CMSC 5718

INTRODUCTION TO COMPUTATIONAL FINANCE

Lecture 1

Course description (from the department)

"This course introduces some basic concepts in computational finance. Topics include risk and return, modern portfolio theory, calculating the efficient frontier, multiple factor models, various models for portfolio optimization, utility functions and evaluation of portfolio performance."

The scope of this course

- Apply models / algorithms in managing the risks and making decisions regarding the trading of financial assets

- We will look at two main areas in this course
  - Modern Portfolio Theory: concern with the equilibrium pricing of assets
  - Pricing of derivative instruments and related concepts

Some financial jargons

- **Buy/sell**
- **Long/short**: long = buy, short = sell
- **Bid**: the price that the buyer is prepared to pay
- **Ask**: the price that the seller is willing to sell
  - e.g. HSBC stock price $63.00/63.05
- **Take a "position"**: enter into a trade
- **Close a "position"**: enter into trade(s) to neutralize an existing position

Some financial jargons

- **Risk** (風險): uncertainty in the outcome of investment, with the possibility of suffering a loss
- **Hedge** (對沖): engage in a trading strategy to reduce the fluctuation in profit or loss (but note the name "Hedge Fund" (對沖基金) could mean the opposite...)
- **Arbitrage**（套戥）: engage in a trading strategy which is supposed to generate a "riskless" profit, i.e. no matter how the market will move in the future, a guaranteed profit can be made.
- **"P&L"**: profit and loss

The different financial markets

- Currency (Foreign Exchange, or FX) market 外匯
  - E.g. US dollar against Euro
- Fixed Income market (including the interest rate market) 定息工具
  - credit trading 信貸
- Equity (or stock) market 股票
- Commodities market: e.g. gold, silver, coffee 商品
- Derivatives market 衍生工具
  - a sub-group which exists under each market

