collection, cleaning, and analysis of Fannie Mae loan data. The application of regression techniques and machine learning algorithms within Python showcased my ability to develop predictive models that estimate loss severity for Loss-Given Default Loans, a critical factor in risk assessment.

Another project, Portfolio Risk Management in Python, demonstrated my proficiency in evaluating risk and returns, constructing market-cap weighted equity portfolios, and forecasting performance using Linear Regression Models. This project emphasized the practical application of quantitative techniques in making informed investment decisions.

Professional Networking and Insights

Networking is a vital aspect of a quantitative researcher's journey, and NC State has provided me with opportunities to connect with experts in the field. A ending conferences, seminars, and workshops has allowed me to engage with industry professionals and fellow researchers, gaining valuable insights into the latest trends and innovations.

One particularly enlightening experience was an interview I conducted with a seasoned quantitative finance professional at Citi Bank. Our conversation delved into the intricacies of applying mathematical concepts like Lagrangians to real-world financial scenarios. The interview experiences and insights not only broadened my understanding of the field but also reaffirmed my commitment to a career in quantitative research.

Looking Forward

My journey in the world of financial mathematics at NC State has been a rewarding and enlightening experience. The program, the research projects, and the networking opportunities have collectively shaped my career aspirations. As I look to the future, I aspire to continue exploring the frontiers of quantitative research, particularly in risk assessment, investment strategies, and predictive modelling. My goal is to contribute to the development of innovative models and tools that can benefit investors and financial institutions. In conclusion, my journey at NC State has been a dynamic voyage of discovery, learning, and practical application. These experiences have been fueled by passion and driven by the desire to make a meaningful impact in the field of quantitative research. NC State has provided the ideal environment to nurture a quantitative mind, and I am excited about the opportunities that lie ahead as I continue to navigate the ever-evolving world of financial mathematics and quantitative analysis.

Jasmine Chen

Fixed Income Bond Pricing: Interest Rate & Volatility Calibration

In the financial market landscape, fixed income bonds emerge as a foundational element, offering unique insights into market stability and valuation. A deep understanding of these bonds is rooted in the mastery of interest rate modeling, a pivotal aspect of financial analysis for accurately predicting market trends and valuing bonds.

At the core of this analysis lies interest rate modeling, an indispensable tool for investors and analysts. It plays a critical role in determining the current and future values of bonds. The Vasicek Model, introduced in 1977, is renowned for its simplicity and its capacity to incorporate negative interest rates, using the Ornstein-Uhlenbeck stochastic process for a mean-reverting behavior in interest rates. The Cox-Ingersoll-Ross (CIR) Model, developed in 1987, offers a realistic approach by avoiding negative interest rates and is beneficial for historical estimation and practical application. Meanwhile, the Hull and White Model of 1994 stands out for its flexibility and accuracy in fitting observed term structures, a feature increasingly relevant in today's economic environment.

The methodology behind this study is meticulous, focusing on a detailed analysis of bond data characterized by credit rating, maturity, and bond type. A crucial aspect of this methodology is the calibration of bond pricing data. Here, the focus is on minimizing the Mean Squared Error (MSE) in an optimization process to determine the most suitable parameters for each interest rate model. This approach is essential for ensuring the accuracy and applicability of the models to real-world scenarios.

In comparing the calibration results of the Vasicek, CIR, and Hull-White models, it's evident that each model has distinct strengths in predicting interest rates under varying market conditions. This comparative analysis is not just about model effectiveness but also about their practical applications in financial markets. The results, benchmarked against established models and analyzed through error distributions, offer critical insights for investors and policymakers.

This exploration into fixed income bond pricing transcends academic interests, delving into the fundamentals of financial markets where understanding current dynamics is crucial for predicting future trends. As financial markets evolve, the quest for refined and accurate models becomes imperative. This study not only illuminates current market dynamics but also sets the stage for future research, particularly in enhancing models like Hull-White for improved accuracy and reliability. In this evolving financial world, the study of bond pricing is a continuous journey, adapting and evolving with the market's ever-changing tides.

Ming-Hung Chen

Types of Portfolio Optimization and the Black-Litterman Model

Portfolio optimization serves as the bedrock of success for traders, investors, and portfolio managers alike. Portfolio optimization refers to the process of selecting the best combination of assets for an investment portfolio to achieve a desired level of return while minimizing risk or limiting the risk to designated risk tolerance. In this article, we will delve into different types of portfolio optimization and focus more on the effectiveness of Black-Litterman Model.

Mean-Variance Optimization (MVO): Developed by Harry Markowitz, this is the most widely known and used approach. This strategy considers the expected return and standard deviation (or risk) of the portfolio to find the combination of assets that provides the highest expected return for a given level of risk or the lowest risk for a given level of return.

Minimum Variance Portfolio: This is a specific case of mean-variance optimization where the goal is to find the portfolio with the lowest possible risk (variance) regardless of its expected return.

Tangency Portfolio: Tangency Portfolio is a specific portfolio on the efficient frontier that represents the optimal combination of risky assets. This technique is the portfolio that provides the highest Sharpe ratio, which is a measure of risk-adjusted return.

Risk Parity: Risk parity aims to allocate capital in a way that the risk contribution of each asset to the overall portfolio is equal. This approach is different from traditional allocation methods that typically focus on equal dollar amounts.

Black-Litterman Model: This approach combines subjective views of an investor with the objective output from a quantitative model (usually MVO). This method starts with a set of market equilibrium returns and adjusts them based on an investor's subjective views.

The expected return of Black-Litterman Model can be written of:

$$E[R] = [(\tau\Sigma)^{-1} + P'\Omega^{-1}P]^{-1}[(\tau\Sigma)^{-1}\Pi + P'\Omega^{-1}Q]$$

E[R] is the Expected Return Vector;
τ is a scalar, typically between 0.01 and 0.05, and then calibrates the model based on a target level of tracking error
Σ is the covariance matrix of excess returns;
P is a matrix that identifies the assets involved in the views;
Ω is a diagonal covariance matrix of error terms from the expressed views representing the uncertainty in each view
Π is the Implied Equilibrium Return Vector;
Q is the View Vector of the prospective views the investor has, not necessary to apply subjective views on every single assets.

Due to incorporating subjective views in the Black-Litterman Model, its return depends on whether investor's insight is accurate. Therefore the effectiveness of this model may vary dramatically according to different investors. Still, The Black-Litterman model allows investors to add their own beliefs and insights into the portfolio optimization process, which can be particularly useful when there is a lack of historical data or when the investor has unique market insights. By blending subjective views with quantitative modeling, the Black-Litterman model provides a more customized approach to portfolio construction.

Overall, these optimizations are only tools, as for how to leverage them to receive profitable outcomes with acceptable risk is the key. A great portfolio manager will combine some of them with their own optimization methods, or even solely based on their own ways.

Wan-Yung Chen

Stress Testing for Credit Risk Model

Introduction:
In the intricate realm of financial risk management, default risk is a critical and multifaceted element, especially when considering mortgages and loans. This comprehensive study draws upon the informative Single-Family Loan Performance Dataset from the reputable Fannie Mae, harmonizing with pivotal macro-economic parameters like the ever-fluctuating unemployment rates, the nuanced 30-Year Fixed Rate Mortgage Averages, and other significant economic indices. By meticulously consolidating this vast expanse of data into a singular, structured dataset, we were poised to harness the power of a logistic regression model. With diligent training and calibration, this model was primed to project a wide spectrum of severe macroeconomic eventualities. Further enhancing our analytical depth was the methodical visualization of numerous variables, offering a rich tapestry of insights into their respective impacts on our predictive models.

Detailed Process:
Confronted with the daunting magnitude of the available data, our strategy was unequivocal: divide and conquer. This entailed segmenting the entire performance dataset into sizeable, manageable chunks, each of which was then subject to our rigorous analytical framework. Each data segment offered a wealth of information, and through painstaking identification, we unearthed the variables that, as per our intensive research, wielded the most profound influence on default rates. For unambiguous interpretation, we anchored our model around the premise that a default would manifest as a 3-month delinquency.

Our exploration then ventured into the realm of exploratory data analysis (EDA), a stage where these pivotal variables were placed under a microscopic lens. The dual objectives here were to unravel their intricate distribution dynamics and to maintain the highest standards of data integrity by swiftly addressing any missing values. Upon completing this exacting data refinement process, we synergized the cleansed data with its corresponding macro-economic markers and default rate indicators. This amalgamated dataset then became the bedrock upon which our logistic regression model was meticulously trained. Interestingly, a discernible bias became evident, as the model was initially predisposed towards non-default predictions due to the predominant non-default instances in the original dataset. However, strategic adjustments and iterative recalibrations substantially alleviated this concern, propelling our model to an impressive accuracy rate nearing 75%.

To challenge and validate our model's robustness, we juxtaposed its performance data with datasets emblematic of severe economic turbulence. This step was critical in assessing whether our model could, in real-time, recalibrate and respond aptly to unforeseen economic crises.

Expanded Conclusion & Forward-Looking Recommendations:
Currently, our research endeavors are channelized towards integrating data that mirrors extreme economic scenarios into our primary model. Concomitantly, efforts are afoot to vividly visualize and interpret salient outcomes. Recognizing the inherent unpredictability of economic landscapes, exact prognostications remain elusive. Yet, the entire trajectory of data procurement, meticulous refinement, calibrated model training, strategic optimization, and resultant visualization has been an intellectually rewarding odyssey.

While our model's present incarnation showcases promising potential, we firmly believe that its horizons can be expanded. Beyond the confines of logistic regression lie a plethora of advanced classification models, ranging from the logical matrices of decision trees to the complex algorithms of neural networks. For a more grounded and authentic rendition of our model's forecasting capabilities, especially during tumultuous economic phases, we advocate delving into historical data archives. Events such as the 2008 housing mortgage maelstrom or pandemic-induced economic gyrations offer invaluable insights. Harnessing these empirical datasets can exponentially amplify our model's predictive acumen, rendering it a cornerstone in future financial risk evaluations.

Bhaskar Durvasula

The Integration Of Quantum Computing In Financial Forecasting Models

The realm of finance has perpetually been a fertile ground for the application of cutting-edge technologies, with quantum computing emerging as the new frontier. My career goals are rooted in the amalgamation of financial expertise with quantum technology to yield unprecedented computational capabilities. As a researcher at NC State, I chose this institution for its pioneering work in quantum computing and its applications in finance, where I have been actively involved in groundbreaking research that stands at the confluence of quantum theory and financial forecasting.

Quantum computing holds the promise of solving complex problems that are intractable for classical computers. In finance, this translates to the capability of performing intricate calculations for portfolio optimization, risk assessment, and option pricing at speeds unfathomable to traditional computational methods. My current research focuses on developing and testing quantum algorithms tailored for financial forecasting models, particularly in the volatile landscape of stock market predictions.

