Algorithmic Trading & Quantitative Strategies

Lecture 1 (1/30/2024)

Giuseppe Paleologo (gardener)

Hello, World

Topics

- Linear Models of Asset Returns (Factor Models)
  - Fundamental
  - Statistical
  - Time-Series
- Portfolio Optimization
  - Basic Mean-Variance
  - Advanced Mean Variance
  - Some Hedging
- Model Selection and Backtesting
  - Alpha Research
- (Multi-Period) Portfolio Optimization
- Performance Attribution

Why These Topics? What are the Guiding Principles?

- **Theory is cheap**. Useful theory is invaluable. Investment Science is an experimental science.
- **Everything is a model**. There are models you know you are using, and models you don't know you are using. There is no pure atheoretic approach to finance (e.g., Deep Learning).
- **Think deeply of simple things**. Always follow reasoned, first-principles approach to problems.
- **Start with problems, not with techniques**.
- **Simple models work, when applied thoughtfully**.

Practical Things

- Starting Lesson 2: Quizzes every week. Multiple questions. Just checking you had a pulse during class. 1/3 of total grade.
- In Lesson 2 and Lesson 4 I will hand homework/simple projects. Maybe one analytical, not hard; and one model+coding. 1/3
- One final: 1/3
- Lesson 3: A project. Risk model+portfolio optimization 30%
- I also value a) participation in class; b) pointing out mistakes in my lectures and notes
- I will post notes and lecture slides. Notes are a superset of class material
- N.B.: I don't care so much about grades. You and I should care that you learn. In hiring, grades don't matter.

This is What Minor Internet Fame Looks Like

Nishant Kumar · 8:10 am

see you there. haven't got the invite though

your story is second most read on terminal right now

Byrne Hobart @ByrneHobart · Jan 10

Peak performance

Gardening Leave
Gardening Leave
Nov 2023 - Present · 3 mos
the roof of my house · Remote
Training to compete in the world championship of non-compete.

Head Of Risk Management
Hudson River Trading · Full-time
Mar 2021 - Nov 2023 · 2 yrs 9 mos
New York, United States · On-site

Gardening Leave
my frontyard
Dec 2020 - Mar 2021 · 4 mos
(Because it is winter, I shall tend to books, which were once trees)

Visiting Lecturer
Cornell University
Aug 2017 - Mar 2021 · 3 yrs 8 mos
New York
Teaching a course on selected topics in finance for M.S. students in Financial Engineering.

Head of Enterprise Risk
Millennium
Oct 2018 - Nov 2020 · 2 yrs 2 mos
New York

Gardening Leave
my backyard
Jul 2017 - Oct 2018 · 1 yr 4 mos
Working extremely hard at non-competing.

Director, Risk & Quantitative Analytics
Citadel LLC
Dec 2015 - Jul 2017 · 1 yr 8 mos
New York

101 · 3.2K · 33K · 2.5M

Posted by u/NothingIsTheSame 11 days ago

759

Job Hopping in Quant Finance? i.redd.it/0fikpx...

Career Advice

Gardening Leave
Gardening Leave
Nov 2023 - Present · 3 mos
the roof of my house · Remote
Training to compete in the world championship of non-compete.

Head Of Risk Management
Hudson River Trading · Full-time
Mar 2021 - Nov 2023 · 2 yrs 9 mos
New York, United States · On-site

Gardening Leave
my frontyard
Dec 2020 - Mar 2021 · 4 mos
(Because it is winter, I shall tend to books, which were once trees)

Visiting Lecturer
Cornell University
Aug 2017 - Mar 2021 · 3 yrs 8 mos
New York
Teaching a course on selected topics in finance for M.S. students in Financial Engineering.

Head of Enterprise Risk
Millennium
Oct 2018 - Nov 2020 · 2 yrs 2 mos
New York

Gardening Leave
my backyard
Jul 2017 - Oct 2018 · 1 yr 4 mos
Working extremely hard at non-competing.

Director, Risk & Quantitative Analytics
Citadel LLC
Dec 2015 - Jul 2017 · 1 yr 8 mos
New York

Why would someone job hop as a quant when there are such restrictive non-competes?

