The Complete Guide to Capital Markets for Quantitative Professionals

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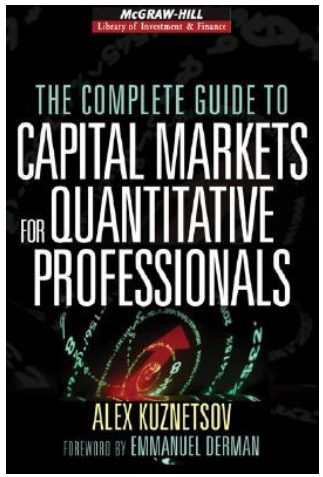
January 2, 2015



History of Markets

- There has always been a need for, raising capital for one set of people and a need for, investing capital for another set of people.
- Debt and Equity have served as a way to move money from those who have it to those who want to use it.
- The concept of debt predates recorded history. Earliest recorded laws - Hammurabi dating about 1800 BC.
- In ancient Rome, the govt outsourced tasks such as tax collection to semi private entities that raised their operating capital by selling shares to the public.
- The roots of modern capital markets are in the medieval trade fairs that began to appear all over Western Europe in eleventh century AD.
- Govt of Venetian Republic imposed so-called forced loans on its more prominent citizens.
- Dutch govt issuance of Perpetual annuity.
- By late nineteenth century, investors' preferences had shifted from perpetual bonds towards bonds where principal was returned.

Trivia..

Coupons

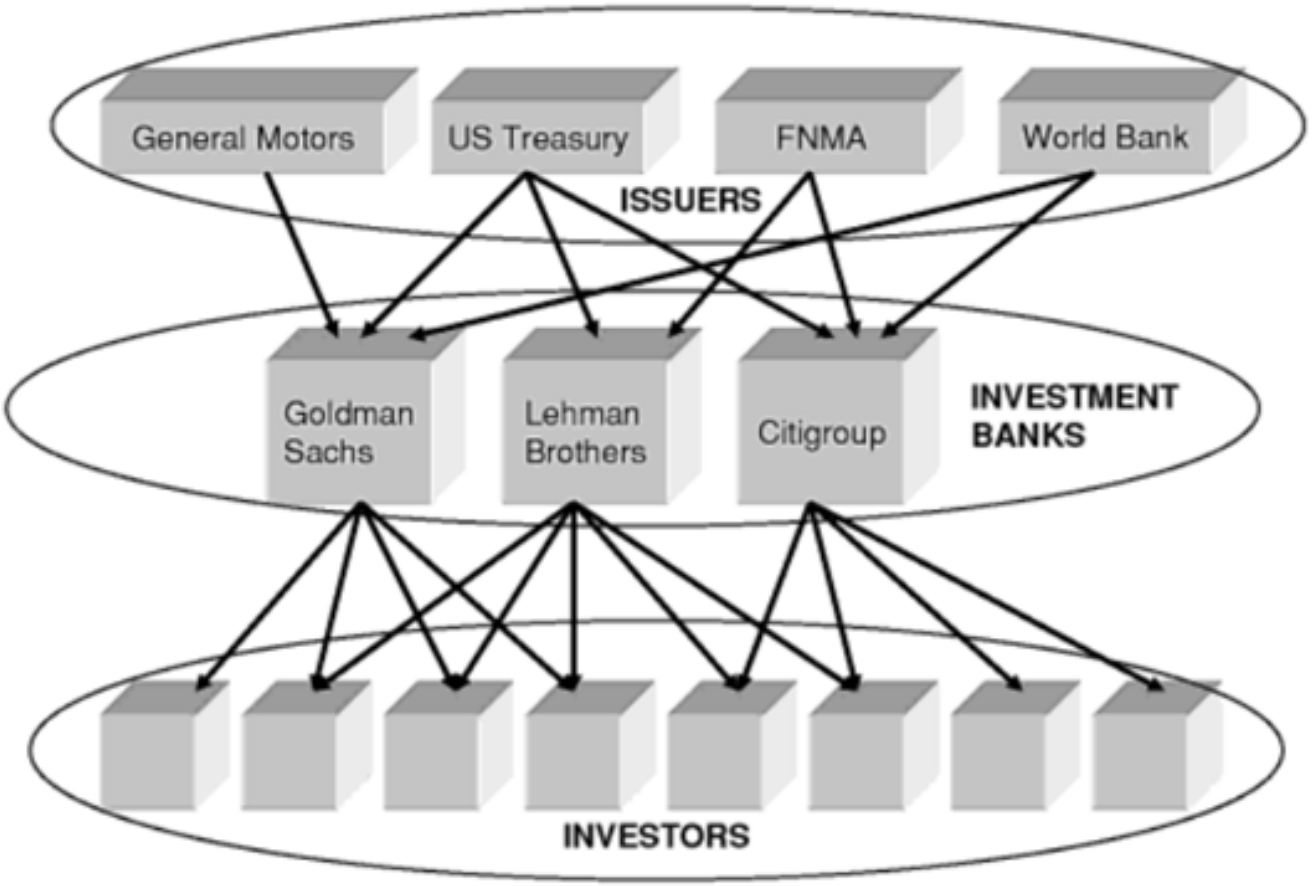
Why are interest payment called coupon payments ?