Our project at NC State utilizes a quantum annealer to tackle the optimization issues inherent in financial models. The premise is to encode a financial forecasting problem into a quantum system, where the natural evolution of the system corresponds to an algorithmic search for the optimal solution. Early results have been promising, with quantum-enhanced models demonstrating the ability to sift through vast data sets and identify patterns that elude classical algorithms.

The impetus for this research was not just academic curiosity but a practical response to the challenges faced by financial institutions in modeling market behaviors that are increasingly complex and data intensive. Quantum computing, with its ability to perform parallel computations and evaluate multiple probabilities simultaneously, presents a solution to these challenges.

One of the most profound insights from our work has been the quantum approach to risk management. By leveraging the principles of superposition and entanglement, quantum algorithms allow for a more nuanced exploration of risk factors, enabling a more holistic view of potential market scenarios. This aspect of quantum computing could revolutionize the way we understand and mitigate financial risk.

Professional networking has been a cornerstone of this research endeavor. Engagements with industry leaders through NC State's strong alumni network have not only provided valuable insights into the practical demands of the finance sector but have also opened up avenues for collaboration. These partnerships are vital as they facilitate a bridge between theoretical quantum models and real-world financial applications.

Interviews with finance professionals revealed a burgeoning interest in quantum computing but also a significant knowledge gap. To address this, our team has conducted workshops aimed at demystifying quantum concepts for non-physicists, thus fostering a community that is well-informed and ready to integrate these advancements into mainstream financial practices.

The implications of quantum computing in finance are vast, and we are just scratching the surface. As quantum technology continues to mature, we anticipate a paradigm shift in how financial models are constructed and executed. This aligns with my career trajectory, where I aspire to be at the forefront of this integration, pushing the boundaries of quantum finance and shaping the next generation of financial technology.

Qinyang Huang

Predicting Loan Defaults with XGBoost Model

During the fall 2023 semester, my group undertook a project to implement the XGBoost model for forecasting bank mortgage delinquencies, with an emphasis on algorithm utilization and feature identification to mitigate loan default risks. The XGBoost algorithm was chosen for its effectiveness in handling the vast and varied data types presented in this challenge.

In our project, my work was mainly focused on data preprocessing, feature selection, and model optimization.

The first step in data preprocessing involved conducting an exploratory data analysis to identify patterns and outliers. Missing values were addressed using median imputation—a reliable method that avoids the distortions often caused by outliers. To confront the dataset's fluid characteristics, I employed forward feature selection, a straightforward approach that reduced computational demand and distilled the dataset to six essential features. This step was essential to cut through the noise and prevent overfitting.

Addressing the imbalanced dataset was critical for model accuracy, and this was achieved through the application of SMOTE, which provided a more even distribution of class labels. Categorical variables were converted with one-hot encoding, ensuring they were appropriately formatted for the XGBoost algorithm.

Model tuning was both methodical and insightful. Delving into XGBoost's mathematical underpinnings, I worked with the second-order Taylor expansion to understand how the model calculates predictions and evaluates feature interactions. Adjusting the main tuning variables was a balancing act that brought clarity and precision to the model's performance.

$$obj = \sum_{i=1}^{n} l(y_i, \hat{y}_i^{t-1} + f_t(x_t)) + \Omega(f_t) = \sum_{i=1}^{n} l(y_i, \hat{y}_i^{t-1} + f_t(x_t)) + \gamma T + \frac{1}{2}\lambda \sum_{j=1}^{T} \omega_j^2$$

4 Critical Parameters for Tuning:

- η: ETA or "Learning Rate"
- max_depth: Controls the "height" of the tree via splits.
- γ: Minimum required loss for the model to justify a split.
- λ: L2 (Ridge) regularization on variable weights.

Throughout this project, I deepened my understanding of data science workflows, from the initiation of model building to detailed feature engineering and meticulous model comparisons. Our efforts were validated by the robust performance and practical utility of the final model, marking the project as both a successful learning experience and a valuable analytical undertaking.

Franco Iozzo

Transitioning Into The World Of Quantitative Finance

The Quantitative Finance industry has experienced a major growth in popularity over the past few years. With the advancement of computer systems, securities trading looks very different now compared to what it used to be at the start of the century. Long ago were the days of trades needing to be placed over the phone and agents being present on the exchange, with investments nowadays being as easily accessible to the population as they have ever been. Even discretionary trading has been eclipsed by the use of algorithms and complex mathematical models, which represents the majority of the trading volume present today in the markets. All these factors have contributed to an exponential innovation of the financial industry, but what does this mean for those of us in the pursuit of a career in trading?

While obtaining my Bachelor's degree in Finance and Business Administration, I was introduced to the concept of derivatives trading, which instantly caught my attention. As a young adult, the sheer potential of returns in the derivatives market, combined with the increased volatility and the multiple strategies available, forms a combination hard to resist. Clearly, these returns are neither easy to achieve, possess an exponentiated risk, and require an additional degree of risk management in comparison to their passive peers. The challenge presented to excel as a derivatives trader fueled my passion for finance, and motivated me to pursue a career in trading.

Once graduated, I accepted an offer from TD Ameritrade (soon to become Charles Schwab), to work as a stock-broker for the company. During the broker licensing process, my knowledge of the markets was exponentially increased. One of the things I love the most about finance is that, the more you increase your knowledge, the more you realize how much more there is to learn. Having completed my licensing process, the next few months were no exception to that rule. Quickly after becoming a broker, I transitioned into helping clients with options positions, and enjoyed multiple months of learning more every single day. By this time, I already had 3+ years of trading experience on my personal accounts under my belt, and my desire to transition from helping clients with their accounts to being in a hands-on trading role myself grew larger. Since there was no direct path to get there via the broker roles, I decided to study the requirements to obtain a position as a trader for firms, and stumbled along the world of quantitative finance.

Learning that it was possible to automatize my trading strategies for personal use, as well as the immensely interesting job opportunities in the field, gave me the final push to leave my job in favor of choosing a graduate program focusing on quantitative finance. After considering some options, I decided to join the Financial Mathematics Masters here at North Carolina State University. Given my non-quantitative background I knew the transition would not be easy at first, but accepted the challenge, and prepared for it. In the almost 3 months since joining the program, I've discovered that the world of quantitative finance is even more interesting than I thought. Being able to take my finance and trading knowledge to the next level by adding mathematical, statistical, and programming concepts, seeing how related those practices are, and the infinite innovations and ideas possible arising from those discoveries create an everlasting exciting experience. My passion for trading is as fueled as it has ever been.

As mentioned, the discipline of finance presents an endless knowledge pursuit, and the world of quantitative finance plays a big role in the process. As a lifelong learner, I will continue to explore this world and develop my skills, with the hopes of a soon to start successful trading career.

Brian James

Probability of Default Model for Single Family Mortgage Project

During the fall 2023 semester, I teamed up with a group of 4 peers from the financial mathematics program to build a probability of default model for single family mortgage loans. Our goals for the project were to identify strong predictor variables, on both a loan and macro-economic level, and use them to create a logistic regression model that would predict the default status of a loan two years in the future. Being able to calculate the probability of default is critical for measuring the potential losses that can be realized on a portfolio of loans. Working on this project has been a great learning experience and has allowed me to expand my knowledge of data analytics and the processes of model building.

Throughout the first month of our project work, our group collected loan level data from Fannie Mae's single family mortgage loan performance data. We conducted bivariate analysis to determine the correlation between the fields within the collected dataset and the current loan delinquency status. From this bivariate analysis we were able to select the input variables which would be included in our probability of default model, with some of the best indicators being loan to value ratio, debt to income ratio, and borrower credit score. Macro-economic indicators such as unemployment rate, VIX, 15 and 30 year mortgage rates were collected from Federal Reserve Economic Data. After collecting data and choosing the appropriate variables to include in the model, we created a data pre-processing procedure which would allow us to scale our model fitting in the future. Once the data was merged and processed, we began implementing random sampling methods to create our final dataset.

When fitting our logistic regression model, we used the train test split technique to properly train our model and test for accuracy. During the beginning stages of our model fitting, the largest challenge that we faced was dealing with an imbalanced dataset for training and testing. To overcome this challenge we tested multiple solutions such as a downsampling of our majority class, a bootstrapping method for upsampling the minority class, and adjusting class weights within the model fitting. Encountering a problem such as this was a good learning opportunity, as it taught me multiple approaches for dealing with imbalanced data. These approaches proved to be effective, reducing the number of false positive and negative predictions and increasing the accuracy score of the model to over 70%.

The conclusion of this project is still yet to be drawn, as more simulations need to be conducted under different economic environments. However, working on this project has been an amazing learning experience for me. It has allowed me to utilize my finance and data analysis skills as well as cultivating new technical skills. It was a pleasure to work alongside my fellow group members and put our communication and project management skills to the test. I look forward to the continued testing of our model and I'm excited to see the final product.

Manoj Katravath

The Intricate Interplay of Behavioral Finance and Quantitative Analysis

"In finance, as in life, behavioral aspects play a pivotal role. Emotion and reason, intuition and logic, human quirks, and mathematical models coalesce to shape the intricate fabric of the financial world."

Behavioral Finance and Quantitative Analysis, two distinct fields in the world of finance, converge in a fascinating interplay that sheds light on the complex nature of financial markets and investor behavior. This article delves into the intriguing relationship between these two domains and explores how their combination leads to a more comprehensive understanding of financial decision-making and market dynamics.

Behavioral Finance: Unraveling Human Quirks: Behavioral finance is a discipline that examines how psychological and emotional factors influence financial decisions. This approach recognizes that human beings are not always rational actors, as traditional financial theories assume. Instead, we often exhibit cognitive biases, emotions, and irrational tendencies that can have a profound impact on investment choices.

A survey by Barclays found that 61% of investors admitted to making impulsive investment decisions driven by fear or greed during times of market volatility. This impulsive behavior often stems from cognitive biases such as loss aversion and overconfidence.

Quantitative Analysis: The Power of Numbers: Quantitative analysis, on the other hand, leverages mathematical and statistical methods to analyze financial data, model market behavior, and optimize investment strategies. This field relies on hard numbers and mathematical models to predict and explain market trends, portfolio performance, and risk.

Quantitative analysis has demonstrated its prowess in risk management. According to a report by Axioma, portfolios optimized using quantitative models exhibited a 25% reduction in downside risk compared to market-cap-weighted portfolios.

The Intersection: Understanding Market Anomalies: The interplay of behavioral finance and quantitative analysis occurs at the intersection of human psychology and statistical models. This junction is where researchers and practitioners seek to understand market anomalies, situations where market prices deviate from what quantitative models predict.