Is it a viable option to progress in your career?

55 Comments · Share · Unsave · Hide · Report

America's funniest quant is showcasing the best use of gardening leave

by Sarah Butcher • 24 hours ago • 2 minute read

Giuseppe Paleologo is known for three things: being a quant at various top hedge funds and trading firms, being on gardening leave, and being a great wit.

Get Morning Coffee ☕ in your inbox. Sign up here.

In his two decade+ career, Paleologo has worked for Citadel (twice), for Millennium and for electronic trading firm Hudson River. In the past five years, he's had nearly two years of gardening leave and is currently tending his crop again. Paleologo left his job as head of risk management at Hudson River in November 2023, which means he's now sitting out the market. When this latest period of enforced rest is over, he'll join hedge fund Balyasny as head of quant research.

It is strange when people find you "funny" or "superweird" when you are trying to be neither

This Lesson

- The Playground
  - The players
  - Where alphas come from
  - The elements of Investing
- Asset returns
  - Stylized facts
  - How to measure asset returns
- Basic state space models

The Playground

Players

- Modes of exchange:
  - Trading exchanges
  - OTC
  - Dark pools
- Participants:
  - Sell-Side:
    - Brokers
    - Dealers
    - Broker-dealers
  - Buy-side:
    - Indexers
    - Hedgers
    - Institutional managers
    - Asset allocators
    - Retailer traders
    - Informed Investors

Where Does "Alpha" Come From?

"A capital market is said to be efficient if it fully and correctly reveals all available information in determining security prices. Formally, the market is said to be efficient with respect to some information set, φ, if security prices would be unaffected by revealing that information to all participants. Moreover, efficiency with respect to an information set, φ, implies that it is impossible to make economic profits by trading on the basis of φ." (Malkiel)

Publicly Available Information in the US

"Any information that you reasonably believe is lawfully made available to the general public from:

(i) Federal, state or local government records;

ii) Widely distributed media; or

(iii) Disclosures to the general public that are required to be made by federal, state or local law".

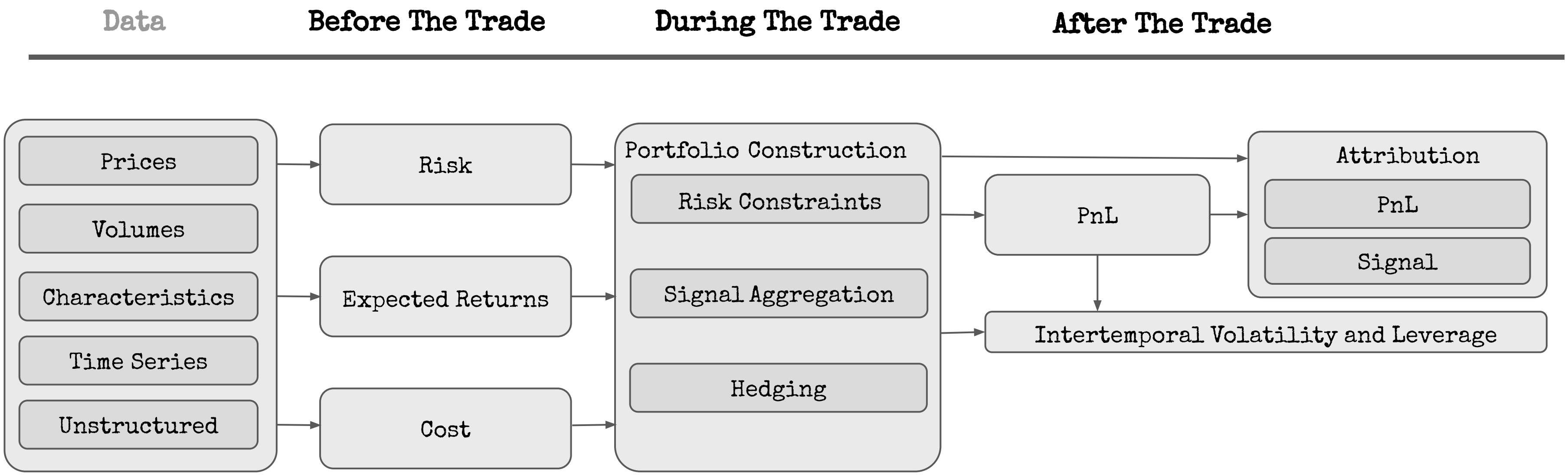
Information and Constraints

A unified interpretation: **alphas come from investor heterogeneity**.