Because coupons were clipped on to the bond

History of Markets

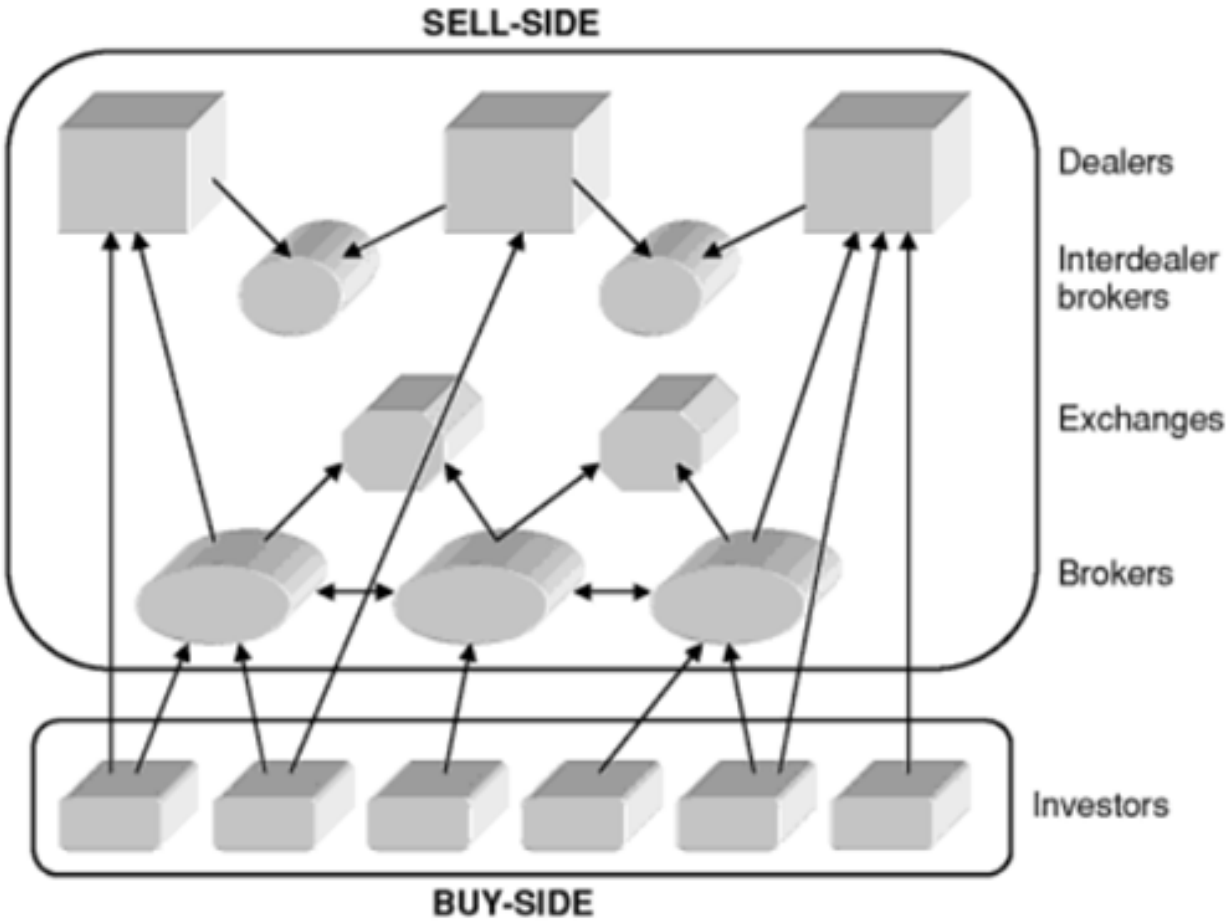
- Dutch East India company's most important financial innovation of the last 500 years : equity finance
- Money Markets : Markus Goldman, a German immigrant made money by selling handwritten discount bills. Founded Goldman Sachs
- FX markets boorn in the late Middle Ages in the form of *bill of exchange*
- Commodity futures
- Index Options, Stock options, Commodity options, FX options
- Interest rate futures
- Interest rate swaps

Organization of primary financial markets



Securities flow downward on this chart, from issuers through the investment bankers to the end-user investors. Money flows the other way.

Organization of secondary financial markets



The investors as buy-side companies, can trader with dealer firms or on exchanges through broker intermediaries

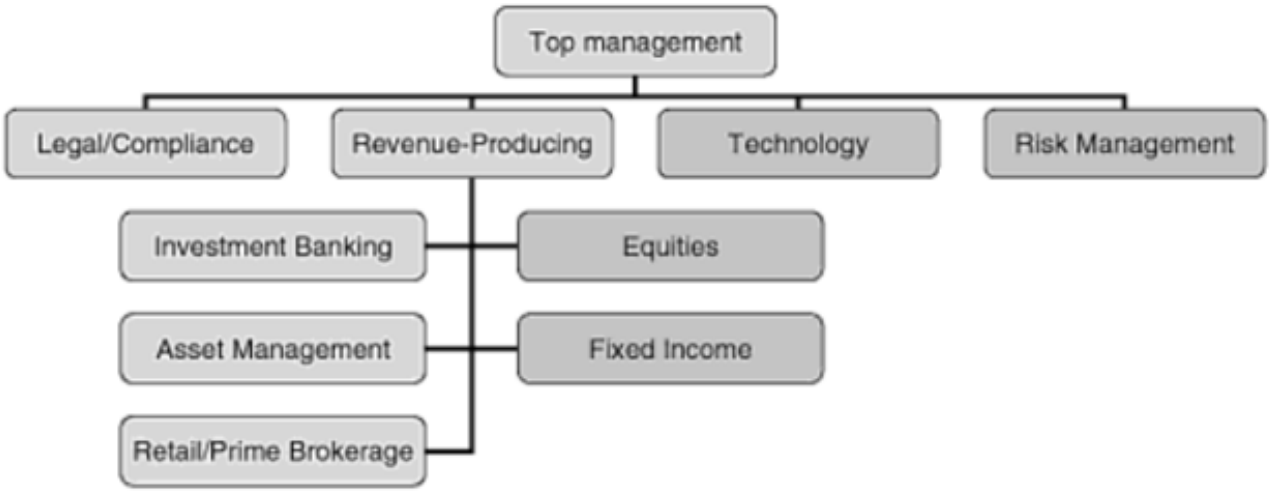
The Structure of Financial Markets

- sell side entities (like used car dealers)
- almost all IBanks also act as market makers in those securities that they help in bringing in to the primary market.
- buy side - mutual funds, pension funds, hedge funds
- dealers - make a living by matching buyers with sellers
- interdealer brokers
- retail broker
- prime broker
- specialist or floor traders
- Not long ago, messengers were sent across to deliver security certificates and checks for payments
- Birth of Depository Trust Company(custodian) who took charge of maintaining securities
- Clearing Services (Netting)

What brings in money ?

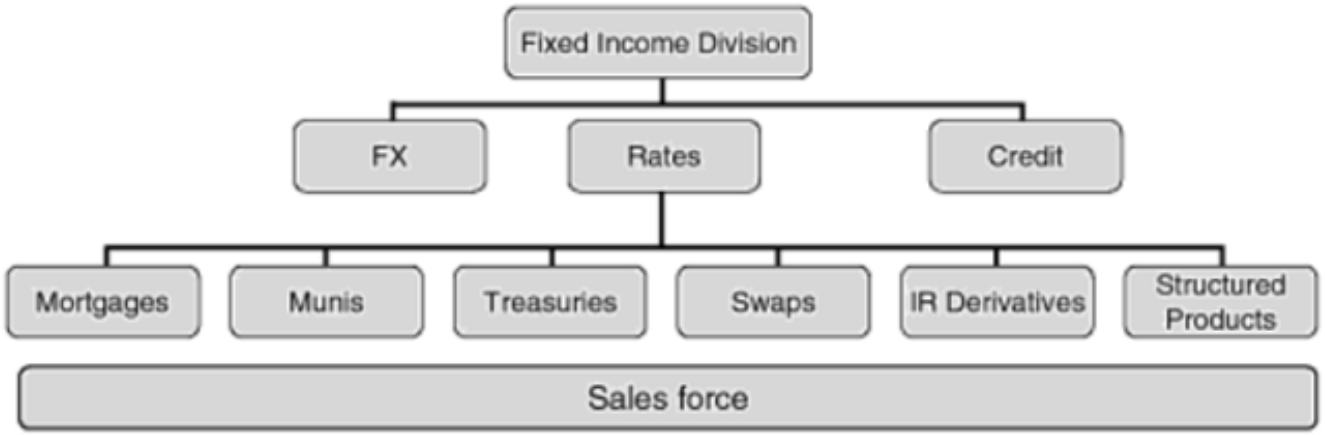
- Investment banking fees
- Asset management fees
- Brokerage commissions and exchange fees for executing other people's trades
- Market-making from providing liquidity to other people
- Proprietary trading from successful investment of one's own capital

Internal organization of a broker-dealer



- *firmwide* divisions: Many nonrevenue-producing units, such as compliance and technology are designed to work with all divisions.