One classic example is the momentum effect. Research by Jegadeesh and Titman found that over the past 40 years, strategies based on the momentum effect have outperformed the market by an average of 9% annually, demonstrating the practicality of applying quantitative techniques to behavioral biases.

Examples of the Interplay: Value vs. Growth Stocks: Investors often favor growth stocks over value stocks, exhibiting a behavioral bias. Morningstar data shows that growth stocks outperformed value stocks by 3.4% annually in the past decade, reflecting the impact of investor sentiment.

Herding Behavior: Behavioral finance recognizes the tendency of investors to follow the crowd, leading to market bubbles and crashes. Quantitative models can analyze this behavior, identifying potential market inefficiencies and providing opportunities for contrarian strategies.

Sentiment Analysis: The integration of social media sentiment analysis into quantitative models is an emerging trend. Behavioral finance insights guide the creation of sentiment indicators, while quantitative models process and interpret large volumes of sentiment data to predict market movements.

Benefits of the Interplay: The interplay of behavioral finance and quantitative analysis provides several benefits:

Improved Decision-Making: By recognizing and accounting for cognitive biases and emotional factors, investors can make more informed and rational decisions.

Risk Management: Combining behavioral insights with quantitative models allows for better risk assessment and mitigation strategies.

Enhanced Portfolio Management: Portfolios combining market anomalies and investor behavior achieved a 15% lower volatility with competitive returns, as per BlackRock.

Conclusion: The interplay of Behavioral Finance and Quantitative Analysis presents a powerful approach to understanding and navigating financial markets. By bridging the gap between human behavior and mathematical modeling, this synergy offers insights into market anomalies, enhances decision-making, and optimizes investment strategies. The recognition that financial markets are not solely driven by numbers but also by the complexities of human psychology underscores the importance of this interplay in modern finance.

Kundan Kotte

Quantum Leap in Finance

Quantum computing is an emerging technology leveraging the principles of quantum mechanics to perform complex calculation at an unprecedented speed and accuracy. By exploiting quantum bits also known as qbits that can exist in multiple states simultaneously, quantum computers can analyze vast datasets and multifaceted models much more efficiently than classical computers, through this quantum computing can revolutionize financial industry in multiple areas, some of which include:

Portfolio Management: Portfolio optimization is the process of optimizing the allocation of assets to balance the trade-off between risk and return. This involves analyzing historical data, predicting future performance and formulating investment strategies that can withstand market volatility. Quantum algorithms, such as Quantum Optimization Algorithm (QAOA) can potentially solve such problems more effectively compared to classical counterparts which often struggle with the sheer complexity and dimensionality of financial data. This could enable portfolio managers to identify optimal asset allocations that consider a broader range of factors and constraints, potentially leading to higher returns for a given level of risk. Quantum computing can also analyze complex nonlinear correlations between assets to achieve a more robust diversification strategy that minimizes risk.

Risk Analysis: Quantum computing can significantly improve the speed and accuracy of risk analysis by using quantum simulation techniques to run parallel simulations of multiple scenarios of economic and market conditions. This would provide more accurate risk assessments in a faster time, allowing for us to make real-time changes and adjustments in our position to navigate an adverse situation.

Predictions: Machine learning models with large and complex datasets can be enhanced using quantum algorithms, Quantum enhanced machine learning can further accelerate the advancements of AI. These algorithms could potentially analyze market sentiment, financial news, economic indicators with greater nuance leading to more informed and timely decisions while also preventing novel risks.

At the leading edge of quantum revolution, many companies are building quantum computer that aim to do things that classical computers cannot do or could only do in thousands of years. However, the capacity is only half the story, the notion of “quantum supremacy” is yet to be achieved for any practical applications. Moreover, the development of robust quantum algorithms for financial applications is an area of ongoing research.

Nevertheless, the financial industry is preparing for the quantum future. Banks and investment firms are beginning to invest in quantum computing research and collaborations between firms and quantum physicists are becoming more common. Given the pace of development, the big leap into the quantum age is not far ahead which would change the landscape of finance.

Lucas Li
Pairs Trading

In the last few months, I have been working on this pairs trading project and want to give a brief introduction to pairs trading.

Pairs trading is categorized as a statistical arbitrage strategy. This strategy remains market-neutral (or beta neutral) throughout the lifetime of trades and enables traders to profit from any market conditions: trend movements or sideways. Mathematical and statistical models are used to identify pricing disparities and bets that the spread will revert to its historical mean.

There are five main approaches relevant to pairs trading: distance approach; cointegration approach; time series approach; stochastic control approach; and, other approaches including machine learning and PCA. Here we mainly focus on the cointegration approach.

The framework relies on three key steps: preselection of potentially cointegrated pairs, testing for tradability, and trading rule design. Let's take a close look at these three steps.

In the preselection step, the common trends model(CTM) is often used to explain price variations. The log price is decomposed in a nonstationary, common trends component and a stationary, idiosyncratic component. A distance metric based on the absolute value of the Pearson correlation coefficient of the common factor returns is introduced to rank all possible combinations of pairs. The top pairs of the ranking have a higher probability of being cointegrated and thus of being suitable for trading.

In the testing for tradability step, the log prices of the preselected pairs are regressed according to a linear regression model. We test the residuals for stationarity with an adequate unit root test. One aspect I often pay attention to is the zero-crossing rate that has an effect on our trading rules.

Lastly, when designing trading rules, the general idea is that a trade is triggered when the spread deviates sufficiently far from its mean and closed upon mean-reversion. Some optimization techniques may be applied to determine optimal trigger level. They take into account the number of times certain trigger level is exceeded and therefore find the optimal level specific for each pair.

After going through these three steps, we analyze the results and test different trading rules in order to scale it up in the future. Statistical arbitrage is an interesting area. It will never go away because as more people pile into a strategy the alpha quickly vanishes, but it tends to create other opportunities. I will try to research more in the upcoming year.

Robin Li
Quantitative Risk Analysis

My career goal is to pursue a path in risk management and quantitative analysis, a field that combines my passion for mathematics, data analysis, and the thrill of managing and mitigating risks in various industries. This career choice is driven by a strong desire to work at the intersection of finance, statistics, and technology, where I can leverage my skills to make informed decisions that can have a significant impact on organizations and their stakeholders.

Risk management is an essential aspect of any business or financial institution. This field involves identifying, assessing, and managing risks that can affect an organization's performance and financial stability. Quantitative analysis, on the other hand, is a crucial tool in this process, as the work involves using mathematical and statistical models to evaluate data and make predictions about future outcomes. By combining these two disciplines, I aim to become a professional who excels in managing and optimizing risk through data-driven strategies.

In my future career, I envision working for a reputable financial institution, such as an investment bank, hedge fund, or insurance company, where I can apply my quantitative analysis skills to identify and mitigate risks effectively. These organizations deal with complex financial instruments, such as derivatives, and require individuals who can develop models to assess and manage the associated risks. My role would involve developing, implementing, and refining these models to help the organization make informed investment decisions, manage its portfolio, and ensure regulatory compliance.

I also see myself working closely with trading desks to provide insights based on quantitative analysis. This might involve developing algorithms for algorithmic trading, optimizing trading strategies, and creating risk management frameworks to ensure that the organization operates within predefined risk limits. This hands-on approach to risk management is something I find exciting, as it offers a dynamic and intellectually stimulating work environment where I can continually adapt to changing market conditions.

One of the appealing aspects of a career in risk management and quantitative analysis is the opportunity to make a positive impact on an organization's bottom line. By effectively managing risks, businesses can optimize their returns and weather economic downturns more effectively. This not only benefits the organization itself but also contributes to overall economic stability. Moreover, my work in this field would enable me to help protect the interests of investors, ensuring that their hard-earned money is managed with the utmost diligence.

To achieve my career goal, I have been diligently acquiring the necessary knowledge and skills. I have completed a rigorous education in mathematics, statistics, and financial modeling. I am well-versed in programming languages like Python and R, which are crucial for data analysis and model development. Additionally, I have gained practical experience through internships in financial institutions and research projects that have allowed me to apply quantitative analysis techniques to real-world problems.

Xinqian Li

An Exploration of Investment Management: A Dive into My Current Academic Project

In the expansive realm of finance, investment management stands as a paramount discipline, vital for both individual investors and colossal institutions alike. My current academic project “Quantitative Methods for Portfolio Optimization and Trading Strategies” aims to research and develop these techniques in an novel way, and gain significant knowledge and skills specific to mathematical modeling and quantitative portfolio optimization.

My journey began with a comprehensive study of "The Theory and Practice of Investment Management." This foundational text elucidates the principles that underline the complex world of investments. Grasping these principles was crucial, as they would later inform the analytical aspects of my project. With theoretical knowledge, I ventured into the practical realm, selecting diverse assets for analysis. These assets spanned various classes and sectors, ensuring a broad perspective. Each asset underwent a rigorous examination to gauge its historical performance, volatility, and potential returns. This step was vital for the subsequent portfolio creation. After an in-depth analysis, I embarked on the construction of what I termed the "ideal portfolio." This portfolio wasn't just a mere aggregation of assets; rather, it was crafted with a balance, ensuring optimized returns with minimized risks. The portfolio reflected a blend of both aggressive and conservative investment strategies, making it versatile across various market conditions.

To ascertain the portfolio's potential efficacy, I set benchmarks against recognized market indices. This comparative analysis provided insight into how the portfolio might perform in real-world scenarios and highlighted areas for potential improvement. One of the key components of the project was constructing the Efficient Frontier—a concept from the Markowitz Portfolio Theory. This frontier represents the set of optimal portfolios offering the highest expected return for a defined level of risk. This tool aids investors in understanding the risk-return trade-off.

While the Markowitz Portfolio Theory provided a foundational understanding of portfolio weights, I took it a step further by juxtaposing these weights against those determined by Market Capitalization. This comparison lent a practical edge, aligning theoretical knowledge with market realities. Stock prices, though seemingly unpredictable, often follow certain patterns or stochastic processes. Leveraging this, I applied a Stochastic Process on stock prices, using long-term mean and volatility data. This process was pivotal for generating views on potential stock movements.

The final phase of my project encompassed a comparative study between the Black-Litterman Model (BLM) and the traditional Markowitz Model. By applying both models to the same set of assets, I discerned the nuances in their views and the consequential changes in portfolio weights.

In conclusion, this academic project has been a holistic exploration into the intricate world of investment management. Through this endeavor, I have not only enhanced my understanding of investment strategies but have also equipped myself with tools and methodologies that are indispensable in the modern financial world.