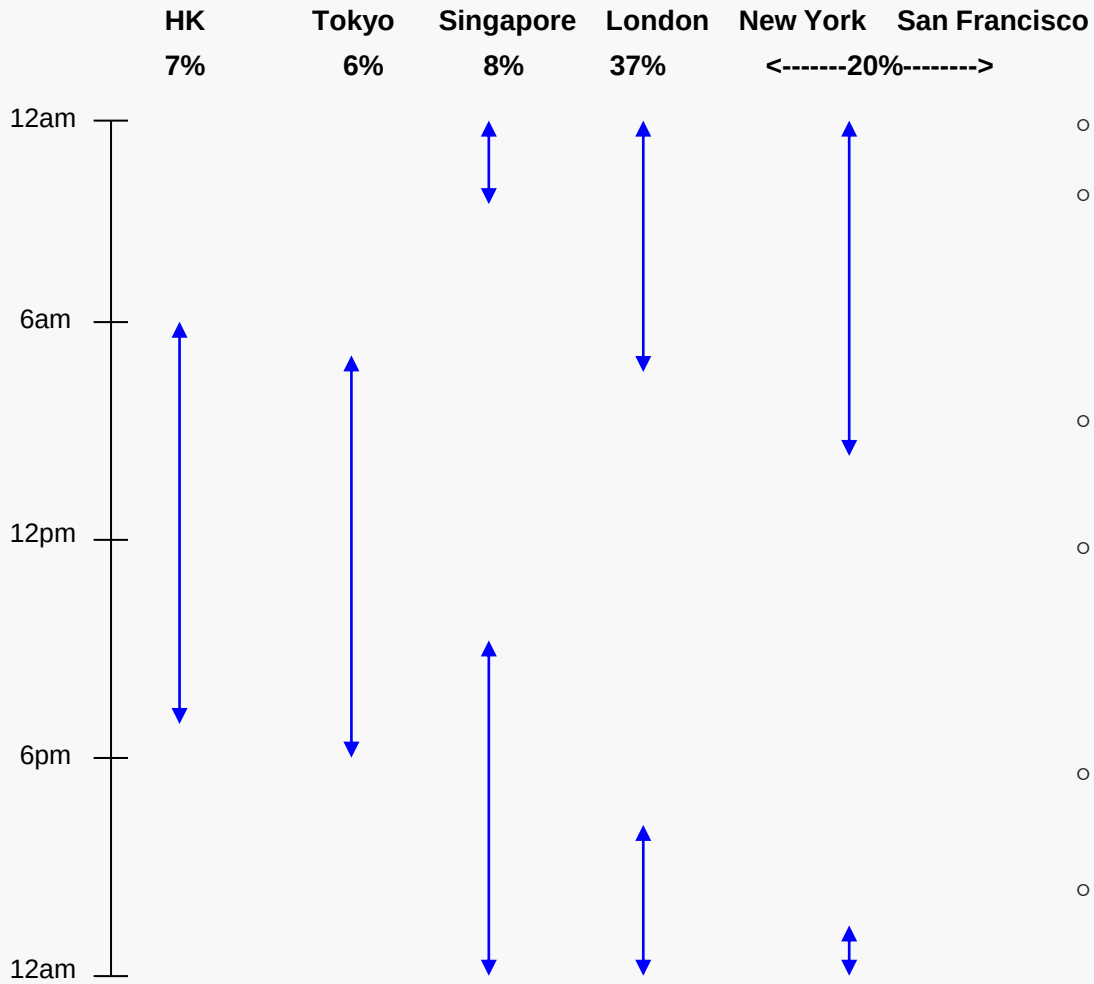
Financial markets in Hong Kong / China

- Total market capitalization of the Hong Kong listed stocks HK$ 24.8 trillion (Dec 2016), average daily turnover HK$ 66.9 billion (2016)
- Total market capitalization of Chinese listed stocks in Shenzhen and Shanghai RMB 50.8 trillion (Dec 2016) (average daily turnover around CNY 500 billion)
- Total outstanding amount of Exchange Fund Bills and Notes HK$ 963.1 billion (Dec 2016), average daily turnover HK$ 9.96 billion (Dec 2016)
- FX market in Hong Kong: daily turnover US$437 billion (April 2016) (ranked behind UK, US and Singapore)
- sources: Hong Kong Exchange, HKMA, Bank for International Settlements

FX spot and forward markets

- Spot market
  - Market players: central banks, major FX trading houses (banks), some customer demands
  - Note the quoting conventions for different currency pairs
  - Account for about 32% of all FX transactions (April 2016)
- Forward market
  - Normally below 1 year in maturity
  - Risk hedging or speculative trades
  - Including FX swaps, account for 60% of all FX transactions (April 2016)

Spot FX market



- Truly global and 24-hr market
- Asia time zone
  - Tokyo 7am (HK time 6am)
  - Singapore 7am (HK time 7am)
- Europe time zone
  - London 7am (HK time 3pm)
- US time zone
  - New York 7am (HK time 8pm)
  - San Francisco 7am (HK time 11pm)
- Very few "global" holidays (e.g. January 1)
- The % represents the market share of these centers as of April 2016

Spot FX trading

- A contract between 2 parties, i.e. not through any intermediate party (e.g. an Exchange)
- Buy currency A, sell currency B at an agreed exchange rate
- Trade to be settled at "spot", usually 2 business days after the trade date
- For liquid currencies, it is closest to the theoretical "perfect" market
- Very tight bid/ask
  - E.g. USD/JPY 116.75/77
- Example: Bank X agrees to pay USD 1 million to Bank Y and receive JPY, at an FX rate of USD 1 = JPY 116.75; actual payments to occur 2 business days after today
  - USD = US dollars, JPY = Japanese Yen

