Quantitative Investment Management
MIT Sloan Course 15.439, Spring 2023

Class schedule: Monday, 4:00 – 7:00 pm

Instructor: Prof. Matthew Rothman
Email: rothmanm@mit.edu
Office hours: Monday12:00-1:00 pm and upon request
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Course Overview:
This is a course in the implementation of successful investment strategies from the perspective of quantitative institutional money management. This is not a course in managing your own personal finances. Rather, it is a course that blends academic finance with the practice of investment management as actually carried out by many of the most sophisticated quantitative investors in the world. Students considering a career in any aspect of the financial services industry would be well served to take this course. By its very nature, this course is quantitative and requires an understanding of basic statistical and financial concepts. Most of all, it requires a willingness to learn, to be challenged, and a desire to actively engage with the material.

Our primary tools in this course will be a mixture of textbooks, lectures, academic articles and active class discussion.

We will also be joined by a number of luminary industry speakers, including: Brian Fagen, the Global Co-Head of Trading at BNP and formerly Global Head of Electronic Trading at Deutsche Bank; Scott Richardson, Head of Systematic Credit Strategies, Acadian Asset Management and formerly Partner at AQR, Head of Credit Strategies; Steve Cash, co-founder and CIO of Seven Eight Capital. And, finally, we will have a panel conversation on the future of asset management with Lenny Carr, Head of Investor Relation and Head of Strategy at PDT Trading and Sivan Gamliel, Head of Quantitative Strategies Hedge Fund Solutions at BlackRock.

We will also hold small intimate dinners with our outside speakers, as well as dinners with myself throughout the semester. These will provide an opportunity for you to get to interact with the speaker, me and your classmates in an intimate (6-9 people) environment. These dinners will only be open to students taking the class for a grade (e.g. not for listeners).

The course is divided into four parts. First, we will focus on why inefficiencies in the market may arise and persist – this topic is known as behavioral finance and was the subject of a recent Nobel Prizes in Economics. We will read some of the classic texts in this field including the seminal work on the failure of the CAPM to explain returns. Second, we will discuss a number of investment strategies that have and are being used by investors and how one constructs investment strategies and an actual model.

Again, we will be reading important academic and practioner papers in these areas, as well as drawing on materials from textbooks as appropriate. Third, we will discuss the issue of portfolio construction and trading. Topics in this section will include the consideration of transaction costs, risk management and the efficient execution of trading given the current market microstructure. We will discuss how poor risk management and modelling of transactions costs can be fatal to seemingly successful investment strategies. Additionally, we will explore the relatively arcane and nuanced world of short-selling. Fourth and finally, we will discuss the dynamics of institutional investment management today, including the shift to more passive investment and low fee vehicles such ETFs and Alternative Risk Premium (ARP). We will discuss the topics of machine learning and big data from time-to-time when the techniques are applicable to the broader question under consideration.

Despite this being a class in quantitative investment management this is *not* a class in quantitative math and the teaching of various algorithms per se. This class is much more heavily focused on making you ***think***: carefully and thoughtfully and critically about the quantitative analysis you are undertaking. This is not a mathematics class or a formula driven class. It is a class for students who want to think deeply and critically about the process of doing quantitative research and analyzing the research of others. At the same time, this is not a philosophy class. You will need to understand quantitative methods in order to think deeply and critically about their appropriate application to real-world problems.

Please note: I have some clear biases that will be apparent from my bio. I am a quant – that is, a quantitative asset manager/researcher/hedge-fund manager. That means, I am skeptical about the value of fundamental analysis and as such we will spend little time on this topic. I believe in the scientific process and empirically testing hypotheses. I love theory and make models to understand the world around me; yet, models that do not provide us with testable implications strike me as uninteresting. Imprecise language, arguments that are not well thought-out and sloppy empirical economics try my patience.

It does not, however, mean that one can ascertain capital "T" Truth through model building. Models are just that: models. They are an abstraction of reality. By definition, all models are false. Otherwise, they wouldn't be called "models". But what they allow you to do is, hopefully, avoid the flaws of behavioral biases and heuristics (and in fact profit from others' use of them) as well as demand a level of precision and clarity from you in your own thinking. Moreover, as stated above, there is bad quantitative research too. We want to avoid that as well.

There will also be a clear tilt to equity markets as opposed to fixed income, commodity or currencies as the majority of my career has been spent thinking about equities.

Grading Policy:
In-class discussion/participation: 20%
Problem Sets / Assignments: 40%
Final Exam: 40%

Assignments will be graded on a "check plus", "check", or "check minus "system. A clear solid and sincere effort will earn you a "check". To earn a "check-plus", you must do something exemplary or really "nail" the issues. "Check minuses" are reserved for those showing minimal to no effort. Of course, not handing in a homework is a more serious issue, which could well lead to your failing the class.