Juan Lopez Cubides

About Cat Bonds And Their Dynamics With Financial Markets

CAT bonds were initially created to increase the capital available to cover catastrophes by insurance and reinsurance companies through transferring the higher end or the tail risk to the market. Since 2020, it is playing a key role for insuring flood events in states like Florida by ceding risks from the National Flood Insurance Program (Evans, FEMA gets upsized $275m new NFIP cat bond, but Reinsurance Tower shrinking 2023).

CAT bonds are fixed income instruments, where the face value amount to be paid to investors at the maturity of the security is contingent upon an event ensuing. An event is broadly defined as a natural peril (e.g. hurricane, earthquake, wildfires) occurring and the incurred losses or index or parameter due to the event reaching some predefined level, called the attachment point.

The second largest reinsurer in the world named Swiss Re, developed Cat Bond indices to further increase the attention of the market about the opportunities available in this alternative investment given its track record of positive returns over many years and as part of its ESG Strategy. In principle, the index is calculated with a value-weighted methodology across a basket of CAT Bonds from US Wind 25%, North America Multiperil 40%, North America Earthquake 9% and Europe 11%. The objective of the index is to tracks the prices, return and dynamism of a portfolio of CAT bonds representative of the market. The Bloomberg ticker of the index is SRGLTRR (Swiss Re Cat Bond Indices Methodology 2014).

Nowadays, issuance of bonds where the underlying risk are insurance risks other than catastrophes are increasing by nominal amount and also by the range of the underlying risks; in 2012, it was almost always the case that the bonds were issued for catastrophe purposes, but as of today there are also instruments called ILS that cover risks like Surety and Casualty (PIMCO Seeking Returns Beyond Traditional Assets 2019).

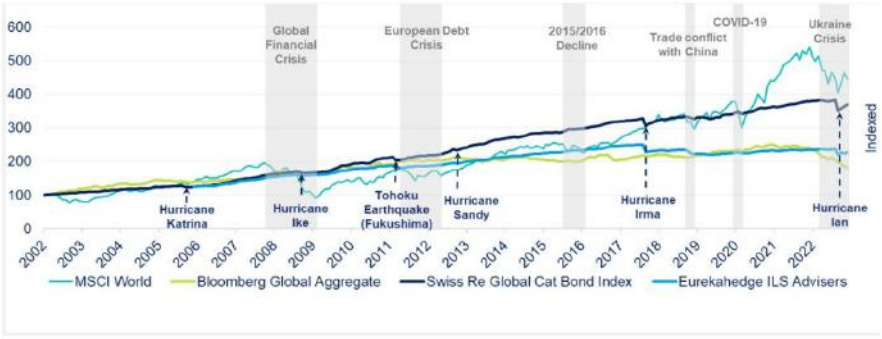


Figure 1 Normalized performance of various indices against the Swiss Re Global CAT Bond Index (SRGLTRR)

Asset Managers like PIMCO and Schroder, have introduced ILS (CAT and non-CAT) to institutional investors because of the portfolio's diversification potential and upward movement to the Markowitz efficient frontier when compared to portfolios without ILS (PIMCO Seeking Returns Beyond Traditional Assets 2019). In essence, these findings were the result of simply calculating the correlation matrix between the underlying risks of the CAT bonds and the other types of traditional asset classes.

Figure 2 Asset matrix correlation (Amundi Asset Management, Pioneer ILS Interval Fund 2023)

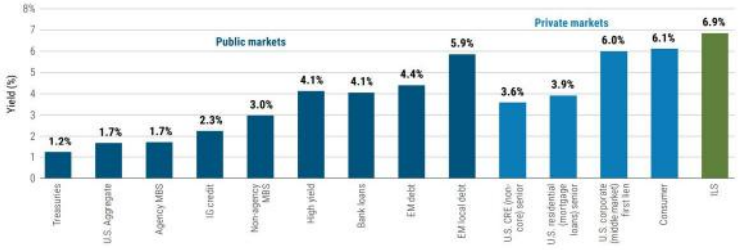


Figure 3 As of 12/31/21 using well-known indices for comparison purposes (PIMCO Seeking Returns Beyond Traditional Assets 2019)

	ILS model	60/40 portfolio	60/40 portfolio with 10% ILS
Estimated return[6]	8.0%	4.8%	5.1%
Estimated volatility[7]	14.6%	9.4%	8.8%
Sharpe ratio[8]	0.46	0.37	0.44
CVaR (95%)[9]	36.7%	17.9%	16.1%
Equity beta vs. MSCI ACWI	0.12	0.62	0.57

Figure 4 metrics calculated as of 12/31/21 using portfolios composed of well-known indices purposes (PIMCO Seeking Returns Beyond Traditional Assets 2019)

However, it is important to argue this approach is myopic, as it takes as assumption that not only the ILS underlying risk is not correlated to the systematic risk of the market, but also: the product placement is efficient and effective; capital is unlimited in the market; investors are only guided by risk-return metrics when choosing an investment; markets are efficient (Twelve Capital Annual Cat Bond Review & Market Outlook 2023).

The natural perils and the probability of the damaged caused to the insured portfolios reaching the triggers is not correlated to the systematic returns of the market, hence at time t=0 in the primary issuance offering the yield offered to investors, assuming this probability P is unique, is equal to P plus expenses and commissions.

(Continue Next Page)

Juan Lopez Cubides

About Cat Bonds And Their Dynamics With Financial Markets

(Continued From Previous Page)

At time t>0, in the primary issuance offering, the following arises:

I. CAT bonds compete for funding against other alternative investments like subordinate bonds, corporate hybrids, and structured credit. Accordingly, investors demand similar risk/return characteristics and conditions to be reflected in the indenture: this is cause because the lack of capital available, otherwise called lack of demand does not match the supply of CAT bonds. In 2022, there was a decrease in issuance activity because of the market unwillingness or lack of capital to absorb it (Twelve Capital Annual Cat Bond Review & Market Outlook 2023)

II. Competing alternative investments have a duration greater than 0, i.e. they are sensitive to the changes in interest rates. During the current Fed campaign 2021-2023 to reign down inflation in the US, these alternatives investments had their price marked down and consequently their yields increased. To stay competitive, CAT bonds during 2022 also saw the yields increasing by an unweighted average of 418bps. It is clear then, that by means of competition to other alternative investment, the duration is great than 0 and the correlation to Treasury yields is positive.

III. CAT bonds could be regarded as opaque markets because all the variables to determine their pricing are not available freely in the market. To determine their price investors should have access to the natural peril model being used, the insured portfolio and the expenses and commissions charged by the brokers for placement. However, there is model uncertainty because the CAT modelling used to price the bonds usually comes from results of AIR Worldwide and Moody's RMS modelling software and the version of the models between pricing and issuance might change the results drastically as models are revisited and improved based on new historical data. Furthermore, commissions and expenses are usually charged to the issuer of the bonds and not disclosed to the market. As there are drivers for uncertainty investors will charge a greater risk premia.

Despite the current shortcomings for CAT bonds, they are an attractive portfolio's diversifier for any institutional investor, as their risk-return characteristics are very competitive versus other securities available in the market.

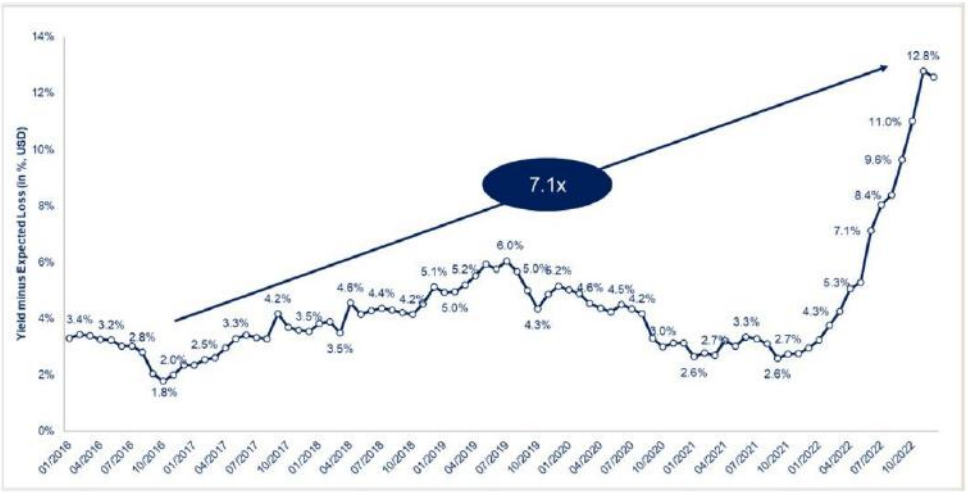


Figure 5 Expected total return: total yield minus expected losses for the period 2016 to 10-2022 for a representative basket of assets (Twelve Capital Annual Cat Bond Review & Market Outlook 2023).

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Prithwish Maiti

Understanding Federal Funds Rate and Interest Rate Modeling

The federal funds rate is the interest rate range established by the Federal Open Market Committee (FOMC). This rate correlates itself to the average rate that banks use for overnight borrowing from each other. Various financial managers, including those from insurance companies, pension funds, and hedge funds, heavily rely on the federal lending rate to rebalance and fine-tune their investment portfolios. In essence, this influences the rates at which banks offer loans to businesses, consumers, and other clients. When the federal funds rate is low, this typically leads to reduced interest rates on loans, thus promoting increased spending by businesses and consumers. Adjustments in the federal funds rate also has a ripple effect on other interest rates, including the Secured Overnight Financing Rate (SOFR), which serves as a benchmark used by banks to determine the interest rates applied to mortgages, other types of loans, and financial derivatives.

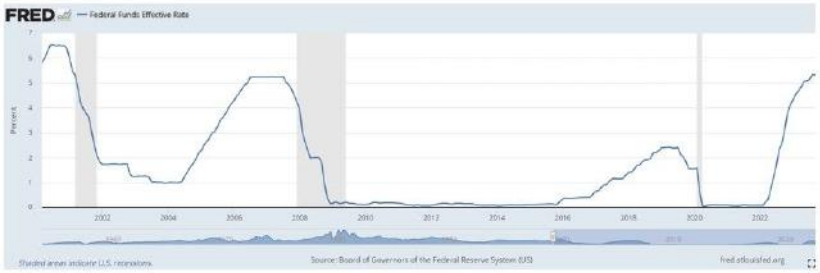
The Federal Reserve (the Fed) analyzes a lot of data, often called economic indicators, from various sources to understand the current state of the economy.

Consumer Price Index (CPI): The CPI, created by the Bureau of Labor Statistics, tracks the price changes of many goods and services. This is a key measure of inflation and affects things like cost-of-living adjustments, Social Security benefits, and government payments.