Organization of a trading division



- Each trading desk has about 5-25 traders depending on the size of the book
- Trading desk is like a mini-solar system
  - traders at the center
  - next layer are assistants
  - next layer are salespeople
  - next layer are quants

Use of technology on Wall Street

- 1960s - first mainframe computers were installed
- 1970s- some terminals connected to firm's mainframes (traders could run simple computing jobs)
- mid-1980s - Personal computers
- First batch of quants were hired around mid 1980s
- 1990s - quants were separated in to "pure quants" and "software developers"
- By late 1990s, the allure of "pure quants" began to dim as every firm was pretty much using the same models
- Birth of inhouse trading systems. Main drivers were
  - Market data platforms
  - Internet
  - Quantitative risk management(marked to market valuation)

Other players

- Asset Management firms
- Hedge funds
- Exchanges
- Interdealer brokers
- Financial Software companies - Bloomberg and Reuters

Wall Street Jobs for Technical People

- Salespeople who are now increasingly able to analyze historical data in order to produce trade ideas
- traders in dealer banks
- quant traders
- desk quants
- sales research
- front-office technology
- middleware

Technical people vs Traders

Analogy

The technical people are like car mechanics, who know how the car is put together and worry about keeping it in good running order, while the traders are like drivers, who know how to operate the car, but mostly focus on figuring out where they want to go.

Role of Central Banks

- Prior to Federal Reserve, big banks got together to handle "bank runs"
- Panic of 1907 was too big to handle for the biggies and for the first time Treasury intervened
- Outcome of 1907 - Federal Reserve System was born - lender of last resort
- Banks have a *reserve account* at Fed where they keep a required average of the two-week average of checking account deposits. These are called *fed funds*
- Fed funds rate is not directly set by Fed.
- Most visible function of Fed is the conduct of *monetary policy*
- Fed influences the amount of money in the system via *open market operations*
- Fed funds target rate was not a public announcement before 1995. Market participants had to guess from open market operations

Role of Central Banks

- Since 1995, Fed started explicitly stating the target fed funds rate
- By manipulating short-term interest rates, Fed impacts several aspects of economy
- In 1999, central banks of 11 European countries that adopted euro merged in to the eurosystem with ECB at its center
- ECB is analogous to Fed Board of Governors. It is more decentralized in its functioning than Fed

How interest rates are set ?

- *Treasury bond market* gives the answer to "What does the market expect the interest rate to be at a specific time in the future ? "
- Yield to maturity vs maturity is called *yield curve*
- Basic terminology - maturity, DV01, duration, convexity (asymmetric payoff)
- Market prices of Treasuries with similar maturities but different coupons can be very different and would be all over this chart, but the yields are quite close
- Yields make more economic sense to compare than prices

Yield curve

- Yield curve begins at a level very close to the current value of the central bank target
- Slopes upwards or downward depending on what people think the central bank will be doing in the foreseeable future.
- Beyond the first few years, the yield curve levels off around a rate that mostly depends on what people think about future inflation.
- Market blends the following three factors to give different shapes to yield curve
  - Inflation expectation
  - Risk premium
  - Convexity

Yield curve related

- Yield curve moves mirror significant economic report releases like unemployment report etc
- Market move in which prices go up and yields go down is called a *rally*
- Market move in which prices go down and yield go up is called a *sell off*
- Other kinds of movements are *steepening rally* and *flattening rally*
- Other factors influencing yield curve - oil price, currency movements, gold prices etc
- Supply and Demand arguments can sometimes be used to explain whatever behavior we see in the interest rate movement
- Most participants in fixed-income market prefer to think in terms of rate expectations and inflation expectations

The Structure of U.S Government Debt

- Why should Treasury market exist in the first place ?
  - Government has to manage its income and expenses(receipts and outlays are the right words) and in the times of budget deficit, there is a need for financing.
  - This kind of money is difficult to raise from banks. Hence govt. issues bonds, notes and bills.
  - US Budget deficit as of 2014 is $483 B.
- *Issuance program:* Periodic sale of securities with a certain number of years to maturity.

What securities does U.S Government issue ?

- *Bonds:* Debt securities with over 10 years to maturity
- *Notes:* Debt securities with less than 10 years to maturity
- *TIPS:* Treasury Inflation linked securities. TIPS are issued in terms of 5, 10, and 30 years.
- All Treasury bonds and notes have semi-annual coupon payment.
- Treasury at various times has issued bonds and notes with the following maturities : 2, 3, 4, 5, 7, 10, 20 and 30 year

How much to issue ?

Expected amount of new issuance = Expected bugetary shortfall + Amount needed to payoff outstanding securities maturing during the period

Factors to consider in an issuance program

- What is the total amount maturing for the year ?
- What is the average duration of the debt ?
- What's the short term and long term yields ? In times of recession, short term debt issuance is preferred.
- What is mix of on-the-run and off-the-run securities ?

On-the-run issues

The most recently issued securities in each of the maturity series are called on-the-run issues

What are the steps in the auction process?

1. *Announcement date*
2. When-issued-trading
   - Begins within seconds of the auction announcement.
   - Occurs in both dealer-to-customer and interdealer markets
   - Customers are institutional investors and hedge funds
   - Customer's motivation : Roll their positions in to the current on-the-run from off-the-run
   - Dealers can submit direct or indirect bids
3. *Auction date*
   - Treasury auctions are *single-price format* auctions.
   - All winning bidders pay a single yield, clearing yield regardless of their bidding level.
   - The coupon is always set at or below the clearing yield.
4. Becomes *On-the-run* one day after the auction date. Trades cannot settle before the issue date.
5. On *Issue date*, the security trades with a regular settlement (T+1)

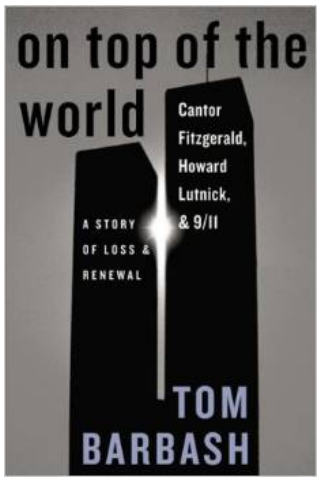
Secondary Market trading

- Two types of trades - dealer-to-customer trades and inter-dealer trades
- Electronic interdealing trading networks - *eSpeed* and *BrokerTec*
- Analog trading networks -*Garban* and *Liberty*
- Trade execution is different from what one knows from the equity markets.
  - The trade can last a significant amount of time
  - During this time, there is only one trade price
  - This makes prices "sticky" and dampens the market volatility
  - *Trade workup* process makes prices move slowly than they would be in an exchange market
- The daily trading volume of 10 year on eSpeed is $30B, the same order of magnitude as the NYSE volume for all stocks on a typical trading day(NSE avg $3B)

Aside on ... eSpeed

Cantor Fitzgerald

Cantor Fitzgerald started eSpeed and revolutionized bond trading. People outside Wallstreet came to know about the firm because of 9/11 attack.On September 11, 2001, the firm lost 658 of its 960 New York employees in the World Trade Center attacks. Since 9/11, the firm worked to rebuild and establish a new global headquarters in Manhattan.