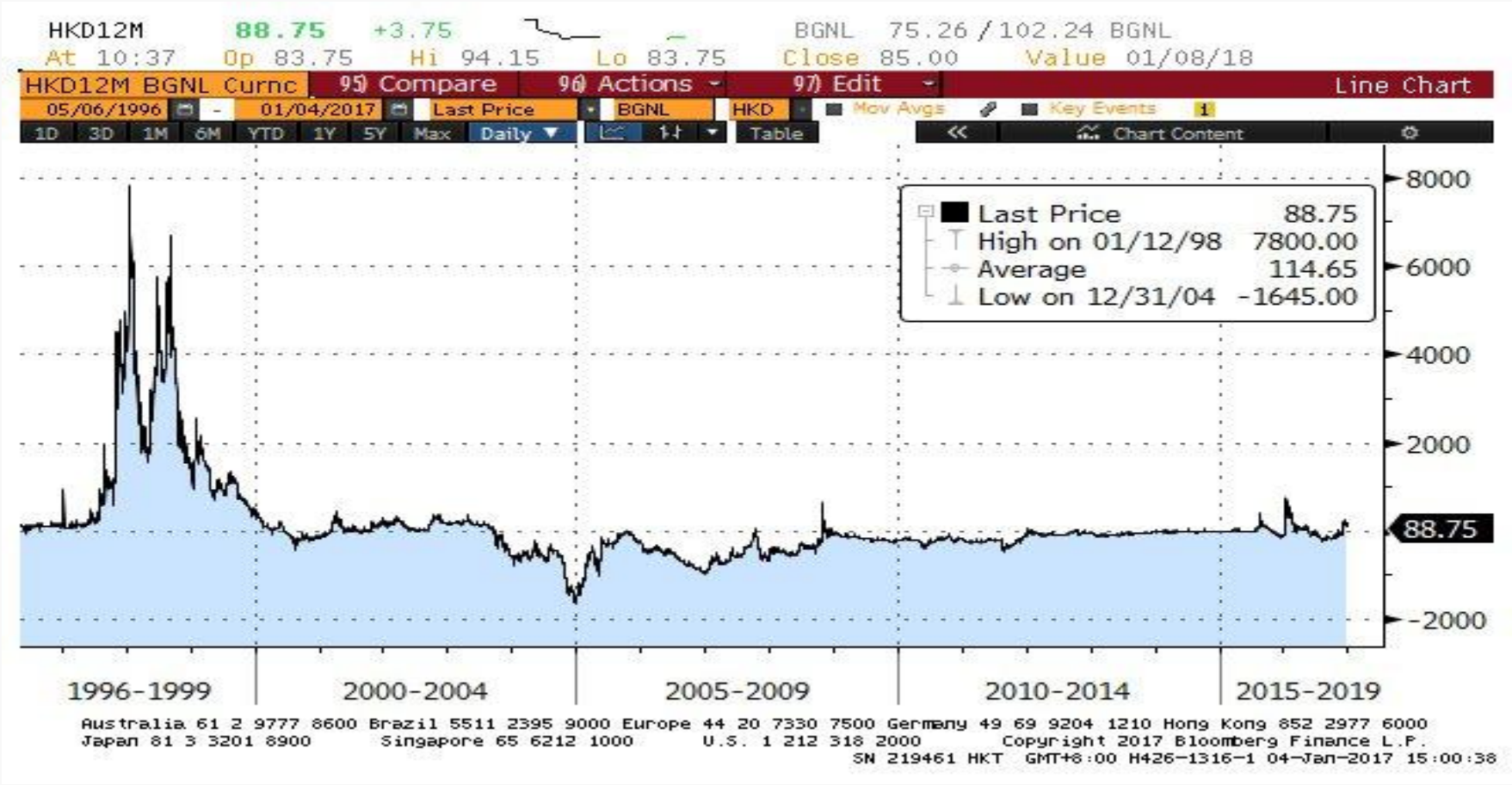
Forward FX contract

- In a spot contract, the trade would usually be settled within 1 or 2 days
  - e.g. Bank A buys USD 1 Million from Bank B, and receives JPY 116.75 Million, to be settled within 2 days of the trade date
- In a forward contract, an agreement is made on trade date, but settlement is a date in the future
  - E.g. Bank A agrees to buy USD 1 Million from Bank B, and receives JPY 115.5 Million , to be settled 1 year from the trade date
- In this example, 115.5 is the forward FX rate of USD/JPY
- There is no cost to enter into this trade on the trade date