Homework assignment that are not handed in on-time *will not* be graded.

Please do not ask for regrades. They will only be granted when there are clear mathematical errors in adding up the scores. In the exceedingly rare case where a regrade is given, it will also result in the entire assignment / exam being regarded, which may end up with a new net lower score.

Office Hours, TA Sections, and Email
Besides teaching at MIT, I work in NYC as the Deputy Head of Quantitative Strategies at Millennium Management, one of the largest head funds in the world with over $58 bln in AUM. Consequently, I am only on campus on Monday's, arriving early in the morning.

I will be holding office hours from Noon-1 pm on Mondays. If you would like to schedule an appointment with me outside of office hours, please email and I will do my best to set-up another time for Monday. If you need to speak with me at another time during the week, please email my assistants at Millennium: Julia.Taylor@mlp,com and Jennifer.Lopez@mlp.com

Our TA for the course is Thomas Britten. He will be holding bi-weekly office hours during the beginning of the semester and towards the end of the semester will be holding more frequent office hours, with the exact frequency dependent upon demand. Please feel free to email him with questions pertaining to any of the course materials, homeworks or other related course matters. If we are finding that there are a number of questions coming up around the homeworks then Thomas will be holding additional office hours.

Please note that I am often delayed in reading emails. Accordingly, please cc Thomas on all emails. If you do not hear back from me within 72 hours, please email me again. For more urgent, questions please email the Thomas.

Please be deliberate with whom you put in the 'To:' field and whom you put in the 'cc :' field. If it is meant for me to answer place me in the 'To:'; if it is meant for TA put them in the 'To:' field. Please only place one person in the 'To:' field. Please change the Subject of the email when the topic of the email changes.

Course Expectations

Prior to each class, you will be required to read the materials.

Class attendance is required. It is essential that you come to every class, come on time and *stay for the entire time* and participate, both actively and when called upon.

We have a lot of material to cover in the class. It will not be uncommon that we run 10-15 minutes over. I will try my best not to do so but it will happen. If you need to leave in those situations that is absolutely fine.

Please note that in accordance with MIT Sloan Classroom policy, MIT Sloan requires that students schedule campus interviews outside of scheduled class times and to make every attempt to schedule second round interviews and site visits outside of class times. Classes missed for such activities are not excused absences and will count against your participation grade.

In-class discussion thoughtful participation is key, with quality (but not exclusively) more than sheer quantity will determine your participation grade. Please be sensitive to allowing others to participate, talk when you truly have something important to say, and do not dominate the conversation. I am happy to have more detailed conversations after class or in office-hours.

In years past, there have been clear gender and ethnic biases in student participation levels. This bothers me greatly. ALL students are encouraged to speak up. I do not want to be in the position where I need to start cold-calling on students but I will do so if the class conversation starts to become dominated by a few voices. Know also to be successful in industry (and academia) you need to be comfortable speaking and articulating your thoughts. So, consider this good training for the workplace. *In short, participate in class.*

It is your responsibility to familiarize with the MIT Sloan Classroom Policies and Norms and please abide by them (as will I). Please note that cell-phones and PDAs are not to be used or permitted to ring in the classroom; texting or other social messaging apps are absolutely not to be used during class.

Note: I am absolutely horrible at remembering names – it is not just a bad characteristic of mine but, in fact, a part of a diagnosed neurological condition. I wish it is something I could change as it is embarrassing to me but I can't. So please do not be offended if out class I do not remember your name or even your face. It truly has nothing to do with you.

It is always critically important to recognize others' contributions to the discussion and when disagreeing to do so respectfully. Few of the complex issues we will be discussing have an absolutely "right" answer so it is important to acknowledge that multiple perspectives on these problems may likely be valid.

It is especially important to remember that many of the people will likely come from different personal, cultural and/or professional backgrounds from your own. Please be sensitive and respectful of these views. It is helpful to *actively* acknowledge multiple perspectives on complex issues can be valid.

That said, unwelcome or derogatory remarks based on sex, gender identification, national origin, race, sexual orientation, age, body shape, physical ability, socio-economic status, neurological divergence, or any other similar characteristic or trait of a person will not be tolerated. We should all be vigilant to address the situation immediately if it happens. We should all feel comfortable and empowered to address these situations – whether it is by me, a fellow student, or a visitor to our class.

Furthermore, I feel strongly that the language one uses is important. Even in what may seem "trivial" situations the language we use imparts values in subtle ways. I will do my best to be sensitive on this issue – feel free to call me out when I slip.