Tom Barbash's book chronicles the events following the tragic day.

Secondary Market trading

- off-the-run issues are far less liquid than on-the-run, but value of the former are linked to the latter.
- *bond switch:* Buy an off-the-run issue and simultaneously sell on-the-run issue
- Yield spread trades

Treasury Bills & STRIPS

- TBills
  - Bills that are non-interest-bearing securities that trade on a discount yield basis.
  - Issued at a discount to par
  - Three on-the-run bills : six month, three month and one month
- STRIPS
  - Zero-coupon bonds
  - Became popular for tax avoidance but soon investors realized their other important features.
  - Under *STRIPS program*, a dealer who owned a Treasury bond could ask FED to replace it with principal STRIPS and coupon STRIPS
  - Major success of STRIPS program lead govt to discontinue callable bond issuance
  - *STRIPS reconstitution program* allows dealer to reverse the stripping process
  - The dealers monitor the STRIPS market and constantly compute *recon* prices for all bonds and notes. Most of the time, the recon price and market price are within a tick of each other.

Darlings of Financial Theorists

STRIPS and zero-coupon-bonds

These are the darlings of financial theorists as they appear to be a pure representation of the concept of the present value of future cash flows.

- By using the STRIP prices from the market, one can compute the *discount curve*
- Used in Bootstrapping(a method for constructing a (zero-coupon) fixed-income yield curve from the prices of a set of coupon-bearing products)

Mechanics of Bond Trading

- Default settlement date is T+1
- Amount paid is trade price + accrued interest = Dirty price
- *Repo agreement* : Borrowing dirty price of the note from a repo dealer and transferring the legal ownership of the security to the dealer for a period of time, at the end of which it repurchases the securities for the same dirty price plus an interest charge.
- Repo market is a convenient form of financing the transactions
- Bonds have a positive carry : Every day we hold a position, we come out ahead as accrued interest dominates repo charges.
- Forward prices are lower than spot prices as securities have a positive carry
- *Price drop*: The difference between the spot and forward price

Mechanics of Bond Trading

- General collateral : Repo lender just wants to invest money and does not care what particular Treasury he receives as collateral
- Special repo : Repo lender wants a particular security as collateral.
- *Reverse Repo agreement* : Lend the price of the bond in the repo market and requests that particular security as collateral so that it can deliver that security to the customer
- Forward price has nothing whatsoever to do with what the market price will be a week from now. It is merely a way to account for the carrying costs.
- PnL components
  - daily carry PnL
  - position PnL
  - trading PnL

Risk and Hedging

- DV01 - Price change caused by 1-bp
- Duration hedge risk : One can compute the position DV01 and then try to hedge it via taking a position in another security that has a similar DV01.
- Factor hedging : In reality duration hedge does not protect us from *curve risk* - the risk that that there is a nonparallel shift of yield curve.
  - Factor hedging is done via computing factor risk.
  - For every bond on the Treasury curve, factor sensitivities are computed that represent the sensitivity of bond's yield to changes in each of the on-the-run yields
  - Use the factor sensitivities to take a position in the on-the-run securities for hedging.
  - The factor risk approach recognizes that the price movements of all Treasury securities are very strongly but imperfectly correlated.

Trading Modes and Strategies

- Two major modes of trading in terms of PnL sources : flow trading/market marking & prop trading
- Curve trade
- Steepener spread
- Flattener spread
- Butterfly spreads

Issuance of Equity Securities

- Selling shares to the public entails going through IPO(Initial public offering) phase
- Firm takes the services of an IB(Investment bank) for underwriting
- What does underwriting entail ?
  - Get the paperwork done that is needed by SEC and state regulators
  - Provide analysis of company's business prospects
  - Talk to clients to get an indication of interest
  - Conduct the offering on a *a best effort* basis or *firm commitment* basis
- IB forms a syndicate through which the IPO process is carried out
- Once the regulators approve the offering, sales force of the syndicate bank pitch the issue to the buy side
- IB also lists the stock on one of the exchanges ahead of IPO so that it can trade right away
- After listing, the syndicate is disbanded.

Life after IPO - Corporate Actions

- Splits
- Rights
- Dividends
- Mergers
- Reverse split

Evolution of Exchange venues

- Specialists at NYSE were in charge of the actual trades.
- NYSEDirect executes orders without specialist's participation
- AMEX : goto exchange for smaller stocks
- NASDAQ : established to solved the mess of OTC trading of small stocks. It addressed the lack of price transparency
- NASDAQ SOES : First electronic trading system called SOES
- Order Handling rules (1997) : Display customer orders alongside the market makers orders
- Proliferation of ECNs
- Centralized Limit Order Book
- Crossing Networks
- Dark pools

Indexing

- Charles Dow - Came up with three main ideas underpinning modern finance (Wall Street Journal, Dow Jones Index, Dow theory used in technical analysis)
- Emergence of Price weighted index and Value weighted index.
- Market-cap weighing approach has become the standard for a great number of new indices. Reason price weighted index is not an investible index.
- Wilshire index includes 5000 stocks, broadest index in US markets
- Index explosion - style indices, small cap, mid cap, country based, etc.
- Float adjusted indices
- Index products - Financial products whose value is tied directly to an equity index. (Index funds, futures and options)
- ETFs - Works like an index and trades like a stock
- AMEX trades most of the ETFs

Development of Futures Market

- Futures(unlike stock and bonds, which originated in Europe) are an American invention
- Brought to life by the political geography of US
- Chicago grain hub status - Commodities flowed from Mid West to East coast and money flowed the opposite way
- Commodity exchanges formed around 1840s to standardize features of commodities (types, grades, etc.) and make them *fungible*
- CBOT began standardizing various aspects of futures contracts
  - underlying commodity to be delivered
  - quantity, quality of the deliverable
  - delivery times
  - delivery location
  - trading details - trading hours, the way prices are quoted, tick size, max daily price shifts
- increased liquidity more than makes up for reduced delivery choices.