Forward FX as speculation tool

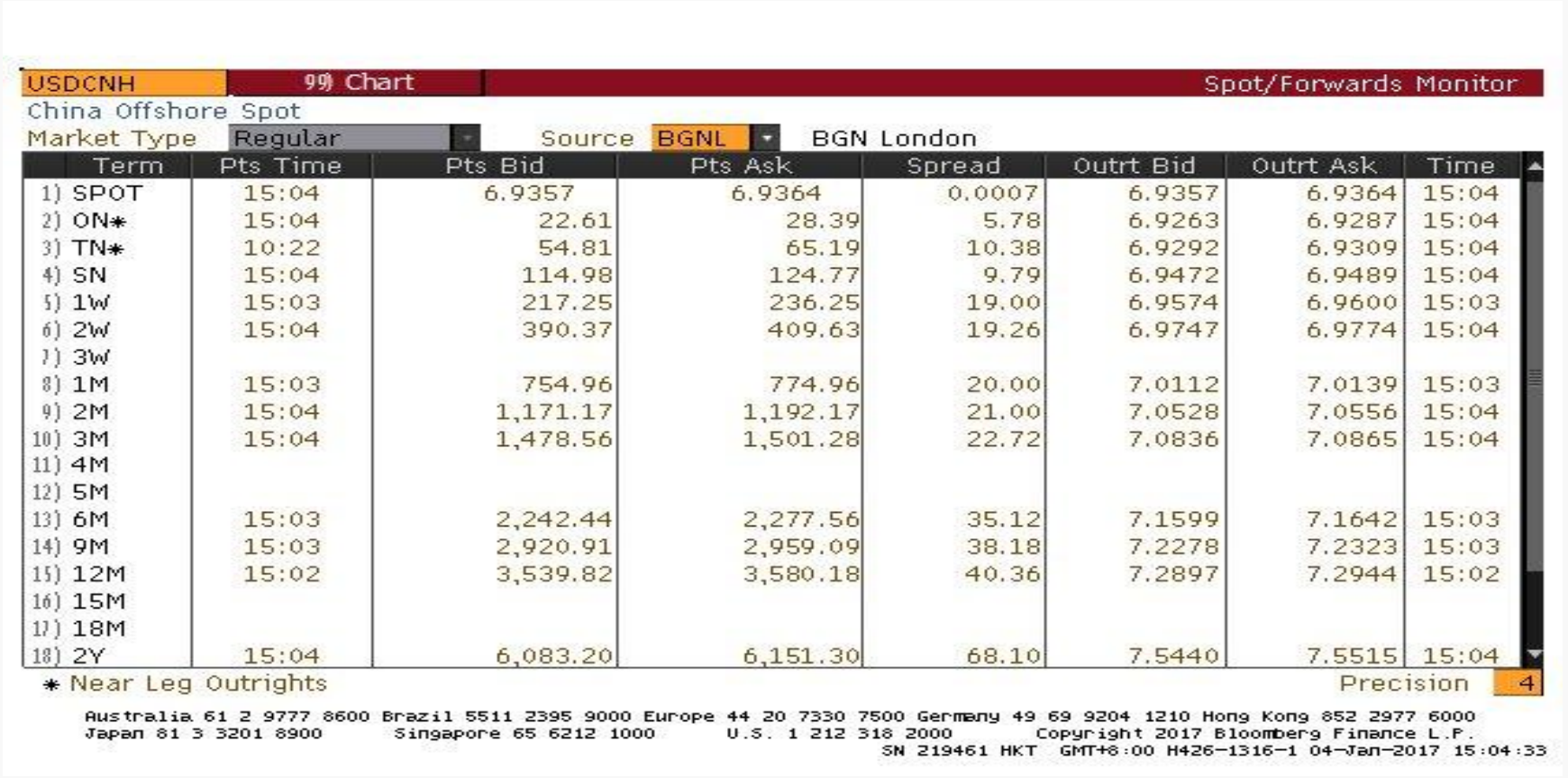
- Assume that some speculators think that the peg would be changed, and that HKD would appreciate (go up in value)
- One way to express this view is to enter into a spot FX position, by buying HKD and selling USD – however this strategy requires USD
- A typical strategy is to enter into a forward transaction, to buy HKD in (say) 6 months – no initial amount is required, and the position could be closed out at any time before maturity

USD/HKD 12-month FX forward



Source: Bloomberg LP

USD/CNY Offshore FX forward



USDCNH 99) Chart Spot/Forwards Monitor

China Offshore Spot

Market Type Regular Source BGNL BGN London

Term	Pts Time	Pts Bid	Pts Ask	Spread	Outrt Bid	Outrt Ask	Time
1) SPOT	15:04	6.9357	6.9364	0.0007	6.9357	6.9364	15:04
2) ON*	15:04	22.61	28.39	5.78	6.9263	6.9287	15:04
3) TN*	10:22	54.81	65.19	10.38	6.9292	6.9309	15:04
4) SN	15:04	114.98	124.77	9.79	6.9472	6.9489	15:04
5) 1W	15:03	217.25	236.25	19.00	6.9574	6.9600	15:03
6) 2W	15:04	390.37	409.63	19.26	6.9747	6.9774	15:04
7) 3W							
8) 1M	15:03	754.96	774.96	20.00	7.0112	7.0139	15:03
9) 2M	15:04	1,171.17	1,192.17	21.00	7.0528	7.0556	15:04
10) 3M	15:04	1,478.56	1,501.28	22.72	7.0836	7.0865	15:04
11) 4M							
12) 5M							
13) 6M	15:03	2,242.44	2,277.56	35.12	7.1599	7.1642	15:03
14) 9M	15:03	2,920.91	2,959.09	38.18	7.2278	7.2323	15:03
15) 12M	15:02	3,539.82	3,580.18	40.36	7.2897	7.2944	15:02
16) 15M							
17) 18M							
18) 2Y	15:04	6,083.20	6,151.30	68.10	7.5440	7.5515	15:04