Gross Domestic Product (GDP): GDP measures the total value of goods and services a country produces. Think of this as a nation's yearly earnings. The Fed closely watches GDP to determine if the economy is growing or in a recession. GDP also impacts the stock market, but this is reported quarterly, so it is not an immediate indicator.

Unemployment: The Bureau of Labor Statistics monthly surveys employment in the U.S. The Fed pays close attention to unemployment to gauge the effects of policies. High unemployment might lead the Fed to take action like stimulus programs.

Stock Market: The stock market is important to the Fed because stock prices are based on a company's future earnings, not past performance. Some economists see this as a predictor of the economy's future behaviour, especially about six months ahead.



Amid the COVID pandemic, the Federal Reserve reduced the federal funds rate target by a total of 1.5 percentage points in meetings held on March 3 and March 15, 2020. These rate cuts brought the funds rate to a range of 0% - 0.25%. The federal funds rate is a reference point for various short-term and long-term interest rates, and this action aimed to stimulate spending by making borrowing cheaper for households and businesses.

As of October 2023, the key federal funds rate remains steady in a target range of 5.25% - 5.5% since July. This is a 22-year high designed to combat high inflation, which had recently reached near-record levels. The Federal Reserve continues to maintain their rate target within this range. In response to these high rates, investor confidence in their investments has dwindled, and concerns about potential losses or negative outcomes are growing.

Long-term interest rates, notably affecting mortgage rates, have surged. Thirty-year mortgage rates have reached their highest levels in over 20 years. Consequently, prospective home buyers are showing hesitation, and existing homeowners are reluctant to sell due to the increased costs associated with new mortgages needed to purchase homes. Existing home sales have declined to their slowest pace since October 2010. A combination of limited housing inventory and elevated borrowing costs has created affordability challenges for potential home buyers.

Hence interest rate modeling and forecasting become an integral part of portfolio management. These strategies become really important in hedging scenarios where the market risks, counter party, and credit risks have been eliminated.

(Continue Next Page)

Prithwish Maiti

Understanding Federal Funds Rate and Interest Rate Modeling
(Continued From Previous Page)

Here I will be discussing 4 methods:

$$r_t = \alpha + \beta r_{t-1} + \varepsilon_t$$
$$where\ \varepsilon_t = model\ error\ term\ at\ time\ E(\varepsilon_t) = 0;$$
$$\alpha, \beta = model\ coefficients\ to\ be\ determined$$

- A time series model, where Fed Funds rates are determined solely by past rates;

$$r_t = 1 + 1.5\, p_{t-1} + 0.5(u_{t-1} - 4)$$
$$p_{t-1} = lagged\ monthly\ inflation\ measured\ by\ CPI$$
$$u_{t-1} = lagged\ monthly\ unemployment\ rate$$

- The Taylor Model: Interest Rates Are Functions of Past Influential Factor. This method argues that Fed Funds are determined by the Fed's objectives to promote price stability and economic growth.

$$r_t = \alpha + \rho r_{t-1} + \beta(p_{t-1} - 2) + \lambda(u_{t-1} - 4) + \varepsilon t$$
$$p_{t-1} = inflation\ rate\ at\ time\ t - 1$$
$$u_{t-1} - 4 = excess\ unemployment\ at\ t - 1$$

- The Economic Model:Interest Rates Are Functions of Past Rates as Well as Influential Factors
- Higher-order non-linear predictive methods including neural networks predicting from macroeconomic parameters discussed above.

Using monthly data from 1958 to 2005 of several important macroeconomic variables, the results show that econometric modelling performs better than the other approaches. Other data segregation procedures to perform local learning. One such example is splitting the data based on ranges of federal rates- high (> 10%), mid (5-10 %), and low (< 5%). Thus, the FFR shows a lot of regime behavior. There is also scope of introducing and adding a seasonality effect.

Jayanth Maruthayan Elangovan

Mortgage-Backed Securities

Mortgage-backed securities (MBS) are a financial instrument that revolutionized the way mortgages are financed and traded in the United States and beyond. These securities play a critical role in the modern financial system, providing benefits to both borrowers and investors.

Mortgage-backed securities are financial instruments that represent a claim on the cash flows generated by a pool of residential mortgages. They are typically issued by government-sponsored enterprises (GSEs), such as Fannie Mae and Freddie Mac, or by private financial institutions.

The process begins with the origination of individual mortgages, which are then bundled together to create a mortgage-backed security. These securities are typically divided into different tranches, each with varying levels of risk and return. Investors can purchase these tranches, thereby investing in a portion of the underlying mortgage pool. The structure of mortgage-backed securities is characterized by the "pass-through" feature, where the interest and principal payments made by homeowners are passed through to MBS investors.

Investors receive periodic payments in the form of interest and principal, which can vary based on the performance of the underlying mortgages. This structure effectively transfers credit risk from the originators of the mortgages to the investors in the MBS. In addition to the pass-through structure, there are other MBS variations, such as collateralized mortgage obligations (CMOs), which further divide cash flows and risk among different tranches.

Mortgage-backed securities have had a profound impact on the financial markets and the housing industry. They offer several advantages to both investors and borrowers. For investors, MBS provide a diversified and liquid investment option, as they can invest in a broad portfolio of mortgages rather than individual loans. This diversification helps spread risk.

MBS are also considered relatively safe, particularly when backed by government agencies like Fannie Mae and Freddie Mac, as they are implicitly guaranteed by the U.S. government. On the borrower side, MBS have contributed to the availability of mortgage credit. By allowing lenders to sell mortgages in the secondary market, originators free up capital, which can then be used to make more loans. This increased liquidity in the mortgage market has resulted in lower interest rates for borrowers, making home ownership more accessible.

However, the widespread use of MBS also played a role in the global financial crisis of 2008. Complex MBS structures, including subprime mortgage-backed securities, led to uncertainty and losses among investors. The crisis exposed weaknesses in risk management, rating agencies, and regulatory oversight, resulting in widespread economic consequences.

In conclusion, mortgage-backed securities have been a transformative financial innovation that has shaped the housing market and investment landscape. They offer diversification, liquidity, and accessibility for investors and borrowers alike. Nevertheless, their complexity and the lessons learned from the 2008 financial crisis emphasize the importance of robust risk assessment, regulatory oversight, and responsible lending practices in the MBS market. Mortgage-backed securities remain a significant and evolving component of the global financial system, and their impact continues to be a subject of debate and study in the finance industry.

Sagar Prasad

Navigating The World Of Quantitative Finance: My Journey At Nc State

In the dynamic realm of quantitative finance, the pursuit of knowledge and the relentless quest for optimization propel us forward. At North Carolina State University, I've had the privilege of embarking on a journey that brings me closer to my career goals and equips me with valuable insights and skills. In this article, I'll share my experiences and research endeavors, the wisdom I gained from a conversation with a Vice President in Risk at Nomura, and how the courses I'm taking at NC State are shaping my path toward a successful career in quantitative finance.

Currently, my research focus is on collar strategies, a captivating area in options trading. Collar strategies aim to hedge risk while still participating in the potential upside of an underlying asset. Specifically, I'm working on finding the most optimized collar for a naked long position on an index with various money-less levels of out-of-the-money (OTM) call and put options. The objective here is to strike the perfect balance between risk mitigation and profit potential.

A crucial aspect of collar strategies that I've learned is the need to tailor the strategy to one's specific market outlook and risk tolerance. Depending on the market conditions and your view on the underlying asset, you can fine-tune the collar to either maximize protection or allow for more upside potential. This customization highlights the flexibility and adaptability required in quantitative finance.

Recently, I had the privilege of conversing with a Vice President in Risk at Nomura, a global financial services group. Our discussion provided me with invaluable insights into how Nomura operates and optimizes risk management. One essential takeaway was the significance of a comprehensive risk management framework in financial institutions. Nomura's approach to risk optimization is grounded in rigorous quantitative analysis, underscoring the importance of quantitative skills in the industry.

As a student at NC State, I have the honor of learning from accomplished professors and participating in courses directly relevant to my career aspirations. Some of the courses I am currently taking, such as "Applied Time Series Analysis," "Machine Learning in Finance," "Options and Derivative Pricing," and "Statistics," are instrumental in my journey toward becoming a successful quant.

In "Applied Time Series Analysis," I've learned how to model and forecast financial time series data, a skill invaluable for understanding market trends and making informed trading decisions. Machine learning in finance has exposed me to cutting-edge techniques for pattern recognition and predictive modeling, giving me a competitive edge in the field.

Options and derivative pricing, a cornerstone of quantitative finance, is equipping me with the knowledge and skills required to value and trade these financial instruments. This knowledge is essential for anyone aiming to navigate the complex world of financial derivatives.

Statistics, the backbone of quantitative analysis, provides me with a solid foundation in data analysis, risk assessment, and decision-making. The ability to analyze data and make data-driven decisions is a critical skill in the financial world, where precision and accuracy are paramount.

One unique aspect of my experience at NC State is the weekly seminars with top industry professionals. These seminars have been a treasure trove of knowledge and insights into the industry. Learning from seasoned experts in the field has been an eye-opening experience, and has given me a clear understanding of the skills and knowledge required to thrive in the quantitative finance sector.

Another significant aspect of my journey at NC State is getting accustomed to wearing business attire. While this may seem like a minor detail, it's an essential part of preparing for the professional world. Wearing business attire to seminars, meetings, and presentations has not only boosted my confidence but also instilled a sense of professionalism crucial in the financial industry.

In conclusion, my journey in quantitative finance at NC State is a testament to the transformative power of education and networking. Through my research on collar strategies, I'm developing a deep understanding of options trading, and my conversation with the Vice President in Risk at Nomura and other top industry professionals has enriched my knowledge of risk optimization in the industry. The courses I'm taking at NC State are honing my quantitative skills, equipping me with the tools necessary to succeed in this demanding field.

As I continue this path, I am excited about the opportunities that lie ahead. With the knowledge and experiences gained at NC State, I am well-prepared to face the challenges of quantitative finance and pursue my career goals with confidence and enthusiasm.

Zhao Qu

The U.S. Economic Cycle: Consumer Behavior and Federal Reserve Policies Analyzed

In recent years, the U.S. economy has successfully maneuvered through a range of ups and downs, starting with the aftermath of the financial crisis and extending to the challenges posed by a global pandemic. Throughout this period, the U.S. economy has consistently demonstrated an ability to adapt and expand. The economic journey can be divided into four distinct phases chronologically：

1. Post-Financial Crisis Recovery (2008-2010):
The 2008 financial crisis dealt a heavy blow to the U.S. economy, causing a spike in unemployment rates, a crash in the housing market, and unsettling financial markets. Government intervention, including financial institution bailouts and stimulus packages, helped stabilize the economy. Over time, with declining unemployment and recovering GDP, the economy gradually improved. This phase underscored the stabilizing effect of prompt government action, which, despite short-term fiscal deficits, laid the groundwork for long-term economic stability.