Development of Futures Market

- *open interest* is the number of open contracts in the market
- *closeout* process reduces open interest and does not entail delivery
- Clearing houses formed in 1880s to take care of settlement issues
- Gains and losses are made real at the end of each trading day via *mark-to-market* settlement
- All prior trading history becomes irrelevant after marking process is complete
- *initial margin* is what a member should deposit before he can place his buy or sell order
- *variation margin* : the minimum amount that the member should hold after each day's mark-to-market settlement
- Margin system prevents the accumulation of losses for clearing house.

Major futures exchanges as of early 2006

- CBOT -Chicago Board of Trade
- CME - Chicago Mercantile Exchange
- NYMEX - New York Mercantile Exchange
- EUREX
- LIFFE - London International Financial Futures Exchange
- IPE - International Petroleum exchange

Financial Futures

- Instruments where the underlying is a financial product rather than a commodity
- IMM started trading foreign exchange futures in 1972
- CBOT traded the first interest-rate futures in 1975
- CME traded the first Tbill futures contract in 1976
- CBOT traded the first Treasury bond futures in 1977, which remains the world's most liquid securities to this day
- CBOT also lists Treasury futures contracts on other sectors of Treasury curve

Conversion factor for Treasury futures settlement

- Conversion factor may be thought of as the price of the delivered security as if it were yielding 6%.
- Delivery for a Bond future can be done by choosing from a *delivery basket* of bonds
- Choice of the instrument for delivery is imperative to avoid *delivery squeeze*
- When a short makes delivery of securities in satisfaction of a maturing futures contract, the long will pay a specified invoice price to the short. The futures contract permits the delivery of a wide range of securities at the discretion of the short. That invoice value must be adjusted to reflect the specific pricing characteristics of the security that is tendered.
- To make all the bonds in the basket, the contract specifies a different *delivery price* for every bond in the basket
- futures price $\times$ *conversion factor* is the delivery price of a bond.

Cash securities as forward contracts

Carry mechanism

Unlike the futures market where trades are settled on the same day they are transacted, it is customary to settle a cash transaction on the business day subsequent to the actual transaction.

Thus, if you purchase the security on a Thursday, you typically settle it on Friday. If purchased on a Friday, settlement will generally be concluded on the following Monday.

Theoretically, there is no effective limitation on the number of days over which one may defer settlement. Thus, these cash securities may effectively be traded as forward contracts.

Terminology used in trading futures

- cheapest to deliver
- implied yield curve
- bond basis trading
- gross basis
- net basis
- time option
- long basis
- short basis

How/Where are Futures are traded ?

- pit trading vs electronic trading
- Futures markets have depth unlike cash markets thorough its workup mechanism extends price in time. Hence futures are more liquid than cash market
- Venues
  - LIFEE First financial futures exchange in Europe (1982)
  - DTB, german exchange formed a joint venture with SWX and called it EUREX(1997)
- front Bund futures contract is most liquid security in the world, with over 1 million contracts trading daily.
- Bund futures : Narrower range of maturities for the deliverable bonds single delivery date.
- Futures can be used as more liquid replacements for the underlying bonds

Money Market Futures

- CME launched Tbill futures in 1976 was a disaster.
- What challenges did the short-term interest-rate futures contract had to over come ?
  - Depression years - U.S. capped the deposit rates of the banks
  - Banks started issuing CDs that were exempt from rate cap. Banks cared more about CD rates than Tbill rates.
- CBOT's commerical paper futures contracts did not take off
- CME & CBOT's CD futures contracts did not take off. Key reason for the failure - Participants did not know "Whose bank CD was the deliverable "?
- Rise of Eurobond business in London
- By 1980s, the rates of Eurodollar deposits were very much relevant to U.S banking system

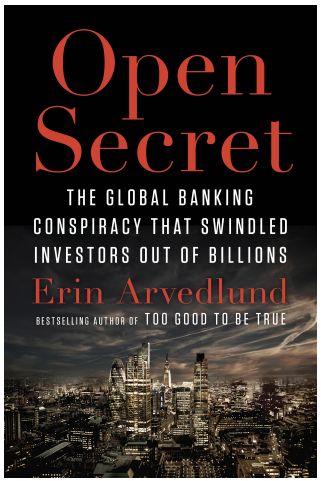
Rise of Euro Dollar Futures

- Problem : What would be the deliverable for Euro dollar futures ? The Eurodollar CD were not nearly widespread in U.S
- Solution : CME's idea revolutionized financial futures, *cash settlement*
- Eurodollar futures payoff is $100 - R$ where R is the reference rate
- What should be the reference rate? Birth of LIBOR, London Interbank Offered rate
- LIBOR - How is it calculated?
  - Several leading banks submit their offer quotes for $ 1M Eurodollar deposit for various terms(overnight to 12 months) every morning to BBA(British Bankers Association)
  - BBA computes the average of values between first quartile and third quartile
  - The average across various maturities is disseminated to all

Libor Scandal

Barclays

On 27 June 2012, Barclays Bank was fined $450 by various regulator and exchanges The United States Department of Justice and Barclays officially agreed that "the manipulation of the submissions affected the fixed rates on some occasions".



Ervin Arvedlund has made a crime thriller out of it.

Rise of Euro Dollar Futures

- Eurodolar futures started trading on CME in Dec 1981.It was an instant hit
- CME extended futures strip to 40 contacts covering 10 years.
- Asymmetric liquidity : 90% of liquidity is within in the first three year maturity futures
- Relation between Eurodollars futures prices and future LIBOR rates are tied by "Law of one price"
- Eurodollar futures were among the first securities to *trade around the world* and *around the clock* (LIFFE, SIMEX)
- platforms
  - GLOBEX went live in 1992 - became the dominant platform for Eurodollar futures
  - LIFFE's CONNECT platform
- Rise of other region specific money market futures - EURIBOR, TIBOR, FF, EONIA

Stock Index Futures

- Kansas City Board of Trade - first exchange to think about stock index futures
- Value Line Index futures start trading in 1982
- Trading of S&P futures on CME started in 1982
- Trading of S&P E-mini futures on CME started in 1997
- DJIA futures in 1997
- Contracts are cash settled(obvious)
- Final settlement price based on *SOQ* - Special Opening Quotation
  - SOQ is based on the opening values of the component stocks, regardless of when those stocks open on expiration day
  - if a stock does not open on that day, its last sale price will be used in the Special Opening Quotation
- Index futures popularity - Helps in hedging market risk & Helps one take Leveraged bets

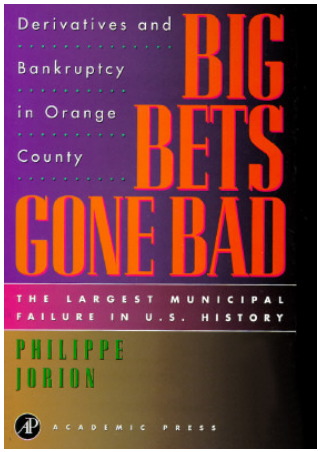
How are these products different ?