* Near Leg Outrights Precision 4

Australia 61 2 9777 8600 Brazil 5511 2395 9000 Europe 44 20 7330 7500 Germany 49 69 9204 1210 Hong Kong 852 2977 6000
Japan 81 3 3201 8900 Singapore 65 6212 1000 U.S. 1 212 318 2000 Copyright 2017 Bloomberg Finance L.P.
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Data as of Jan 4, 2017; Source: Bloomberg LP

Equity and debt

- Two ways for companies to raise money
  - Issue bonds
    - Investors are holders of the company's debt
    - Investors have no control over the management of the company
    - Investors have claims over the company's asset in the event of liquidation
  - Issue shares
    - Investors are shareholders, i.e. owners of the company
    - Shareholders usually have voting rights
      - i.e. could affect how the company is run

Interest rate and fixed income markets

- Money markets: maturity < 1 yr
  - E.g. Interbank market: loans and deposits
- Capital markets: maturity >= 1 yr
  - E.g. government and corporate bonds

Bills, notes and bonds

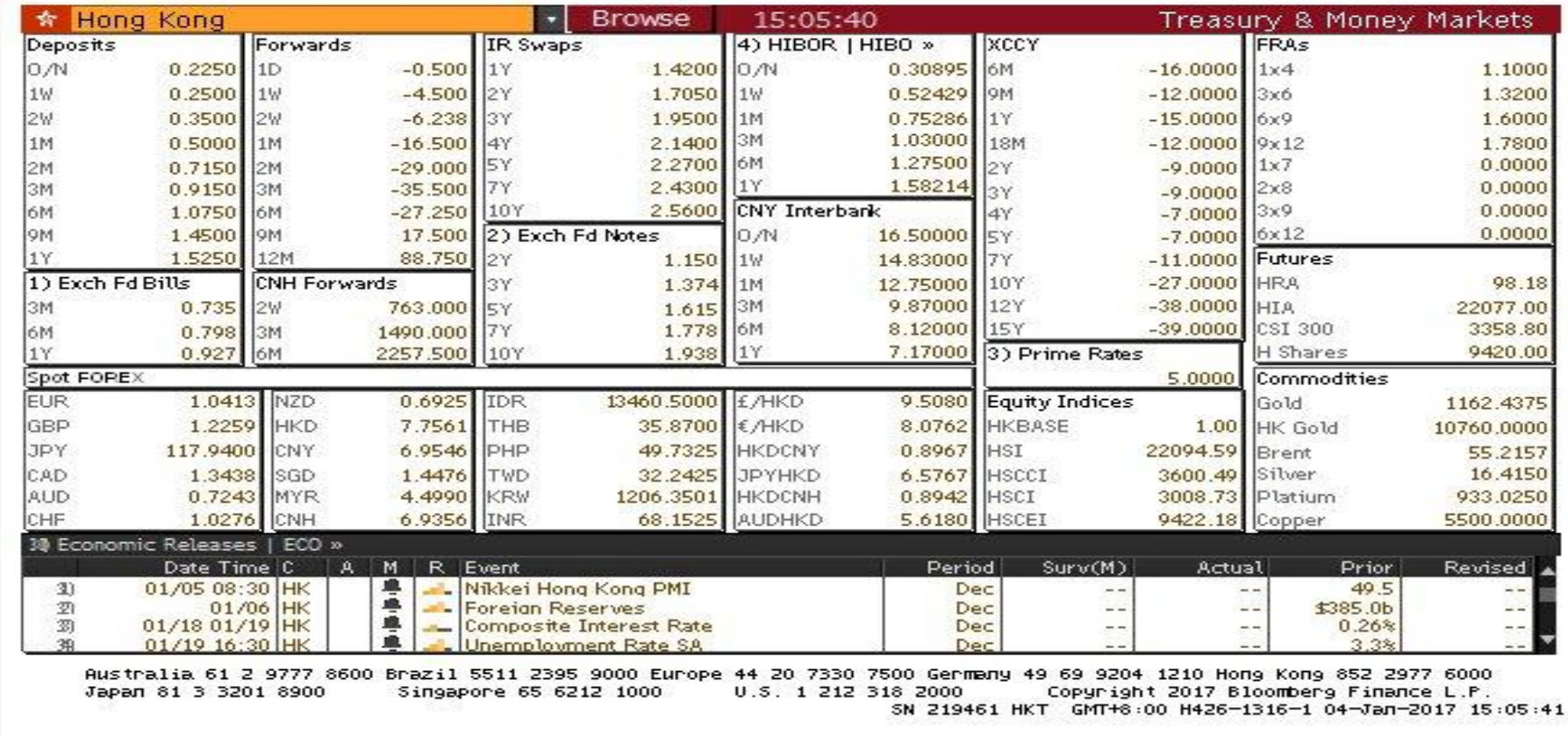
- A means of borrowing money
- Usually refer to instruments issued by governments
- Differ by maturity
  - Bills (<1 yr), notes (1-10 yrs), bonds (>10 yr, can go to 30 yrs)
  - US Government stopped issuing 30 yr bonds in Oct 2001; program resumed in Feb 2006
  - Longer maturity exists in some European countries, e.g. UK has issued a 50-year government bond in 2005 (maturity 12/7/2055)
- Examples: US Treasuries, Exchange Fund Bills and Notes (Hong Kong)
- Instruments issued by corporates are usually known as "bonds"