2. Sustained Recovery and Job Growth (2010-2016):
In the years following the crisis, the U.S. experienced steady recovery, marked by robust job creation and gradual GDP growth. Low-interest rates and proactive monetary policy fueled consumption and investment. The rise of the tech industry became a growth engine, generating numerous high-paying jobs. Yet, this period also highlighted growing income inequality, with some groups experiencing slower wage growth, prompting an issue policymakers would need to address.

3. Tax Reforms and Trade Policies under the Trump Administration (2017-2020):
With President Trump's tenure, sweeping tax cuts were implemented to stimulate economic growth and attract investments. Concurrently, the administration's assertive trade policies led to disputes, particularly with China, contributing to global trade tensions. These measures spurred growth but also caused domestic and international contention and volatility. The tax cuts boosted corporate investment but widened the fiscal deficit, while trade tensions disrupted global supply chains and impacted industries, highlighting the need for caution in trade policy to avoid economic disruptions.

4. The Economic Impact of COVID-19 (2020-Present):
The outbreak of COVID-19 in 2020 severely affected the U.S., leading to lockdowns and restrictions that halted economic activities. Unemployment soared, and many businesses struggled. The government enacted massive fiscal and monetary stimulus to support individuals, businesses, and healthcare. With the rollout of vaccines and the pandemic's control, the economy began to recover, yet uncertainties and challenges remain. The pandemic brought unprecedented shocks to the U.S. economy, with lockdown measures temporarily shutting down industries, spiking unemployment, and weakening consumer spending and investment. Government stimulus, including direct payments to individuals and families, business loans, and increased healthcare resources, bolstered short-term recovery but raised concerns over fiscal sustainability and increasing debt.

5. Looking Ahead:
In the coming years, the U.S. economy will face challenges and opportunities. On one hand, sectors like technology innovation, green energy, and infrastructure investment could drive new growth. Technological advancements promise new industries and job opportunities but also demand policies to support development and address potential social impacts. On the other hand, issues such as inflation, income inequality, and trade relations require effective management. Inflation concerns could impact consumer purchasing power, demanding a balanced monetary policy. Income inequality, already a significant concern, may be addressed through tax and welfare reforms. In trade, finding a balance between cooperation and dispute will be crucial for safeguarding economic interests.

Government policy will play a pivotal role in shaping the economic future. With global focus on sustainable development and environmental protection, transitioning to green energy and reducing carbon emissions will be paramount. Additionally, investments in infrastructure, fostering technological innovation, and improving education quality will underpin the future success of the U.S. economy.

Kavya Regulagedda

Fitch Downgrade of U.S. Treasuries Credit Rating

On August 1st 2023, Fitch Ratings downgraded US Treasuries from a AAA rating to AA+. In this article we will analyze the reasons for this credit rating drop and its impact on investments.

Several key aspects are to be considered. The timing of this decision appears unusual since the credit downgrade follows the resolution of the debt ceiling standoff. Treasury notes and bonds are debt instruments issued by the US government due a deficit resulting from their expenditure outweighing their revenues. This fiscal imbalance requires the government to determine the extent of their borrowing, also known as the debt ceiling. The debt ceiling standoff is when the government reaches the debt ceiling and at this point the government needs to increase the debt ceiling to prevent default on its outstanding debt. However, one factor contributing to the downgrade of the credit rating is precisely this rapid increase in government debt and reflects expected fiscal deterioration over the next years.

This credit rating drop is comparable to that made by S&P in 2011 where the rating went from AA+ to AAA as well. However, the drop in Fitch's rating is not expected to have any significant impact on investments since very few investments mandate a AAA rating. Plus, this new rating in no way impacts the US treasury's reputation as a highly liquid and extremely safe investment. There will be no impact on the ability of the US to pay of debt. This also speaks to Fitch as a credit rating agency and its lower relative market influence in comparison to Moody's and S&P.

Fitch also believes that there has been a decline in the state of governance with respect to fiscal and debt management over the past 20 years. Additionally, a complex budgeting process and absence of a medium-term fiscal framework as well as tax cuts and new spending initiatives have subsequently resulted in increased debt.

Despite a lower debt to GDP ratio in the past two years relative to the pandemic high we are still running a higher ratio than pre pandemic and it is predicted to rise reaching 118.4% by 2025. The forecasted predictions in rise of the debt to GDP ratio reflects an increased susceptibility of the US to economic shocks.

The bottom line however, is that this downgrade of US Treasury credit rating by Fitch will have no direct impact on investments and is more of a comment on the willingness of the United States to service debt than it is about the ability of the US to pay off debts which accurately explains why this will have little to no impact on willingness of investors to buy Treasuries and the inherent safety of them.

Yug Sharma

Volatility Index Modeling Project

Forecasting market sentiment has long been a coveted skill I have aspired to cultivate, given its pivotal role in my pursuit of a career as a quantitative trader. During my tenure at NC State University, I seized the opportunity to collaborate on a team project that aligns with this aspiration. I am currently engaged in a project that employs time series analysis, statistical methodologies, and machine learning techniques to construct a model for the Volatility Index (VIX). This model incorporates a diverse set of critical macroeconomic factors, such as the 30-year mortgage rate, BBB corporate bond yield, unemployment rate, and an additional 20 macroeconomic variables.

We began with acquiring data from sources like Yahoo Finance and FRED, followed by meticulous data cleaning within the Jupyter Notebook environment. This initial data preparation phase was critical, as the precision and structure of our dataset hold prominent significance in facilitating accurate model predictions and comprehensive analysis.

After data preprocessing, we partitioned our dataset into two segments: 80% for training and 20% for testing. We subsequently subjected our data to machine learning models, including ARIMA, ARIMAX, SARIMAX, and ARIMAX-GARCH. This data partitioning is a key component of our data analysis, enabling us to assess the performance of our predictive models. We trained our models using 80% of the historical data, allowing them to determine the historical behavior of the Volatility Index concerning our macroeconomic variables. This paved the way for rigorous testing of our models on the remaining 20% of data, evaluating their precision in forecasting the index. Implementing diverse time series analysis and machine learning models yielded varying predictions, underscoring the need to test multiple models within our defined time constraints.

In addition to these model evaluations, we generated visual representations based on the range of outcomes we observed. Presently, our focus lies in the feature selection phase of our modeling. In this phase, we are exploring a range of feature selection methods, including Backward Elimination, Forward Elimination, and Recursive Elimination. We aim to discern which macroeconomic factors are most conducive to enhancing our model's effectiveness in predicting the Volatility Index.

In summary, our project at NC State University has provided a valuable opportunity for us to delve into data analysis and market prediction. By diligently applying time series analysis, statistical tools, and machine learning techniques, we have delved into the intricate connection between the Volatility Index and an array of macroeconomic variables. As we continue to refine our model, we are actively acquiring invaluable skills that can be readily applied in real-life scenarios as we advance in our professional careers.

Shirley Shi

Career Goals as a Risk Analyst

Having worked as a quantitative analyst intern, I aspire to build a rewarding career in risk analysis and management. My work as a quantitative analyst intern entailed reading and making summaries about quantitative trading literatures. During my internship I felt quantitative analysis was more theoretical than practical, limiting its relevance in creating organizational value. In contrast, I found risk analysis and management closely related to applications, such as optimizing capital allocation, enhancing operational efficiency, and strategic decision support. Consequently, with a quantitative background, having completed an undergraduate degree in mathematics, I decided to pursue risk management to solve practical problems facing modern organizations.

I learned the changing risk analysis environment during a recent networking experience. During the conversation, the risk analyst from Société Générale introduced me to the likely emerging risk management priorities in modern organizations. Previously supply chain risk ranked highest in my mind, I learned from the conversation that emerging technologies, such as artificial intelligence, are already shaping the risk management discipline. Moreover, I learned from the panel that organizations are increasingly seeking ways to address environmental, social, and governance risks even as they seek to boost their financial performance. Given the fast-changing nature of the risk environment, I learned that analysts will rely on big data analytics to enhance risk assessment and prediction. This understanding fueled my desire to pursue a financial mathematics course to gain specialized risk analysis knowledge and develop a credible profile in the professional community.

A career in risk management presents immense opportunities for growth and development. Many of the leading risk analysts in the industry started as entry-level risk analysts and rose to chief risk officers, risk managers, and other senior positions. In addition, the career presents sufficient intellectual challenge to promote cognitive learning, creativity, and critical thinking. These skills will help me to navigate the change and uncertainty inherent in the modern workplace. Moreover, the successful handling of risk management challenges will provide a strong sense of achievement and self-assurance, positioning me for even harder challenges and a more rewarding career.

I also aspire to expand my professional network. This network will be a platform for learning and knowledge sharing, enabling me to remain relevant in the fast-changing professional environment. In addition, I will use the network to raise my profile in the industry. Furthermore, the network will enable me to broaden my horizons and learn different perspectives needed to address critical problems.

My long-term goal is to become a risk management subject matter expert. This designation will create opportunities for research, and practice engagements locally and abroad. In addition, this will enable me to solve critical societal challenges. Moreover, the raised professional profile will allow me to foster positive societal transformation, and harness emerging technologies for sustainable development.

Building a successful risk management career has been one of my main goals in life. Besides creating a platform for personal growth and achievement, the career will enable me to solve major societal challenges. Pursuing this financial mathematics course is the first step in the long road to becoming a renowned subject matter expert on risk management. I will use this profile to shape policies on risk management research and practice.

Aman Syed

The Making of a Quant: Financial Mathematics at NC State

Growing up in a middle-class family in India, my encounter with mathematics started from an early age. My father, a metallurgical engineer, passed on his learnings and love for the subject as I started getting familiar with numbers and arithmetic. Sure enough, I shared the same fascination and dived into the intricacies of mathematics with gusto, in awe of its beauty and wondering how it lies at the core of every physical and imaginary phenomenon out there, like a language transcending dimension and providing answers to the ways of the universe.

A strong yearning and an adept aptitude for Mathematics led me to a fulfilling journey on my way to pursuing my Master of Financial Mathematics degree at North Carolina State University (NCSU). At NC State, I have had the privilege of embarking on a journey to decipher the world of Quantitative Finance and bringing me one step closer to fulfilling my career goals. Throughout the course of this article, I will focus on my research at NC State, my career interests and how the academic coursework at NCSU has helped shape my foundation in Financial Engineering and provided a medium to excel in a career in this field.

