Machine Learning And Optimal Trading

M2 Probabilités et Finance — S2 2022

جهـــاز أبـو ظبي للاســتثمـــار
Abu Dhabi Investment Authority

ADIA

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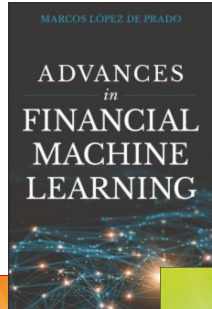
What is happening at Abu Dhabi Investment Authority ?



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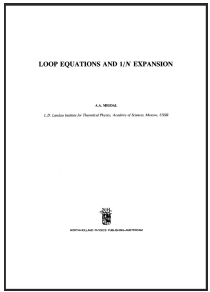
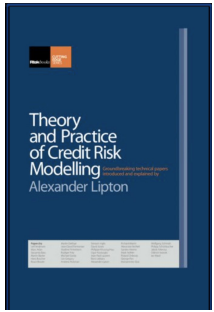
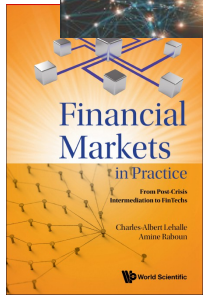
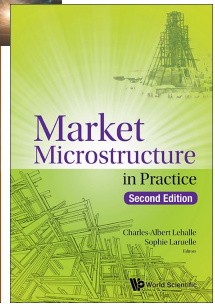








What Is This Course About?

- The financial industry has grown as an important part of the economy,
- thanks to its role in risk intermediation, it can reduce the risk in the real economy
- but only if it does not keep some (hidden) risk inside the balance sheets of the intermediaries
- The Global Financial Crisis has shown a need in controlling this “in house risk”
- as a result, market participants are getting rid of there risk on the fly (hedging their net exposure)

👉 liquidity is now of primary importance, the trading process (and costs) too

- More recently, a hype on “AI” raised
- Machine Learning is not new, Statistical Learning is old,
- All this started with stochastic control of the parameters of approximators during learning
- It ends with fixed points...

👉 everyone wants to play with these tools

- but they are only tools, you should combine them with what we learned in risk control the last 40 years

Why me?

- 7 years in the automotive and aerospace industry
- 7 years on the buy side (brokerage and investment bank, Global Head of Quants)
- 7 years in a (very) large hedge fund (Senior Advisor, Manager and Head of Data Analytics)
- Now in a sovereign fund, Global Head Quant R&D, focus on Data Curation (i.e. Data Integrity and Data Modelling)
- Abu Dhabi Investment Authority is setting up a team of around 120 quants to assess investment problems a scientific way (Marcos Lopez de Prado, Alex Lipton, Sasha Migdal, among others)

- PhD in machine learning for control $\sim$25 years ago
- More than 50 academic papers (ML, control of the trading process, microstructure, MFG, etc)
- 2 books (2 to come in June this year)
- Former member of the Consultative Group on Financial Innovation (ESMA)
- Former member of the Scientific Committee of the AMF
- Former Scientific Director of the “Finance and Insurance Reloaded” ILB Transverse Program

It Is Also A Matter Of Technology

Following the 2008 crisis, the financial system changed a lot:

- "Clients" (from inside or outside) have no more appetite for sophisticated products.

⇒ The system went **from a bespoke market to a mass market**.
Bespoke means to sell products that are very different: no economies of scale but high margins.
Mass market means a lot of similar products + optimized logistics.

- Regulators welcome this change because it can prevent an accumulation of risk in inventories (cf. optimized logistics).