- Bonds, Equities, Bond futures, Equity futures, commodity futures, etc all have well defined properties. All the participants need to do is negotiate the price.*Swaps are different!*
- *over-the-counter derivative* : Interest-Rate Swaps are instruments whose properties are also negotiated. There is no netting that take place at a participant level as each deal is a separate financial product
- Why swaps ?
  - Banks are long duration and hence to hedge the short duration payments against interest rate movements, swaps are a good vehicle.
  - Why not sell treasury bonds or notes or issue bonds? All these alternatives are not good. Some make it imperative to list on company's balance sheet. Some need SEC registration. Swaps, on the other hand can be done by a single mouse click
  - Swaps are structured so that the value of floating leg and fixed leg are same, and hence costs of entering in to a swap is zero.
- Swaps have become mostly vehicles for speculation and risk management

Speculation and Losses

Orange Country Disaster

Swaps make it easier for market players to hedge their interest-rate risks, but they also make it easier to bet on them. Giving such speculative ability to some people who were not trained to understand the risks lead to many losses. Famous case is the bankruptcy of Orange County, California.



Philippe Jurion gives a detailed account of the events leading to bankruptcy.

Swaps curve

- FRAs can be used to hedge a floating payment
- Eurodollar futures can also be used. They are liquid and transparent but they are limited expiry dates
- Birth of *swaps curve* to answer - How many of each Eurodollar contracts do we have to buy or sell to eliminate the interest rate risk on the floating leg ?
  - Key idea is to aggregate all rate information into a single mathematical object *discount curve* in a consistent way
  - *bootstrapping* : use the information from Eurodollar contracts to formulate discount curve
- Swaps curve made it possible to value floating rate payments.
- Inconsistency in payment schedules was fixed by *convexity adjustment*
- *par swap rate* : The value of fixed coupon rate that makes the value of that bond to par.

Swaps curve

- There is no centralized market for swaps, so one cannot directly observe how they trade
- In U.S dollar market, the swap market is driven by Treasury on-the-runs and the linkage between the two is established via *swap spreads*
- Swap spreads are updated infrequently whereas Treasury yields move up and down at every treasury tick. Hence swap rates also move at every treasury tick
- What's the economic meaning of swap spreads? They are measures of
  - Market perception of credit risk
  - Balance between supply and demand - Relative desirability of swaps compared to Treasuries

Swap Trading

- There is no such thing as a position in the 10-year swap or position in OTC derivative. Large swap books contain millions of cash flows
- Traders keep track of
  - What is the net present value of all cash flows?
  - What will happen to PnL if 10 year swap rate changes by 1bp?
  - What is the hedge PnL?
  - What is amend PnL?
  - What is the spread risk ?
- Electronic trading in swaps have brought down a swap trader's profitability by giving direct access to the institutional investor.
- Other types of swaps traded are basis swaps, cross-currency swaps, equity swaps
- What's unique about IR swaps is that their value is a function of the term structure of interest rates today and does not depend on how much those rates will move about in the future.

Context

- Options pricing has earned the status of the rocket science of finance
- In reality, currently only a few quants price options for a living. Most of it is commoditized.
- It remains a matter of professional pride for all the rest of us to be familiar with the subject
- Math is fascinating and but the markets are themselves very fascinating.
- Understanding markets is as important, may be even more important than math behind it

History of Options Trading

- CBOT was the birthplace of organized options.
- *1860's* - CBOT futures trading members began buying and selling what they called "trading privileges". Right but no obligation instruments
- Numerous attempts were made to banish options because of their potential of huge speculation
- *1874* - State of Illinois passed a law making privileged trading illegal. CBOT banned options from its main trading floor.However trading continued in the back alleys.
- *1892* - U.S Congress passed a bill known as Hatch bill that made options, futures and short selling a federal crime. However the bill failed on a technicality and never became a law
- End of *19th century* - option trading was alive and well in Chicago. It also spread to NY, London
- *1920s* - Options were used to "incentivize" brokers
- Equity options survived the financial regulations of early Great

History of Options Trading

- Options on futures were banned during the Great Depression era.
- *1960's* - CBOT saw an opportunity to revitalize the equity options market by restructuring it along the lines of its futures trading model.
- *1973* - CBOT's subsidiary CBOE opened the trading of listed options, sets of contracts similar to futures contracts with a well-defined and limited set of strikes and expirations
- At first, CBOE listed only call options on 16 stocks
- *1975* - AMEX, PhLX started options business
- *1977* - CBOE listed put options
- *1976* - Pacific Stock exchange started options business
- *1982* - Prohibition of options on futures was finally lifted
- *1983* - Options on Stock indices
- *1985* - NYSE and NASDAQ started options business

What's in an option contract ?

- Type : American / European
- Underlying
- Strike price
- Expiration date
- Daily settlement mechanism
- Final settlement mechanism
- What to deliver when the option is exercised ?

Intuitive understanding of Black Scholes Formula

- Value of an option is the expected present value of its terminal payoff
- To compute, the expectation of a function of random variable, we need the distribution of the random variable
- Stock prices are assumed to follow GBM, i.e returns are normally distributed
- Given the distribution function, expectation is obtained by computed by multiplying the probability of realizing a particular stock price at expiration times the option payoff for that specific stock price, across a range of prices.
- The resulting expectation is the black scholes formula for an option
- Volatility is the only free parameter in the formula.

Risk factors affecting options

- Delta
- Gamma
- Vega
- Theta
- Extreme movements on the expiry day and triple-witching days
- A successful options trader keeps a tab on all the above risk factors for his positions

The Structure of Options Market

- Individual $\rightarrow$ Broker $\rightarrow$ exchange
- Buy side $\rightarrow$ Equity derivatives desk on Sell side $\rightarrow$ exchange
- Exotic Options $\rightarrow$ Equity derivatives desk on Sell side $\rightarrow$ Hedge the payoff via other exotics/ combination of plain vanilla options
- Pricing OTC options involves modeling the volatility surface
- Closing vol surface is used for calculating PnL for the day
- As volumes exploded, CBOE came up with RAES , Retail automatic execution system to take the load off market makers
- 2000 - Electronic options exchange started its operations - forced traditional pit-based exchanges to introduce electronic platforms
- Other players entered the market - Citadel, Knight Trading

Fixed-Income Options

- *1980's* OTC options on treasury bonds
- *1990's* Swaptions became popular
- In both the dealer-to-customer and the interdealer market, swaptions are typically quoted in terms of their Black-Scholes volatility
- constant volatility assumption cannot be used as interest rates in the market as interest rates are mean reverting
- Generalizations to Black-Scholes model $\rightarrow$ *term structure models*
  - Hull-White model
  - Black-Karansinki model
  - Black-Derman-Troy model
- Availability of option pricing models $\rightarrow$ structured products
  - binary options
  - barrier options
  - quanto options