A bond example

- Issuer: HSBC Holdings PLC
- Currency: USD
- Issued Date: May 3, 2006
- Maturity: May 2, 2036
- Coupon: 6.50%
- Payment Frequency: Semi-annual
- Face Value: USD 1000
- Credit Rating: A3 / A-

- Price (as of 4/9/2014) = 128.32, equivalent to a yield of around 4.45%

Some HKD market instruments
(source: Bloomberg LP)



Hong Kong | Browse | 15:05:40 | Treasury & Money Markets

Deposits

O/N	0.2250
1W	0.2500
2W	0.3500
1M	0.5000
2M	0.7150
3M	0.9150
6M	1.0750
9M	1.4500
1Y	1.5250

1) Exch Fd Bills

3M	0.735
6M	0.798
1Y	0.927

Forwards

1D	-0.500
1W	-4.500
2W	-6.238
1M	-16.500
2M	-29.000
3M	-35.500
6M	-27.250
9M	17.500
12M	88.750

CNH Forwards

2W	763.000
3M	1490.000
6M	2257.500

IR Swaps

1Y	1.4200
2Y	1.7050
3Y	1.9500
4Y	2.1400
5Y	2.2700
7Y	2.4300
10Y	2.5600

2) Exch Fd Notes

2Y	1.150
3Y	1.374
5Y	1.615
7Y	1.778
10Y	1.938

4) HIBOR | HIBO »

O/N	0.30895
1W	0.52429
1M	0.75286
3M	1.03000
6M	1.27500
1Y	1.58214

CNY Interbank

O/N	16.50000
1W	14.83000
1M	12.75000
3M	9.87000
6M	8.12000
1Y	7.17000

XCCY

6M	-16.0000
9M	-12.0000
1Y	-15.0000
18M	-12.0000
2Y	-9.0000
3Y	-9.0000
4Y	-7.0000
5Y	-7.0000
7Y	-11.0000
10Y	-27.0000
12Y	-38.0000
15Y	-39.0000

3) Prime Rates

	5.0000

FRAs

1x4	1.1000
3x6	1.3200
6x9	1.6000
9x12	1.7800
1x7	0.0000
2x8	0.0000
3x9	0.0000
6x12	0.0000

Futures

HRA	98.18
HIA	22077.00
CSI 300	3358.80
H Shares	9420.00

Spot FOREX

EUR	1.0413	NZD	0.6925	IDR	13460.5000	£/HKD	9.5080
GBP	1.2259	HKD	7.7561	THB	35.8700	€/HKD	8.0762
JPY	117.9400	CNY	6.9546	PHP	49.7325	HKDCNY	0.8967
CAD	1.3438	SGD	1.4476	TWD	32.2425	JPYHKD	6.5767
AUD	0.7243	MYR	4.4990	KRW	1206.3501	HKDCNH	0.8942
CHF	1.0276	CNH	6.9356	INR	68.1525	AUDHKD	5.6180