Currently, I am researching in the pricing of Fixed Income bonds using Interest Rate and volatility calibration models. Using Monte-Carlo methods and Interest Rate models like Vasicek, Cox-Ingersoll-Ross, and the Hull-White model, I have been simulating the interest rates for the next 10 years and using that to create pricing models on fixed-income bonds. These models are then perfected by calibrating the parameters using methods like Maximum Likelihood Estimate, Least Squares, and the Long-Term Quantile method. This project has provided me with a deep insight of the fixed-income markets and bond pricing, as well as helped develop a thorough understanding of stochastic processes and modelling, a skillset that will be an asset in my professional career going forward.

My academic coursework has helped me develop a foundation in courses directly relevant to my career aspirations in Quantitative Research and study under accomplished professors to help refine my craft. The courses that I am taking this Semester, like ‘Statistical Inference, ‘Applied Time Series’, ‘Options and Derivatives Pricing’ and ‘Machine Learning in Finance’, are a steppingstone to the world of Quantitative Finance.

In "Applied Time Series Analysis," I've acquired the skills to model and forecast financial time series data, essential for understanding market trends and informed trading decisions. "Machine Learning in Finance" has exposed me to cutting-edge techniques in pattern recognition and predictive modeling, giving me a competitive edge. "Options and Derivative Pricing" equips me with knowledge to value and trade these financial instruments, a key fundamental in quantitative finance. "Statistics" provides a strong foundation for data analysis, risk assessment, and data-driven decision-making, crucial in the financial world.

Additionally, I benefit from weekly seminars with industry professionals, offering invaluable insights into the field. Learning from experts has provided a clear understanding of the skills and knowledge required to succeed in this industry.

NC State has helped convert my professional journey and career aspirations, into a dream soon to be turned to reality. I have been able to build an all-round foundation in Quantitative Finance, be it in shaping my academic dictionary or building my network with seasoned professionals of the game. I am eager to experience the journey and the joy that lies ahead and can confidently say that pursuing a master’s in financial math at NC State, has been one of the best decisions and definitely the most enriching experience of my life.

Abhiram Vadlamani

Suitability and Aspirations

Pursuing a master's degree in quantitative finance at NC State University is the next logical step in my academic journey, given my strong foundation in actuarial science and finance from my bachelor's degree. During my undergraduate studies, I developed a keen interest in the intersection of mathematics, statistics, and finance, which naturally led me to the fascinating realm of quantitative finance. Through my coursework, I gained a solid understanding of financial theories, risk management, and data analysis techniques, all of which are fundamental to the field of quantitative finance. These skills equipped me with a quantitative mindset, enabling me to analyze complex financial data and make data-driven decisions—a crucial aspect of any quantitative role.

Furthermore, my passion for quantitative finance has motivated me to explore machine learning and its applications in the financial industry. I believe that integrating machine learning techniques with traditional quantitative methods can provide invaluable insights, enhance predictive models, and optimize investment strategies. My background in actuarial science has honed my mathematical and statistical skills, essential for grasping the intricacies of machine learning algorithms. Additionally, my proficiency in finance has given me a deep understanding of the industry-specific challenges and opportunities, allowing me to identify innovative ways to leverage machine learning for financial applications.

In preparation for my future career as a quantitative analyst and researcher, I have actively engaged in hands-on projects and sought practical experience in machine learning. I have undertaken online courses and participated in workshops focusing on machine learning algorithms, deep learning, and data analytics. These experiences have allowed me to explore diverse applications, such as trading, risk modeling, credit scoring, and portfolio management, within the financial domain. By gaining practical exposure to real-world problems, I have cultivated problem-solving skills and the ability to apply machine learning techniques to complex financial datasets, bridging the gap between theory and application.

My decision to pursue a master's degree at NC State University stems from the institution's renowned faculty, cutting-edge research facilities, and industry connections, all of which will provide me with an unparalleled learning experience. I am eager to collaborate with experts in the field, engage in research projects, and contribute to the ongoing advancements in quantitative finance and machine learning. I am confident that the rigorous curriculum, coupled with the collaborative and innovative environment at NC State, will empower me with the knowledge and skills necessary to excel in the evolving landscape of quantitative finance.

In conclusion, my diverse academic background in actuarial science and finance, coupled with my enthusiasm for quantitative finance and machine learning, positions me as a promising candidate for roles in quantitative analysis and research. Through my master's studies at NC State University, I am dedicated to further developing my expertise in mathematics and data science, pushing the boundaries of knowledge, and making meaningful contributions to the intersection of machine learning and finance. I am excited about the prospect of leveraging my past skills and the education I will receive at NC State to shape the future of quantitative finance and make a significant impact in the field.

Yuqi Wu

Reasons Why I Chose NC State's Financial Mathematics Program

Ever since I was a child, I've wondered about the nature of things: Why are bubbles round? Why have humans always fought throughout history? But, when I was in high school, I happened to come across the book Currency Wars by Hongbing Song, which offered a novel point of view on the way things are, but this time with finance adding an added layer of complexity: "History," Song asserts, "is a big movie in which politicians are the stars and financial conglomerates are the directors." While the content featured in this book offered a unique perspective as to how finance factored into some the world's greatest problems, it could not answer all my questions, so I chose to major in mathematics and applied mathematics in university. In doing so, I hope to use the knowledge I obtained throughout my coursework to better explore, and subsequently apply, the nature of finance in the future.

One of the reasons I am drawn to mathematics lies in the fact that "the mathematical method permeates and dominates all the theoretical branches of the natural sciences; in other words, it is at the heart of all scientific inquiry." In my last three years of study, I have not only gained a firm grasp of a variety technical concepts, but also gained certain essential skills, as well, including the ability to analyze problems rationally and systematically. The theoretical courses to which I was exposed are what cultivated such rational thinking.

Throughout all of my studies, however, I never lost sight of my true passion: finance. I watched online courses, studied for the chartered financial analyst exam by myself, and regularly followed all pertinent financial news. All these self-study efforts have enriched my financial knowledge and reaffirmed my commitment to finance as my future area of study.

There are two main reasons that motivated me to apply for NCSU's financial mathematics major, the first of which is that applied mathematics takes the basic theories and methods underpinning the study of mathematics and translates them to meaningful and ubiquitous contexts. This major can use mathematical tools to explain financial principles, thus putting knowledge into practice. Second, with its renowned faculty and advanced teaching methods, NCSU offers the academic environment I have been searching for. Here, I believe I will meet all kinds of people and encounter a host of ideas, which will both broaden my mind and develop me as a person.

Now that I've been in the Financial Mathematics program for almost three months, I've learned what I've been craving, met teachers who are each unique, and made interesting friends. I hope I can continue to work hard, cherish this time and realize my dreams.

Hongyi Xia

Finite Difference Method on Black-Scholes-Merton Model

Black-Scholes-Merton Model is a one dimensional heat equation under the partial differential equation that allows us to determine the value of the option (European call or European put) based on the input variables time t and the price of the underlying asset S, together with other known constant variables risk-free interest rate r and volatility of the underlying asset σ. We can represent the partial differential equation for the Black-Scholes-Merton Model as follows:

$$V_t + \frac{1}{2}\sigma^2 S^2 V_{SS} + rSV_S - rV = 0$$

Considering we have a European put option for a given strike price, a current price of the underlying asset, risk-free rate, and the volatility of the underlying asset, we are interested to find out the value of the put at time 0 for a given price of underlying asset.

One method we can apply to find the solution is the finite difference method. The main idea behind the finite difference method is estimating each individual derivative with finite differences, such that all values of time and Price of the underlying asset are discretized. Our partial differential equation will become:

$$\frac{V_{i,j} - V_{i,j-1}}{h_t} + \frac{1}{2}\sigma^2 S^2 \frac{V_{i+1,j} - 2V_{i,j} + V_{i-1,j}}{h_S^2} + rS\frac{V_{i+1,j} - V_{i-1,j}}{2h_S} - rV = 0$$

After simplification and re-arrangement of the terms, it will become:

$$[\frac{1}{2}h_t(\sigma^2 i^2 + ri)]V_{i+1,,j} + [1 - h_t(\sigma^2 i^2 + r)]V_{i,j} + [\frac{1}{2}h_t(\sigma^2 i^2 - ri)]V_{i-1,,j} = V_{i,j-1}$$

Based on the equation above, we can represent the value of the option for all possible values of price of underlying asset at j - 1 time as the value of the option for all possible values of price of underlying asset at j time multiplied by a matrix shown below:

$$B + AV_j = V_{j-1} \qquad (1)$$

$$V_j = \begin{pmatrix} V_{1,j} \\ V_{2,j} \\ \dots \\ V_{m,j} \end{pmatrix}, V_{j-1} = \begin{pmatrix} V_{1,j-1} \\ V_{2,j-1} \\ \dots \\ V_{m,j-1} \end{pmatrix}, B = \begin{pmatrix} [\frac{1}{2}h_t(\sigma^2 1^2 - r)]V_{0,j} \\ 0 \\ \dots \\ 0 \end{pmatrix}$$

$$A = \begin{pmatrix} 1 - h_t(\sigma^2 1^2 + r) & \frac{1}{2}h_t(\sigma^2 1^2 + r * 1) & \dots \\ \frac{1}{2}h_t(\sigma^2 2^2 - 2r) & \dots & \dots \\ \dots & \dots & \dots \\ \dots & \dots & 1 - h_t(\sigma^2(m-1)^2 + r(m-1)) \\ \dots & \frac{1}{2}h_t(\sigma^2 m^2 - r * m) & 1 - h_t(\sigma^2 m^2 + r) \end{pmatrix}$$

For the boundary conditions, the value of the option with 0 underlying asset price for all values of time can be represented as $V_{0,j} = Ke^{r(j-T)}$ where T is the time of maturity. We determine a large enough boundary for underlying asset price, like 10 times the strike price, such that the value of the option with 10 K underlying asset price for all values of time can be represented as $V_{10K,j} \approx 0$. For the value of the option for all values of underlying asset price at maturity. This can be represented as the payoff of the put option $V_{i,T} = max(\tilde{K} - \tilde{S}_i, 0)$

This method can be realized through applying forward finite difference method. The choice of h_S and h_t needs to satisfy the stability condition, where $h_t \leq \frac{1}{2}h_S^2$.

Going back to equation (1), since we already know all the boundary conditions, we can apply equation (1) recursively starting from the upper boundary $V_{i,T}$ to give us the value of the option for all values of underlying asset price at time 0 represented as $V_{i,0}$. This enables us to find out the solution of the problem.