1. Liquidity constraints
2. Funding constraints
3. Flow constraints
4. Risk constraints
5. Informational advantage

- Usually researchers concentrate on the latter, which is an epiphenomenon of the former. Great traders always ask themselves who is on the other side of the trade.
- With the popularization of black boxes, intelligence (in the original sense of the word, *inter+legere*, "read into [something]") will be in even higher demand
- Keep in mind this statement by Cochrane, first-order correct: "There is no alpha. There is the beta you understand, and the beta you don't understand".

The Elements



Asset Returns

Returns

Dividend-Adjusted Returns:

$$R_i(1) := \frac{P_i(1) + D_i(1)}{P_i(0)}$$

What prices, though? Last trade? Bid, Ask, mid-point?

Stylized Facts

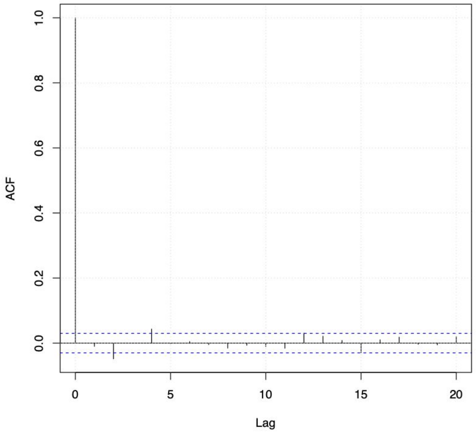
Cont (2001), Ratliff-Crain (2003), Taylor (2007)

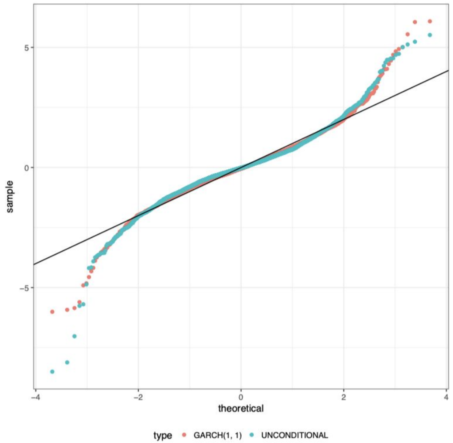
1. Absence of autocorrelations
2. Heavy tails (but finite 3rd moments, and maybe finite 4th)
3. Autocorrelation of absolute returns and of second moments
4. Aggregational Gaussianity

Other facts are weaker or not robust.

Implications

- At shorter time scales, we have heavier-tailed returns, but smaller in scale, at longer time scales, they are more gaussian
- *Unconditional* time-series momentum is weak
- Volatility is persistent. This has implications for vol predictability





GARCH(1, 1)

- Landmark of volatility modeling
- Clever model
- Works well

$$r_t = h_t \epsilon_t$$

$$h_t^2 = \alpha_0 + \alpha_1 r_{t-1}^2 + \beta_1 h_{t-1}^2$$

Intuition

Remove the term $\alpha_1 r_{t-1}^2$. You are left with

$$h_t^2 - h^2 = \beta_1 (h_{t-1}^2 - h^2)$$

$$h^2 := \alpha_0 / (1 - \beta_1)$$

The squared return shocks the system, which converges to an equilibrium. Another restatement: EWMA of **non iid** returns.

$$h_t^2 = h^2 + \alpha_1 \sum_{i=1}^{\infty} \beta_1^{i-1} r_{t-i}^2$$

Intuition (2)