Equity Indices

HKBASE	1.00
HSI	22094.59
HSCCI	3600.49
HSCI	3008.73
HSCEI	9422.18

Commodities

Gold	1162.4375
HK Gold	10760.0000
Brent	55.2157
Silver	16.4150
Platium	933.0250
Copper	5500.0000

3) Economic Releases | ECO »

	Date Time	C	A	M	R	Event	Period	Surv(M)	Actual	Prior	Revised
1)	01/05 08:30	HK				Nikkei Hong Kong PMI	Dec	--	--	49.5	--
2)	01/06	HK				Foreign Reserves	Dec	--	--	$385.0b	--
3)	01/18 01/19	HK				Composite Interest Rate	Dec	--	--	0.26%	--
4)	01/19 16:30	HK				Unemployment Rate SA	Dec	--	--	3.3%	--

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Data as of Jan 4, 2017

Common instruments traded in the Equity markets

- Traded in an exchange
  - Stocks 股票
  - Exchange Traded Funds (ETFs), especially based on Stock Market Index 指數基金
  - Derivative Instruments 衍生工具
    e.g. warrants, index futures 窩輪，期指

- Traded between contract parties
  - Mutual Funds基金
  - Derivative instruments, e.g. options, swaps 期權，掉期合約
  - Structured products 結構性產品
    e.g. Equity Linked Note 股票掛鈎高息票據

Characteristics of common stock

- Residual claim
  - Last in line of all those who have a claim on the company's asset in the event of liquidation
- Limited liability
  - Shareholders are not personally liable to the company's loss; at most they lose their initial investment
- Share the company's profit via dividends
- *Preferred shares usually carry no voting rights*, but shareholders receive dividends ahead of common shareholders

Primary and secondary markets

- Primary market: new shares that are traded for the first time: an increase in the share capital of the company
  - Initial public offering (**IPO**), private placement
- Secondary market: transfer of share ownership
  - Buy/sell shares from a recognized exchange, private transfer

Initial public offering (IPO)

- Investment banks (usually a ***syndicate***) agreed to purchase the securities from the issuing company and then re-sell to the public: the process is known as ***underwriting***

- Investment banks try to collect the responses of interested parties (**book building**)

- **Pricing is critical**
  - Need to make it attractive to potential investors
  - Need to raise as much capital as possible

- Hong Kong has been the biggest IPO market in the world in the past few years

Performance of Postal Savings Bank of China 郵儲銀行 (1658) since IPO

Source: Bloomberg LP (as of Jan 4, 2017)

Performance of Foodwise Holding 膳源控股 (1632) since IPO

Source: Bloomberg LP (as of Jan 4, 2017)

Performance of Chow Tai Fook 周大福 (1929) since IPO

Source: Bloomberg LP (as of Jan 4, 2017)

Rights issue

- An offer to existing shareholders, to buy new shares usually at a discounted price
  - E.g. Shares of ABC are currently trading at $10
  - 1-for-5 rights issue, price $4 means that current shareholders could buy 1 share for 5 shares that they hold, at a price of $4 per share
  - If X holds 1000 shares, he could buy 200 shares @$4

- After the **ex-rights date**, new shareholders do not have the right to subscribe

Dilution effect of a rights issue

- Let's say the total number of shares outstanding for company XYZ is 50,000,000, and current share price is $10
- Say all shareholders take up the 1-for-5 rights issue @ $4; number of new shares is 10,000,000
- Total capital is 50,000,000 x $10 + 10,000,000 x $4 for 60,000,000 shares, or $9 per share
- Say you hold 1000 shares and you don't want to subscribe; after the rights issue, you would suddenly find that the share price has dropped 10% in value (from $10 to $9) because of the dilution)
- **To avoid this dilution effect, existing shareholders are "forced" to pay more cash**

Secondary markets

- Role of exchange
  - no need to find a counterparty, hence more efficient trading possible
- Central clearing house
  - brokerages hold accounts in the clearing house (similar to a commercial bank)
  - settlement is through the clearing house
- Role of brokerages
  - acts as agents, buying/selling shares on behalf of the customers
  - discretionary trading for some accounts