History

- *1903's* - Only about 40% of the population owned their homes
- *1934* - Federal Home Loan Banks(FHLB) formed. Introduction of fully amortized fixed rate mortgage
- *1934* - Federal Housing Administration(FHA). Insured the lender against the risk of default for a few basis points
- Lenders became more willing to lend since they had FHA backing. But soon they ran out of money to lend.
- *1938* - Federal govt came up with another agency, Fannie Mae.It was essentially created to spur the secondary market.
- Fannie Mae freed up a lot of capital for mortgage lending
- *1968* - Fannie Mae became a public company whereas a part of it, Ginnie Mae remained as a Federal govt. arm
- It was Ginnie Mae that introduced the concept of *securitization*, that made mortgages attractive for institutional investors

Securitization

- *Securitization:* Combine individual mortgages in to something larger and standardized
- Mortgage originator, Mortgage servicer, Mortgage owner can be three different entities
- Originator creates mortgage pool, sells them to Ginnie Mae, which authorizes the originator to issue MBS
- 1971 - Freddie Mac starts issuing MBS
- 1984 - Fannie Mae starts issuing MBS
- What makes an MBS different from a regular Treasury bond is *prepayment factor*
- Negative convexity of MBS
- What will happen to both securities under different interest-rate scenarios? Salomon Brothers introduced OAS(Option Adjusted Spread) analysis

Mechanics of Mortgage Trading

- Mortgage trading has a lot of similarities with the Treasury market
- Three major types of MBS are GNMA pass-throughs, Fannie Maes, and Freddie Mac Gold PCs
- Liquidity is spread over a few dozen securities, which differ in terms of their guarantor and their coupon
- MBS are on a monthly issuance cycle
- Market participants trade securities before they are actually issues - *to-be-announced trading*
- Overwhelming majority of mortgage trading is done via TBA basis
- Secondary market for MBS also exists where trades settle on "specified basis"

Agency Markets

- Fannie Mae, Freddie Mac, Sallie Mae, etc all come under the category, *GSE's* - government-sponsored enterprise
- Where do GSE's get money to pay from purchases ? Two main ways :
  1. They insert themselves between originator and the investor and take a cut of the transaction for making the mortgage pool attractive
  2. GSE's issue *agency discount notes* and *agency notes*
- GSE's issuance program gives rise to *agency curve*
- spread trading creates a tight integration amongst
  - agency markets
  - Treasury markets
  - swaps market

Corporate Bonds

- Corporate bonds are like bonds as far as cash flow is concerned, but they are like equities in that their price is sensitive to the fortunes of the issuer corporation.
- Trading of corporate debt and related derivatives is usually organizes as a separate business unit - *credit business*
- Investors need a higher yield on corporate debt than govt debt
- Issuance of corporate debt
  - Corporate bonds are nonexempt securities
  - Corporations turn to debt borrowing far more frequently than equity
  - Bonds are often issued not by the corporation as a whole, but by its individual units
- Most corporate bonds are bullet bonds
- Other popular structures are floating-rate notes, inverse floater, convertible bonds, etc.

Credit Risk

- Besides interest rate, *credit risk* of the company determines the price of a corporate bond
- Spread between treasury bond and corporate bond takes into consideration *probability of default*
- Given market prices, whole *term structure* of implied default probabilities can be computed
- *LIBOR Spreads* : Most common way of establishing corporate spreads has become spreading against the swaps curve instead of Treasury curve
- Spreads are quantitative measures of credit risk but often they are not easy to obtain. Hence many turn to *credit ratings*
- S&P, Moody's, Fitch are some of the popular rating agencies
- Robert Merton's key idea - Equity is the call option on the assets of the company struck at a strike price that is equal to the company's debt.

Secondary Market for Corporate Bonds

- Most corporate bonds never trade in the secondary market.
- Corporate bond market is a dealer market in which Wall Street sell-side firms act as market makers for institutional investors
- Despite low liquidity, trading these bonds is a profitable business
- Traders hedge away the interest-rate risk by entering in to an asset swap and keep only the equity like credit component
- The market was traditionally very nontransparent. But the situation has changed dramatically over the last few years(NASD's TRACE)
- Illiquidity of corporate bonds makes it difficult to short - Solution : *Credit Default Swap*
- CDS captures the credit risk in its purest form, with no extraneous interest-rate component

Product Identifiers

- External Product Identifiers
  - *1964* : American Bankers Association created a CUSIP committee
  - *1967* : CUSIP committee issued its recommendation for securities numbering
  - CUSIP code interpretation : First 6 digits are a numerical code assigned to the issuer, the next two identify an issue and the last one is a check digit computed from the other eight
  - Administration of the system if performed by Standard & Poor's CUSIP Service Bureau
  - LSE administers SEDOL system
  - ISO endeavors to assign 12 character ID called ISIN to every security in the world
  - Bloomberg and Reuters also assign IDs.
- Internal Product Identifiers
  - Every bank has its own database of securities, in which securities are identified by an internal ID.

Populating the Reference Database

- Reference database - combination of internal and external identifiers
- External vendors provide data feeds for new securities as well as corporate action data
- Feed handlers massage the data according to the internal database schema
- Often the feed management is painful problem and hence it is outsourced to third party firms that provide *reference data management systems*
- Original purpose of reference systems was to reduce errors in settlement process. In the last two decades, their uses have grown far beyond the back office, to analytics, trading systems, risk management and research
- Each security is typically represented as `class` and hence to instantiate a class and use it in a software package, reference data is imperative

Historical Data

- Historical data is usually stored in reference data systems
- Information stored typically include closing prices, yields, rates, spreads, closing curves etc.
- Used for housekeeping tasks, research activities such as econometric modeling, regression etc
- Pseudo securities data - Rolling series of various treasury bonds, time series of constant maturity treasuries etc. Each time series is given a security ID
- a growing number of historical databases systems are now tick databases

Types of Financial Analytics

- Fixed Income mathematics - bond math
- Option pricing models
- Curve building models
- Market risk models
- Credit risk models
- Portfolio analytics
- Term structure models
- Prepayment models

Users of Financial Analytics

- Trading systems - internally developed systems that automate and facilitate various aspects of trading
- Front-office traders use it via some excel plugin
- Risk management systems
- Client facing applications - Sell-side firms offer the buy-side clients some form of access to their financial analytics tools as well as historical data.

Contents of Financial Analytics Library

- `date` library nitty-gritties
  - day count convention
  - business-day convention
  - holiday table
  - functions to add terms to date
- yield calculation convention
- `class` representation of security
- curve library
- curve construction
- product libraries
- model libraries
- pricing tree libraries
- simulation libraries

Maintenance of Financial Analytics Libraries

- How should the library be organized ? Single huge library vs loosely coupled components
- Main drivers of financial modeling at present are the credit and energy derivatives businesses
- Bloomberg provides analytics libraries that traders agree upon. For example, OAS calculation for callable bonds on Bloomberg has become defacto standard among traders in agency bonds
- The trend is that more and more analytics libraries will be provided by third party softwares, that traders will find it convenient to use
- Bloomberg now offers customers access to its servers and do financial calculations. This ASP model is the biggest threat to financial analytics development on Wall Street.