Please refrain from sidebar conversations. If you have a question or something is truly unclear to you, it is likely unclear to others in the class. Ask it! On the other hand, if it is just a peripheral conversation with a friend, please wait until after class.

I take the issue of academic integrity and plagiarism with the utmost of seriousness. I will have no hesitancy or leniency in enforcing MIT standards in these regards. It is *your* responsibility to familiarize yourself the document "Academic Integrity at the Massachusetts Institute of Technology: A Handbook for Students" as those articulated by the MIT Sloan School. If you have any questions or are unsure whether some course of action is proper, it is your responsibility to reach out to me and ask for assistance and/or clarification.

Homework Assignments:

There will almost surely be 4 homework assignments; I reserve the right to do a 5th homework but it is highly unlikely I will exercise this right. These assignments will be a very good gauge of whether you are actually mastering the material. These assignments are designed to make you think and collaborate

Some of the homework will be data intensive. It will be an opportunity to learn from the class contents and your classmates. You cannot do quantitative analysis without using data and data does not come to you in pristine form. So do not expect that I will be giving it to you in pristine form. Welcome to the world of quantitative analysis!

Statistics and econometric knowledge are a prerequisite for this course and that knowledge will be critical for the homework assignments and the course. The homeworks could be completed using basic programming experience and Excel *maybe* but I cannot guarantee that. Consequently, the basic programing experience

during the assignment will contribute to the learning experience for a quant career, so I'll encourage those who try. It will likely be helpful for your career in the future.

The homeworks may look deceptively easy but make sure you read them through when you get them and think about what is required to complete them. Accordingly, please leave appropriate time to complete them.

You should form a group of 2-3 people for the homework assignments; if you do not know people in the class please reach out to the TA and me so we can help find you a group.

In keeping, with MIT policies on Group Work, you should consider these to be "Type 3 collaboration" – that is, *each* team member is expected to make a substantial contribution to *each* assignment. Aside from your teammates, the TA and myself, no consultation with anyone else in the class or any other individual is permitted. All person's names should be on the assignment along with their email and MIT ID.

Final Exam:
There will be a final exam in this class during exam week. The final exam will be on the date and time that the Registrar's Office assigns for the exam, which mostly likely bebe at our normal class time. There will be *no alternative exam time* unless you have an exam that is also being held at the same time as scheduled by the Registrar's office. This is as per mandated by the MIT rules and regulations. I have no flexibility on this matter.

At the end of each set of lecture notes, there are a series of "Thought Questions" that are designed to make you think through the issues presented in class. The final exam will feed on these questions and materials you will have learned via the homework assignments. The responses to these questions will help prepare you for the final exam and help you understand the interconnection between all concepts covered will make you stand out.

Hence, if you are able to clearly articulate well-reasoned and thought-out answers to these questions – showing your mastery of the debate – and you have done the reading for the classes then you should be very well prepared for the final exam. If you do not go through all the "Thought Questions", it is likely you will have great difficulty on the exam. Accordingly, it is my strong advice to you read these questions to discuss them with your study group, in depth. Do not wait until the end of the semester to start the process of reviewing the Thought Exercises.

Final Grades:
If you need an early grade for any reason, it is your responsibility to let me know this by April 15th and to "memoralize" it in an email to the TA and me in an email. Reasons for an early grade can include (i) you need a provisional or final grade to graduate; or (ii) your program is on a different academic calendar from MIT.

Early grades will be based on your scores on the homeworks. If your final grade in the class warrants a higher or lower grade than you were originally assigned then I will submit a new grade for you.

Outside Speakers:
We will have a number of true luminary outside speakers coming to our class to discuss a variety of topics.

It is hard to overstate how lucky we are to have this incredible set of speakers this term. Some of them a truly iconic figures. They all are among the very best, most senior and powerful people in our industry. Moreover, they represent a diverse cross-section of the industry coming from sell-side institutions (BNP), hedge funds (PDT and Seven Eight Capital), Fund of Funds (BlackRock Quantitative Strategies Solutions) and traditional asset managers (Acadian).

Please always come prepared to ask them hard (but polite and respectful) questions. They are coming for the opportunity to engage with you. Truly 95% of the reason is that they want to engage with <u>you</u> and only 5% of it is as a favor to me. They talk to me all the time. This is about <u>you</u>.

So please show them the courtesy of being prepared, paying attention and asking them good questions!

Outside Speaker Dinners:
A number of the speakers have agreed to go dinner with students afterwards. These will be small dinners in a local restaurant with approximately 9 students. Students taking the class for a grade will be chosen to attend a small (6-9 people) dinner with the outside speaker.