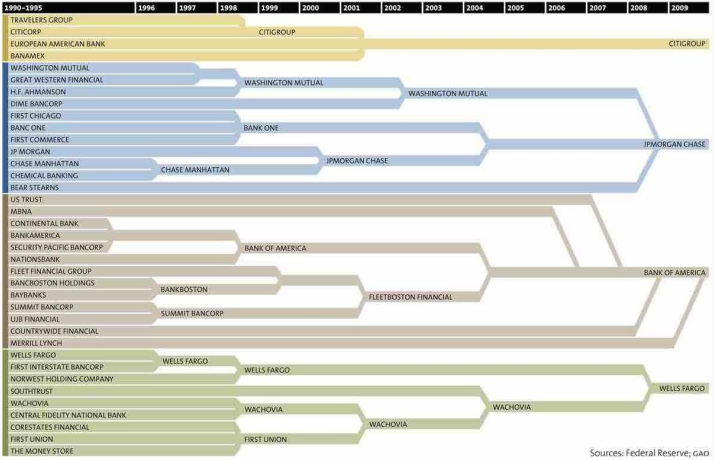
⇒ The G20 of Pittsburgh (Sept. 2009) put the emphasis on **inventory control** (it is the root of improved clearing, segregated risk limits, etc).

⇒ Policy makers took profit of two existing regulations (Reg NMS in the US and MiFID in Europe) to push toward **electronification** of exchanges (i.e. improved traceability and less information asymmetry).

- Technology went into the game. Think about the kind of recent "innovations" (uber, booking.com, M-pesa, blockchain, etc): it is about **disintermediation**.

⇒ How do you desintermediate a system made of intermediates?

Yes, this Industry has Changed



Source FT

Outline of the Sessions

- Market Microstructure: Algorithmic trading in the XXIst century
  - Recent Ways of Trading
  - Adverse Selection and Liquidity “Signals”
- Modeling and Optimal Trading Orderbook (Liquidity) Dynamics
  - Theory and empirics on orderbook dynamics
  - Stochastic Gradient Descent, Reinforcement Learning and Deep Learning on Orderbooks
- Market impact Understanding and Modelling
  - Metaorders and Latent Variables
  - Market Impact estimation with partial information (with a Bayesian Networks)
- Optimal Trading: Stochastic Control (And Reinforcement Learning) Everywhere
  - Optimal Trading Rate
  - Optimal Control of Prices
  - Game Theory Extensions for Kyle’s model and for Cartea-Jaimungal
- Going Further: From Monitoring to Regulation
  - Monitoring Trading Algorithms
  - Regulation

Machine Learning (Hidden) Track In The Lesson

- Error: Bias - Variance Decomposition
- From Jackknife to Boostrap to Cross Validation
- Stochastic Gradient Descent and Boosting as a GD
- A Lazy Universal Approximation Theorem

The Subtile Balance of Intermediaries' Inventories

If we take the viewpoint of looking at the financial network **from the outside**, we need to understands its inputs and outputs, and deduce the features it provides to the rest of the economy.

- We can see how the banking network operates a maturity transformation between natural borrowers at different maturities (mid or long term) and natural lenders (short or mid term).
- Investment banks operate the same way with a lot of other risk transformation (insurance –ie optional payoffs–, structured products, swaps, etc),
- Banks are intermediaries: they have no reason to keep risk in their inventories.
- The bad cases are when all the banks host risks in the same direction (2008), instead of having a diversification at the scale of the whole system.
- Banks are often tempted to take directional risk (sometimes without really knowing it). It is the goal of regulators to force them to maintain the risk of their inventory as low as possible (using capital requirements).
- Nevertheless inflows and outflows in Banks balance sheets (i.e. transactions) are not simultaneous, hence regulators need to give them some freedom to wait for a seller once they sold a contract to a buyer (and the reverse).

Let's see this viewpoint is typically a microstructural one: intermediaries, buyers and sellers, inventory risk... Most of the buzz words are there...