Rewrite the GARCH(1, 1) as

$$h_t^2 = \alpha_0 + \alpha_1 h_{t-1}^2 \epsilon_{t-1}^2 + \beta_1 h_{t-1}^2$$

$$a_t := \beta_1 + \alpha_1 \epsilon_{t-1}^2$$

$$h_t^2 = a_t h_{t-1}^2 + \alpha_0$$

GARCH(1, 1) is a linear random (=random coefficients)

recursive equation; a Markov Process

Kalman Filters and Associated Models

- The Kalman Filter uses linearity and gaussianity
- Same ingredients used in linear regression and linear-quadratic control, with which share some algebraic similarities
- It is simple, easy to understand, flexible and it works
- A Swiss Army tool

Basic Fact

Let Z be a multivariate normal with

$$\boldsymbol{\mu}_{\mathbf{Z}} := \begin{bmatrix} \boldsymbol{\mu}_{\mathbf{x}} \\ \boldsymbol{\mu}_{\mathbf{y}} \end{bmatrix} \qquad \operatorname{cov}(\mathbf{Z}) = \begin{bmatrix} \boldsymbol{\Sigma}_{\mathbf{x},\mathbf{x}} & \boldsymbol{\Sigma}_{\mathbf{x},\mathbf{y}} \\ \boldsymbol{\Sigma}_{\mathbf{y},\mathbf{x}} & \boldsymbol{\Sigma}_{\mathbf{y},\mathbf{y}} \end{bmatrix}$$

You observe **y=b**. Then the conditional distribution of **x|y=b** is

$$E(\mathbf{x}|\mathbf{y}=\mathbf{b}) = \boldsymbol{\mu}_{\mathbf{x}} + \boldsymbol{\Sigma}_{\mathbf{x},\mathbf{y}}\boldsymbol{\Sigma}_{\mathbf{y},\mathbf{y}}^{-1}(\mathbf{b}-\boldsymbol{\mu}_{y})$$

$$\operatorname{cov}(\mathbf{x}|\mathbf{y}=\mathbf{b}) = \boldsymbol{\Sigma}_{\mathbf{x},\mathbf{x}} - \boldsymbol{\Sigma}_{\mathbf{x},\mathbf{y}}\boldsymbol{\Sigma}_{\mathbf{y},\mathbf{y}}^{-1}\boldsymbol{\Sigma}_{\mathbf{y},\mathbf{x}}$$

Model

$$\begin{aligned}
\mathbf{x}_1 &\sim N(\hat{\mathbf{x}}_0, \hat{\boldsymbol{\Sigma}}_0) \\
\boldsymbol{\epsilon}_t &\sim N(\mathbf{0}, \boldsymbol{\Sigma}_\epsilon) && \boldsymbol{\epsilon}_t \perp \boldsymbol{\epsilon}_s, \boldsymbol{\epsilon}_t \perp \boldsymbol{\eta}_{s+1} && s \leq t \\
\boldsymbol{\eta}_t &\sim N(\mathbf{0}, \boldsymbol{\Sigma}_\eta) && \boldsymbol{\eta}_t \perp \boldsymbol{\eta}_s, \boldsymbol{\eta}_t \perp \boldsymbol{\epsilon}_{s+1} && s \leq t
\end{aligned}$$

$$\begin{aligned}
\mathbf{x}_{t+1} &= \mathbf{A}\mathbf{x}_t + \boldsymbol{\epsilon}_{t+1} \\
\mathbf{y}_{t+1} &= \mathbf{B}\mathbf{x}_{t+1} + \boldsymbol{\eta}_{t+1}
\end{aligned}$$

Define

$$\mathbf{Z}_t := \begin{bmatrix} \mathbf{x}_t \\ \mathbf{y}_t \end{bmatrix} \quad \Rightarrow \quad \mathrm{cov}(\mathbf{Z}_t) = \begin{bmatrix} \hat{\boldsymbol{\Sigma}}_{t|t-1} & \boldsymbol{\Sigma}_{\mathbf{x}_t}\mathbf{B}' \\ \mathbf{B}\boldsymbol{\Sigma}_{\mathbf{x}_t} & \mathbf{B}\hat{\boldsymbol{\Sigma}}_{t|t-1}\mathbf{B}' + \boldsymbol{\Sigma}_\eta \end{bmatrix}$$