These will provide a truly unique experience for you to meet some of the leaders in the field in an intimate environment – a chance for you to engage with the outside speaker as well as your classmates. It is no exaggeration to say that you may never be able to meet people of this caliber again in such a small setting. It is also no exaggeration to say that, in the past, these dinners allowed some of your former classmates to start a relationship with the speaker that ultimately culminated in a job for them at the speaker's firm or with another firm to which they were willing to make an introduction for the student.

In short, the dinners are an incredible networking opportunity that you should be leaping to take advantage of.

We will schedule these dinners throughout the semester. Dinner groupings will be chosen at random among those students taking the class for a grade. We will not be

honoring requests for a specific speaker but be choosing students randomly for each speaker.

Required Books:
"Inside the Black Box" by Rishi Narang

"Asset Management: A Systematic Approach to Factor Investing", by Andrew Ang

"Efficiently Inefficient: How Smart Money Invests & Market Prices are Determined", by Lasse Heje Pedersen

"Inefficient Markets", by Andrei Shleifer, Oxford University Press

"Trading & Exchanges: Market Microstructure for Practitioners" by Larry Harris

Lecture Packet:
There is a lecture packet for this course with additional readings.

15.439 Detailed Class Schedule:
*(*Please note: changes to this schedule are likely! Changes will be announced in class and posted on the class website*)*

Module 1 – Capital Markets and Basics of Quant Investing

Monday, February 6th – Intro., Players in the Capital Markets & Intro to Quant Investing
This class features an introduction to the course, followed by an introduction to the major players in the capital markets from both the buy-side and sell-side and exchanges, along with a detailed introduction to quantitative investing.

Readings: Chapter 1 of Ang; Chapter 1 of Pedersen; Chapter 1-2 of Narang

Monday, February 13th – The Rise and Fall of CAPM
In this class, we will review CAPM and the empirical evidence supporting (?) it. In this class, we will review the seminal article in Finance in the last 25+ years: Fama-French (1992) "The Cross-Section of Expected Stock Returns". Read this quite closely and carefully and then we will begin to discuss alternative models to explain equity returns.

- Assignment Homework #1 Release

Readings: Eugene Fama and Ken French "The Cross-Section of Expected Returns", *Journal of Finance*, June1992; and Chapter 6 of Ang (read Chapters 2 and 3 if you need refreshing); "Are Markets Efficient?", Chicago Booth Review (on-line article). Michael Mauboussin "Revisiting Market Efficiency: The Stock Market as a Complex Adaptive System", *Journal of Applied Corporate Finance*, Winter 2002;

Module 2 – Patterns in Asset Returns and Quantitative Investing

Tuesday, February 21st –Where Do Market Anomalies Come From And How Do You Evaluate Success?
Investors are not utility maximizers or computers. They are subject to a number of biases, use rules of thumbs and a number of heuristics. These create patterns in returns. We will seek to understand how investors make systemic mistakes and the impact this can have on markets and decisions by investors across their economic life. Understanding human behavior in this degree can help to understand the type of strategies we should begin to look for and why they might persist.

Readings: Chapter 7 of Ang; Chapter 1 of Andrei Shleifer "Inefficient Markets"; Amos

Tversky and Daniel Kahneman "Judgement under Uncertainty: Heuristics and Biases", *Science*, September 1974; Optional but suggested: Matthew Rabin Article, "Psychology and Economics", *Journal of Economic Literature*, March 1998.

Monday, February 27th - Factors
There are a multitude of factors that have been advanced and a multitude of styles. How does one begin to judge whether a factor is a "real"? What are the possible factors out there? How does one begin to back-test and approach "factor investing"?

- Assignment Homework #1 Due at the beginning of class
- Assignment Homework #2 Release

Readings: Read Chapters 2 & 3 of *Efficiently Inefficient*; Read Chapter 3 and Chapter 9 of *Narang*; Read Rothman, "Lehman Brothers Launch Piece".

Monday, March 6th – More on Factors; Quant Investing and The Quant Crisis Discussion. In this class, we will continue and conclude our conversation on traditional equity factors. We will also discuss the Quant Crash of August 2007 and the issue of how correlated Quant Investors are or are not and the causes of potential crowding.
Readings: Chapter 9 of *Efficiently Inefficient*; Rothman, "Turbulent Times in Quant Land", Lehman Brothers

Monday, March 13h – New Factors, Big Data and Identifying "HogWash" *with outside speaker #1* ***TBD.***

In this class, we tackle a number of interrelated topics. The first, we will want to clearly distinguish between causation and correlation. We will begin our examination of several popular "new factors" and the techniques used to construct them such as Natural Language Processing (NLP). We will also consider several other types of so-called "Big Data" factors. We will not discuss specific machine learning algorithms in this section, as this is a course in and of itself.