Intermediation of Risks

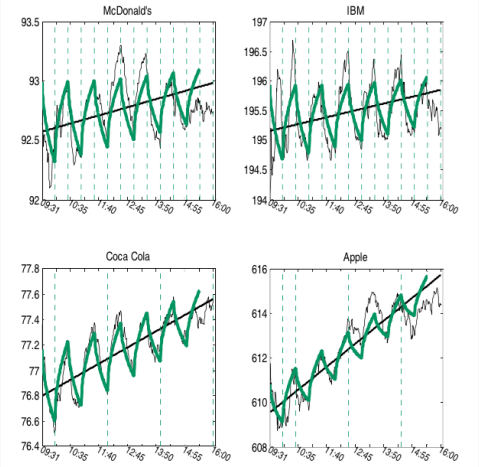
Going back to concepts mathematical finance is more familiar with:

- you are an investment bank, you sell a structured product or a derivative to clients;
- you do not hedge each book separately (or at least you shouldn't): you hope to have other clients consuming other products flattening your (risk) inventory.
- Of course you will not succeed in netting 100% of the risk, hence **you have to hedge the remaining book**, in the markets (we hope they use optimal trading algorithms –i.e. continuous trading– to do this).
- But one step further: if you succeed into hedging continuously on markets (without liquidity, i.e. market impact, issues), it just mean someone has the opposite risk in the market and hedges it on its side: you should / could find it and net both positions (think about the crucial role of CCP here).
- In this sense **wrong way risk is not good for the liquidity on markets** at all, you cannot believe you really hedge if you impact the price.

Two good (but stylized) examples in the literature are [Stoikov and Saglam, 2009] and [Carmona and Webster, 2012].

Sometimes Hedging is Far from Optimal

FIGURE 1: SAWTOOTH PATTERNS ON COCA-COLA, MCDONALD'S, IBM AND APPLE ON 19 JULY 2012



Even on liquid stocks and for vanilla options (close to maturity in this case), hedging can go wrong.

The 19th of July 2012, a trading algorithms bought and sold shares every 30 minutes without any views on its market impact [Lehalle et al., 2012].

For one visible mistake like this on liquid underlyings of vanilla products, how many bad sophisticated hedging processes on less liquid (even OTC) markets...
Anonymous continuous hedging of a remaining position outside of the bank does not mean all is going well.
Nevertheless we have solutions in recent literature: [Guéant and Pu, 2013], [Li and Almgren, 2014].

But nothing more generic, for instance the whole process of hedging books in presence of wrong way risk is not studied (as far as I know). One step in this direction is [Schied and Zhang, 2013].

A Modern Organization For an Intermediary

My advices to an investment bank:

- **Net all your books**, maintain two opposite positions is costly and risky,
- If you can't it may be because you do not communicate enough internally (sometimes because of Chinese walls...), hence **be ready to hedge on the market**,
- But **before try to match your small metaorders**: send them to an internal place and cross them as much as possible;
- You will have synchronization issues (at the level of these metaorders, no reason to be synchronized), ask to your traders to **implement facilitation-like market making** schemes inside the bank.
- The remaining quantity has to be sent to markets as smoothly as possible, but it does not mean you will have no impact. **Who is your counterpart in the market** should be an obsession: if you trade a one way risk, you will pay for this in the future...

Monitoring and Surveillance

The Simpson, Season 12 - Episode 9 - 7:16

Most participant have a surveillance role:

- Banks: money laundering, frauds, etc
- Investment Banks: risk limits, market manipulation, tax evasion, frauds, etc
- Exchanges: risk limits, curcuit breakers.