As we reduce step size of price h_S to increase the number of steps along the price domain, we may realize that the estimated value of the option based on the finite difference method tends to converge to the true value of the option derived from the Black-Scholes formula. We regard the absolute difference between the estimated value and the true value as the 'Error'. As we work out the estimated value of the option with finite difference method based on various feasible number of steps along the price domain, we can derive the corresponding 'Error' values. We gather those feasible number of steps and the corresponding 'Error' values as dataset and abbreviated them as N_S and Err respectively. We generate a linear regression with $\ln(\text{Err}) = \text{m}\ \ln(N_S) + \text{c}$ based on the dataset. We may realize that the value of m in the regression approach -2 as the size of dataset increases. To interpret this -2 in the line$N_S$egression, we can say as is increased by a multiplicative factor of X, EX^2ll reduce by dividing factor of .

Prachi Yadav

WeWork: Entering Chapter 11 Bankruptcy

WeWork, once celebrated as the vanguard of the office industry, now faces severe uncertainties about its future. Unlike traditional real estate booms that left behind tangible assets like skyscrapers or luxurious apartments in rural Italy, WeWork's legacy is less concrete. The company has operated with an "asset-light" strategy—leasing buildings from developers, then renting out subdivided spaces on short-term leases to various businesses, emblematic of the "sharing economy" and the shift toward more adaptable work environments.

Based in New York and grappling with substantial debt and persistent losses for years, WeWork's valuation plummeted from a one-time peak of $47 billion to a current market capitalization of around $60 million. The firm, launched in 2010 during a venture capital market surge, quickly became known for its rapid revenue growth and the dynamic leadership of co-founder Adam Neumann. However, the company's fortunes have drastically reversed, with its stock value halving on November 1st alone. From its 2019 valuation, WeWork has shed $46.4 billion in value over four years—evaporating like a sandcastle in the breeze.

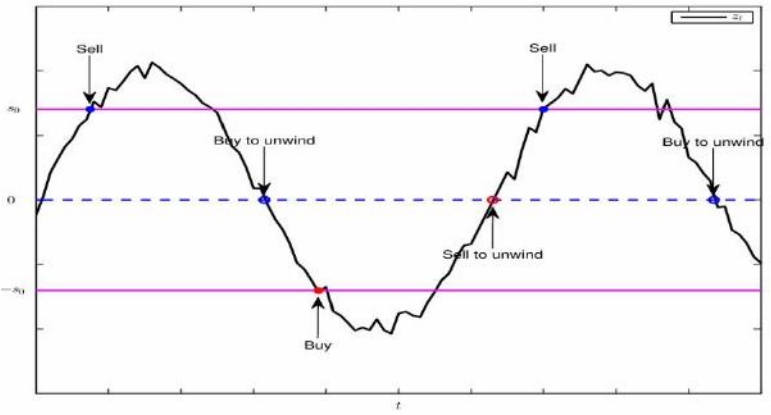
In 2021, the acquisition by BowX was seen as a chance to reverse the company's fortunes. Yet, by 2022, financial struggles forced the closure of 40 locations, and by 2023, the weight of its debt left WeWork struggling to regain stability. Fitch Ratings has highlighted
WeWork's missed interest payments and continued cash burn, signaling trouble ahead. As the startup deteriorates, it's the investors who bear the brunt. SoftBank, especially, has felt the sting, having been a major shareholder through its Vision Fund. SoftBank's significant investment aimed to steer WeWork back to profitability, but the venture now seems uncertain with the Chapter 11 filing looming overhead.

Despite these setbacks for WeWork, Neumann has managed a remarkable Silicon Valley-style return. His new startup secured an impressive $350 million from Andreessen Horowitz in August 2022—the firm's most substantial initial check to date. Neumann is also making waves on the tech-speaker circuit, marking a resurgence after WeWork's downfall.

Zhijiang Yang

Pairs Trading Insights

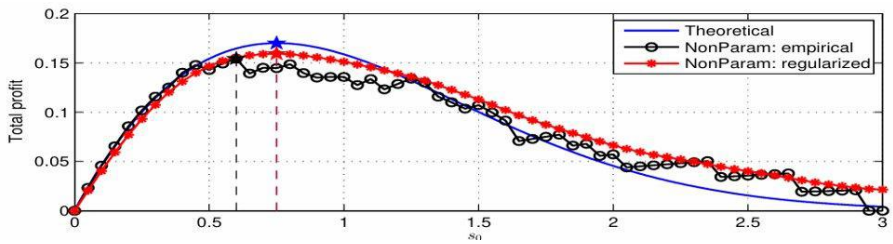
Executive Summary:
This quarter saw a resurgence in the use of quantitative strategies, particularly Pairs Trading, a market-neutral approach that has shown resilience in the face of market volatility. This report describes the strategic implementation of Pairs Trading in the context of portfolio optimization.



Market Review:
Significant market volatility has prompted traders to seek strategies that can capitalize on volatility. Pair trading has emerged as a robust technique that utilizes the covariance of asset pairs to generate returns regardless of market direction.

Cointegration and Pairs Selection:
Cointegration is the cornerstone of currency pair trading and refers to the long-run equilibrium relationship between two assets. Unlike correlation, which is a measure of short-term co-movement, cointegration implies that the price series of the two assets, while each is non-stationary, move together over time, allowing for a mean-reversion strategy. Before implementing the strategy, our focus is on carefully selecting asset pairs that exhibit strong cointegration characteristics to ensure the sustainability of the trading strategy.

Strategic Implementation:
The design of our pair trading strategy involves rigorous cointegration testing and then determining the optimal threshold for trade execution. We use both least squares regression and Kalman filters to dynamically hedge our positions, adjusting in real time to market conditions. This dual approach enhances our ability to maintain a market-neutral stance while also capitalizing on spread anomalies.



Performance and Risk Management:
Our pair trading strategy outperformed the benchmark with consistent returns and a Sharpe ratio that exceeded industry standards. Risk management is critical, with pre-set exit thresholds and stop-loss orders effectively minimizing potential losses. The success of the strategy is due to its inherent market neutrality, which insulates it from broader market declines.

Statistical Arbitrage Evolution:
Based on pair trading, we have begun to explore statistical arbitrage (StatArb) strategies. Optimizing mean-reverting portfolios (MRPs) through vector error correction models (VECMs), we aim to diversify our approach beyond trading pairs, incorporating multiple assets to take advantage of short-term price inefficiencies.

Outlook and Strategy Update:
Looking ahead, we expect markets to continue to be volatile, which bodes well for our pair trading strategy. We plan to further refine our selection criteria by employing machine learning techniques to identify more cointegrating relationships between assets.

Conclusion:
The quantitative field is evolving, and pair trading is at the forefront of this change. Our quantitative analysis and strategic execution allow us to capitalize on market inefficiencies, and we remain committed to advancing our trading algorithms to navigate the complexities of the financial markets.

Hewenbo Zhang

Exploring Risk Modeling

In this semester, I was involved in a risk modeling project with a team consisting of both freshman members and senior students. The project required us to predict the probability of default for specific loans, and we obtained the data from both Fannie Mae and FRED. This project significantly enhanced my programming skills, teamwork, and time management abilities and also had a significant impact on my future career track, which is why I want to discuss this experience.

Our first task was to gather data from Fannie Mae. We quickly realized that the data files were quite substantial, with each file containing over 15 million rows, and we had more than 10 data files in total. Clearly, using all of them for a regression mode model was impractical. Therefore, the next step was to sample the data, and I was assigned to handle this task.

This proved to be a considerable challenge for me. My computer struggled to process the massive amount of data, even with the help of pandas. I also attempted other methods, such as Dask, a specific library for handling large datasets. However, this library proved to be a method for users to learn some basic logic and attributes of the data rather than sampling it. So I tried to use the computers in the university's data center to complete the sampling process. I did successfully finish the data sampling task. However, during the process the university's computer - despite its 128g memory size - occasionally ran out of memory. This made me realize the importance of having specific data processing languages and software like MYSQL available.

This experience impressed me very much as it exposed me to an entirely new level of data handling. Previously I had only dealt with data files that contained at most 10M data rows. And though I did not successfully use Dask to complete the task, I believe this knowledge will benefit me in the future when I meet other kinds of problems with massive data size.

Apart from the academic gains, this project significantly influenced my future career expectations. It deepened my understanding of risk analysis, a field that I never learned nor intended to fully study. Our credit risk analysis project has given me new interest in risk related topics. In the future, perhaps I will learn more about market risk. And after a deep conversation with our group leader, who is currently doing a risk-related internship, I have discovered more about the risk-related job market. I am already considering taking more courses related to risk analysis, such as market risk, and I definitely plan to apply for more risk-related internships this summer.

In conclusion, this project is really helpful and meaningful to me, not only did I learn how to utilize the various libraries, as well as how to deal with massive data size, but I also learned new concepts. Previously, I had set my career goals on the quantitative track but after completing this project I believe that the risk track is also an attractive career option for me. I really appreciate that I had the opportunity to do this project.

Kexuan Zhou

Achieving My Career Goals

Though it has only been 3 months since the beginning of this program, I feel that I have experienced a lot and learned many new things.

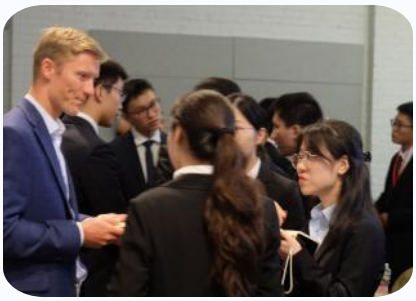
My object was always to become a quantitative analyst in financial institution like a large investment bank, so that was the main reason I enrolled in the Financial Mathematics program at NC State. I am lucky because before coming to NC State, I had several friends in similar quantitative roles and gained further information on my future career goal. From their advice, I knew that I had to start my application for summer internships very early so I began to apply in early August.

After arriving at NC State, I found that finding an internship is not easy. In fact, you needed to spend more time searching and applying, compared to what I previously thought. After the internship search was emphasized within the NC State program I began to spend more time on searching. I would apply to more companies than the required weekly assignment's and also took more time to make my resume look good.

I believe the hard work has paid off. During this semester, I have received three interviews invitation. One recent invitation was from Bank of America for a Superday. To prepare for these interviews, I practiced my interview skills and answers frequently and considered answers to potential questions in advance. I also asked others for advice. No matter what the result would be, I wanted to know that I had I had done my best to prepare.

I believed all these experience are valuable to me. Each one teaches me knowledge and practical skills which cannot be learned in the classroom. I am enjoying my time at NC State and look forward to continued professional and personal growth.

Reflections



Masters of Financial Mathematics Group Photo Fall 2023

Reflections

Masters of Financial Mathematics Group Photo Fall 2023

SAS Hall at NCSU's Main Campus

NC STATE UNIVERSITY

Financial Mathematics Graduate Program

Ranked # 4 by Risk.net Ranked #12 by QuantNet

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