- Assignment: Homework #2 Due
- Assignment Homework #3 Released

Readings: Additional Readings TBD

Monday, April 3rd – Continuing on New Factors, Big Data and with outside speaker TBD In this class, we will continue our discussion of New Factors, ML, Webscraping and NLP. Finally, we will discuss some of issues of fairness and legality surrounding "Big Data" data-sources, including issues of material non-public information (MNLP).

Readings: Read Chapter 8 Narang; Other readings to TBA

Module 3 – Execution and Portfolio Construction

Monday, April 10th – Short Selling *with outside speaker #2* ***TBD***
In order to take advantage of overpriced, as well as underpriced, securities, it is necessary to master the mechanics of selling short. Selling short is not nearly as neat and simple as buying a security (e.g. going long). Moreover, there is no centralized market for shorting (or borrowing) securities. Yet, efficient markets require that overpriced stocks as driven down to their fundamental values. In this class, we will go through and explore the issues associated with shorting.

Readings: Chapter 8 *Efficiently Inefficient*; Article by Owen Lamont, "Short Sale Constraints and Overpricing", working paper (on class website). Chapter 4 of *Efficiently Inefficient*; Chapter 6 of *Narang*.

- Assignment: Homework #3 Due
- Assignment Homework #4 Release

Tuesday, April 18th – Additional Class Portfolio Construction, Risk Models and Portfolio Analytics

Portfolio theory is the basic framework for measuring risk and weighing it against expected returns. It is near-universally used by professional investors -- even those who criticize it need to understand it so as to understand the bogey they wish to improve upon. In this class, we will discuss some of the operational issues of portfolio construction, including the construction of risk models, the realities of portfolio optimization, issues of position sizing, questions regarding model overrides and then understanding the actual drivers of one's portfolio ex-post.

Reading: Chapter 4 of *Efficiently Inefficient*; Chapter 10 of *Narang*; Additional material on optimization to be provided.

- Assignment: Homework #4 Due
- Assignment Homework #5 Release

Monday, April 24th – Portfolio Construction, Risk Models and Portfolio Analytics, Additional Materials to be discussed on Portfolio Construction and Appropriate Considerations for Risk Management. This is one of the principal subject matter areas of expertise that distinguishes successful from unsuccessful portfolio managers. (No alpha alone is not enough!). We will focus not only on the theoretical aspects but on the practical techniques. Additionally, we will discuss a number of other practical issues including how to asses the skill of a portfolio manager with limited data.

Monday, May 1st – Trading, with outside speaker #3 **TBD**
Trading costs have been the death of many well-designed investment strategies. On the other hand, skilled trading can be a source of profit rather than cost. This is one of the more technically complex parts of the course and will require a class and a half to discuss fully.

- Assignment: Homework #5 Due

Reading: Chapter 5 of *Efficiently Inefficient. Read Lindsey et al "History of Market Microstructure Regulation and 1997 Order Handling Rule";* From Larry Harris book on "Trading and Exchanges" read, Chapter 4, Chapter 5, Chapter 14, Chapter 19, Chapter 21, Chapter 25, Chapter 26, Chapter 27 & Chapter 29. Yes, there is a lot of material to read from Harris but it is excellent if you want to know how markets actually work!

Monday May 8th – Trading continued
We will conclude the topic on trading and have an outside speaker in to help illuminate the real-world issues of trading as they are being faced today by investors and the sellside alike.

Readings: *Read from Credit Suisse "We are all High Frequency Traders Now"; Read from Goldman Sachs, "Presentation on Market MicroStructure";* Chapters 13, 14, 15, and 16 of *Narang*.

Module 5 – Future of Asset Management and Quantitative Investing

Monday, May 15th – Active vs. Passive debate, ETFs and Smart Beta The Future of Asset Management, with outside speakers #4. **TBD**

Come to class ready to actively debate these issues. The readings are easy! But the issues are provocative and deeply important for anyone considering a career in Financial Services. You should be inspired to participate and speak up!

Readings: Read Michael Maubissian "Active vs. Passive: Easy Games", Credit Suisse Research Report; Acadian Asset Management Report, "Smart Beta, Constrained Quant"; Financial Times, "Smart Beta Going MultiFactor"; Financial Times, "Smart Beta versus Traditional Alpha Managers"; FTSE Russell "Survey Results on the Use of Smart Beta"; BlackRock Marketing Materials on Factor Investing.