Market Microstructure: Algorithmic trading in the XXIst century

Next Section – Market Microstructure: Algorithmic trading in the XXIst century

Market Microstructure: Algorithmic trading in the XXIst century

Modeling and Optimal Trading Orderbook (Liquidity) Dynamics

Market impact Understanding and Modelling

Optimal Trading: Stochastic Control (And Reinforcement Learning) Everywhere

Going Further: From Monitoring to Regulation

Examples of Trading Activity on Some Instruments

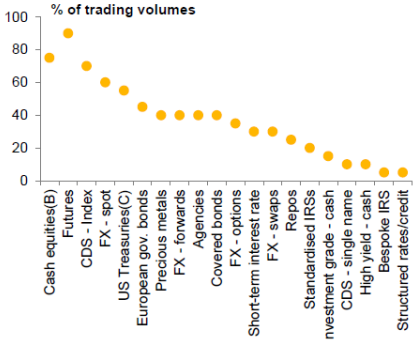
These figures come from the PwC report [Cooper, 2015].

Type	Product	Electronized	ADV	ADV/Amount	Notional
Fixed Income	Rates	50%	$60 b + E30 b	4%	$2,000 b + $ 500 tri
	Credit	10%	$10 b	70%	E 5 tri + $ 9 tri
	(Securitized loans)				
	Forex	50%	$2,500 b		
Equity-like	Commodities	40%	$ 1.4 m		
	Equities	80%	Fut: $ 40 tri		$ 33 tri + ($ 15 tri)
	(Energy)				

How to compare these asset classes? Nevertheless in term of trading style, they are all converging towards the same model: less market making by large inventory holders + electronization.

Is any market “electronizable”?

Figure 5.5: Electronic market development by asset class, 2012



Source: FEMR[245]
Note: includes multi-dealer RFQ

Some technology providers try to answer “yes” using last look and conditional orders. Coming back to [Merton, 1995], intermediaries are ment to

- concentrate the flows;
- assure price and information diffusion;
- anonymize trading + increase matches (anonymous price discovery).

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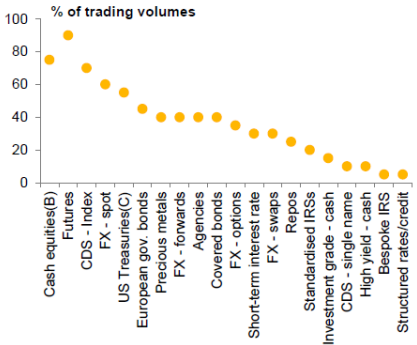

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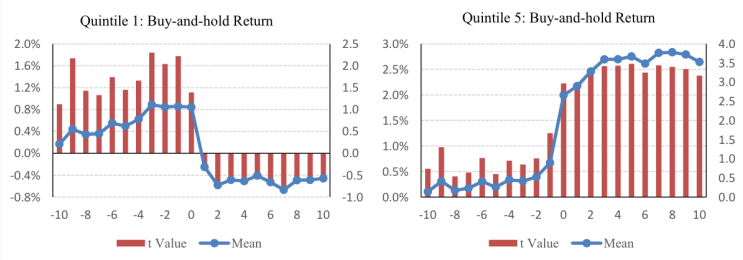
- concentrate the flows;
  New markets are fragmented, but different pools can be connected.
- assure price and information diffusion;
  Easy + big data + open data
- anonymize trading + increase matches (anonymous price discovery).
  If ist is about technological disintermediation, who will provide the search engine?

Disintermediation and New Sources of Data

Technology (the Internet, connected devices, open data, etc) changed a lot the available information.



A careful statistical analysis shows predictive power of indicators based on mobile-based GPS localization of retail consumers on excess returns around quarterly earnings announcements.

Facebook, wikipedia [Moat et al., 2013], linkedin and any connected device could give information (in real-time) on the real economy... A new generation of financial analysis is born...

Moreover this kind of information can be provided by challengers, and not the heavy machineries of JP Morgan, Crédit Suisse, Barclays, etc. We will soon see the “Nate Silver” of financial analysis.

What is a Market / an Exchange?

Trading obviously takes place on Exchanges; hence understanding what an exchange really is has its importance.

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Remark 1 (*What is an Exchange*)

An Exchange is:

1. a place to finance the economy;
2. where sellers meet buyers;
3. the owner of the price formation process;
4. a place where risk decreases.