Now observe $\mathbf{y}_t$

Update step: new conditional distribution:

$$
\begin{aligned}
\hat{\mathbf{\Sigma}}_{t|t} =& \hat{\mathbf{\Sigma}}_{t|t-1} - \hat{\mathbf{\Sigma}}_{t|t-1}\mathbf{B}'(\mathbf{B}\hat{\mathbf{\Sigma}}_{t|t-1}\mathbf{B}' + \mathbf{\Sigma}_{\boldsymbol{\eta}})^{-1}\mathbf{B}\hat{\mathbf{\Sigma}}_{t|t-1} \\
=& [\mathbf{I} - \hat{\mathbf{\Sigma}}_{t|t-1}\mathbf{B}'(\mathbf{B}\hat{\mathbf{\Sigma}}_{t|t-1}\mathbf{B}' + \mathbf{\Sigma}_{\boldsymbol{\eta}})^{-1}\mathbf{B}]\hat{\mathbf{\Sigma}}_{t|t-1} \\
\hat{\mathbf{x}}_{t|t} =& \hat{\mathbf{x}}_{t|t-1} + \hat{\mathbf{\Sigma}}_{t|t-1}\mathbf{B}'(\mathbf{B}\hat{\mathbf{\Sigma}}_{t|t-1}\mathbf{B}' + \mathbf{\Sigma}_{\boldsymbol{\eta}})^{-1}(\mathbf{y}_t - \mathbf{B}\hat{\mathbf{x}}_{t|t-1})
\end{aligned}
$$

Prediction step:

$$
\hat{\mathbf{\Sigma}}_{t+1|t} = \mathbf{A}\hat{\mathbf{\Sigma}}_{t|t}\mathbf{A}' + \mathbf{\Sigma}_{\boldsymbol{\epsilon}}
$$

$$
\hat{\mathbf{x}}_{t+1|t} = \mathbf{A}\hat{\mathbf{x}}_{t|t-1} + \mathbf{A}\hat{\mathbf{\Sigma}}_{t|t}\mathbf{B}'(\mathbf{B}\hat{\mathbf{\Sigma}}_{t|t}\mathbf{B}' + \mathbf{\Sigma}_{\boldsymbol{\eta}})^{-1}(\mathbf{y}_t - \mathbf{B}\hat{\mathbf{x}}_{t|t-1})
$$

Tidying up

$$\mathbf{K}_t := \hat{\mathbf{\Sigma}}_{t|t-1}\mathbf{B}'(\mathbf{B}\hat{\mathbf{\Sigma}}_{t|t-1}\mathbf{B}' + \mathbf{\Sigma}_{\boldsymbol{\eta}})^{-1}$$ *(Kalman Gain)*

$$\begin{aligned}
\hat{\mathbf{\Sigma}}_{t|t} &= [\mathbf{I} - \mathbf{K}_t\mathbf{B}]\hat{\mathbf{\Sigma}}_{t|t-1} \\
\hat{\mathbf{x}}_{t|t} &= (\mathbf{I} - \mathbf{K}_t\mathbf{B})\hat{\mathbf{x}}_{t|t-1} + \mathbf{K}_t\mathbf{y}_t \\
\hat{\mathbf{\Sigma}}_{t+1|t} &= \mathbf{A}\hat{\mathbf{\Sigma}}_{t|t}\mathbf{A}' + \mathbf{\Sigma}_{\boldsymbol{\eta}} \\
\hat{\mathbf{x}}_{t+1|t} &= \mathbf{A}\hat{\mathbf{x}}_{t|t}
\end{aligned}$$ *(Basic Formulas)*

In steady state:

$$\mathbf{X} = \mathbf{A}\mathbf{X}\mathbf{A}' - \mathbf{A}\mathbf{X}\mathbf{B}'(\mathbf{B}\mathbf{X}\mathbf{B}' + \mathbf{\Sigma}_{\boldsymbol{\eta}})^{-1}\mathbf{B}\mathbf{X}\mathbf{A}' + \mathbf{\Sigma}_{\boldsymbol{\epsilon}}$$ *(Riccati Equation)*

Next Time

- A couple of examples of Kalman-based volatility estimation
- First intro to Factor Model
- A quiz
- An assignment