- Real-time data platform as a cross between a network and a database
- Publish-Subscribe paradigm makes a network function like a database
- Market vendors - Reuters, TIBCO, Talarian
- Common vendor-supplied publisher is a *data feed*. It reads quotes using a vendor-provided interface, and publishes them to the data manager so that multiple users inside the organization can see and use these quotes
- *news feeds* - data distributed are news pages rather than market quotes
- Most of the market data systems have a GUI so that trader gets a rich client to work with real time data
- record and playback software - for backtesting and simulation
- hot backups and cold backups
- All market data platforms have Excel interfaces
- Anyone working in the industry is increasingly likely to become either a user of real-time data or a processor of it in a development or a modeling role

- Trading systems have evolved from pencil-and-notebook-based approaches to modern algorithmic trading systems in little more than 20 years
- This is one where a newbie gets overwhelmed as there is little standardization amongst various systems
- Main components
  - Trade solicitation systems
  - Trade pricing systems
  - Trade booking systems
  - Trade and position management systems

Trade Solicitation Systems

- Traditional approach was two fold
  - Salespeople calling up customers and plugging various ideas
  - Establishing a good relationship with customers
- Whenever a customer needed to adjust her hedge, she would call up a salesperson and ask for a quote on a specific instrument, the sales person then had to ask the traders for the price, book the trade and son on, many times a day - perfect task for automation
- Since early 1990s, every dealer firm has attempted to automate this stuff. In the initial days, each buy-side trader had to run a different trading application for each dealer.
- *FIX* standardized this part so that buy-side could have a single interface for sending orders to any dealer
- In the fixed-income side, the problem was different - customer wanting to trade with multiple dealers, through a single application
- *TradeWeb* solved the problem - It was trading platform that made the interaction between traders and dealers a hassle free activity

Trade Pricing Systems

- Dealers can quote either firm or indicative quotes. Depending on the nature of the quotes, actions from the buy side traders kick off a set of activities
- Dealers face the problem of interfacing their market data systems to gateways that buy-side uses.
- To reduce the development and maintenance burden, ION a European company provides consolidation services
- *ION* : It takes on the burden of interfacing with each individual trading platform and gives dealers a single API for their software
- In equity world, a centralized order management system takes care of firm-quote system

Trade Booking Systems

- Many first generation trading systems started out as *trade blotters*, which initially were electronic replacements for the paper blotters on which trades were recorded in the olden days.
- These systems evolved into a full-fledged trading system integrated into a single application
- In modern trading systems, the trades done electronically are also booked electronically as part of STP
- Graph execution engine
- Graph manager
- Graph generation process

Short History ...

- Prior to 1970s risk management meant buying insurance
- Banks going bankrupt because of interest rate swings $\rightarrow$ 1974 Basel Committee
- 1988 - Basel I $\rightarrow$ Banks set up organizational structures that would look over the financial position of the bank as a whole and monitor its exposures
- 1990s - People started worrying about the potential losses from derivatives trading
- 1994 - JP Morgan released Risk metrics. The timing was just perfect(immediately after Orange County bankruptcy)
- Risk Metrics was a huge public relations success for J.P Morgan
- Post 1994 - After some highly publicized financial failures linked to derivatives, Wall Street realized that it should do something about it. *Wall Street relabeled derivatives as risk management tools*

Functions of Risk Management

- Two major components - *risk measurement* and *risk enforcement*
- Risk measurement - Mostly a back office function whereas Risk enforcement is a business function
- Operations and Product control also come under the gamut of risk management
- Basel II - explicitly calls banks to quantify their operational risk $\rightarrow$ most back office operations came under the purview of risk management
- Risk management categories
  - credit risk
  - market risk
  - operations risk
- assess *regulatory capital* requirements

Risk Management Process

- Produce daily PnL reports for each trading desk
- For cash trading it is relatively straightforward. For derivatives, some valuation model needs to be used
- Daily valuation runs can take a long time. However state of art tech in sell-side firms produce $T + 0$ PnL reports (reports that are ready with in an hour of market close)
- PnL report should have the following components :
  - trading PnL
  - position PnL
  - carry
- PnL attribution reports
- Risk runs - sensitivities to various market factors
- VaR of a derivatives book
- Scenario analysis & Stress testing

- The main goal of the research produced by Wall Street is to convince the firm's buy-side clients to trade with it by offering these clients some interesting commentary and analysis of market trends
- *strategy* refers to trade recommendations - part of research output
- Research areas
  - equity research - stock specific research.
  - credit research is corporate bond specific research, directed at institutional clients
  - fixed-income research - much more macro-oriented
  - economic research - comes closest to the academic definition of research
- fixed-income research - demand for quant skills is the highest (Stocks are stories, bonds are mathematics)
- output of research - *piece*, *dailies*, *quarterly publications*, *event based commentary*

How do we use historical data ?

- analyzing co-integrated series
- estimating volatilities at various time scales
- rich-cheap analysis
- curve construction
- technical analysis

Approach

Traditional quantitative analytics is based on the idea of *interpolation* more than on anything else - all derivatives pricing, curve and model fitting, and the like are on some level nothing but glorified interpolation schemes that tell what this derivative should be worth if its neighbors are observed to have such and such prices.

General Gyan from the author

- Modern financial industry is astoundingly fast, and knowledge you will have will age pretty quickly
- Financial industry has become inseparable from technology
- The advent of electronic markets has had the tendency to transform high-margin,low-volume operations in to low-margin, high-volume affairs
- If a computer can do what you are doing better and cheaper, you will not be doing it for very much longer
- Demand for technical and quantitative talent in this space is likely to continue unabated
- If you are working for one of the areas that are at risk of being taken over by the electronic trading wave, you should either join the tide and learn something about electronic trading or try to find another are that is not at risk in that sense

General Gyan from the author

- Wall Street institutions will change from being trading businesses with small technology appendages to being technology companies with small trading businesses on the side
- a lot of stuff that should have been bought has ended up being built in-house. As long as Wall Street firms do not care about how much it costs to develop things in-house, this trend will continue.
- a gradual shift is happening - financial software companies are making inroads in to Wall Street technology turf

What's ahead ?

The future of the financial technology profession may have its ups and downs, but what gives me reason for long-term optimism about its prospects is the remarkable resilience and history of innovation of the financial industry itself. The lure of profits in the market brings out the creativity of the market participants like nothing else, and they will always try to gain an edge through creative applications of technology.

Alex Kuznetsov reflections...

I came to Wall Street from academia, and so did many of my current colleagues, and we as a group never looked back.

Life is very different here, and, as everywhere, it has its frustrations(commercialism, bureaucracy, too little free time, and so on), but there is also dynamism, challenging work, interesting people, and the fact that those around us do care very much if we do a good job (even if for purely commerical reasons).

It is a great place to work if you are up to it.