Examples of corporate actions

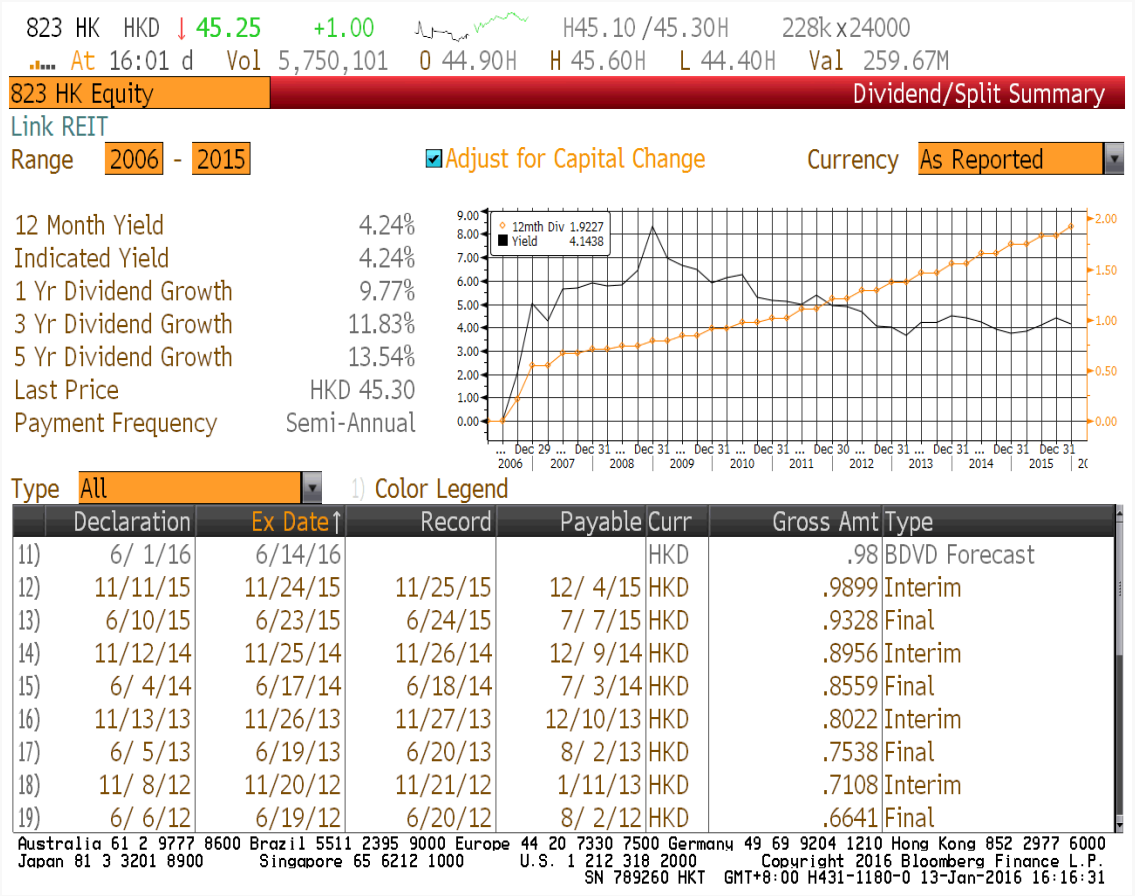
- Dividends
  - cash or scrip (bonus shares)

- Stock split/reverse stock split
  - split into smaller units (stock split) or combined to bigger units (reverse split), to facilitate trading
  - E.g. Ping An Insurance 2-for-1 split on July 27, 2015
    - If you hold 2,000 shares on July 24, 2015 (closing price HKD 97.05), you would hold 4,000 shares from July 27, 2015 onwards (closing price HKD 47.15)
  - E.g. PCCW 1 for 5 consolidation on Jan 8, 2003
    - If you hold 5,000 shares on Jan 7, 2003 (closing price HKD 1.31), you would hold 1,000 shares from Jan 8, 2003 onwards (closing price HKD 6.55)

Dividends

- Current stock price is P, and a single cash dividend amount of D is paid within this year
- If you are a shareholder on the record date, you are entitled to the dividend
- On the ex-dividend date, share price would drop to P–D
- D would only be paid on the dividend payment date
- Dividend yield = D/P x 100%
- Total return = dividend yield, *only if stock price goes back up to the price before ex-dividend* (i.e. P in this example)

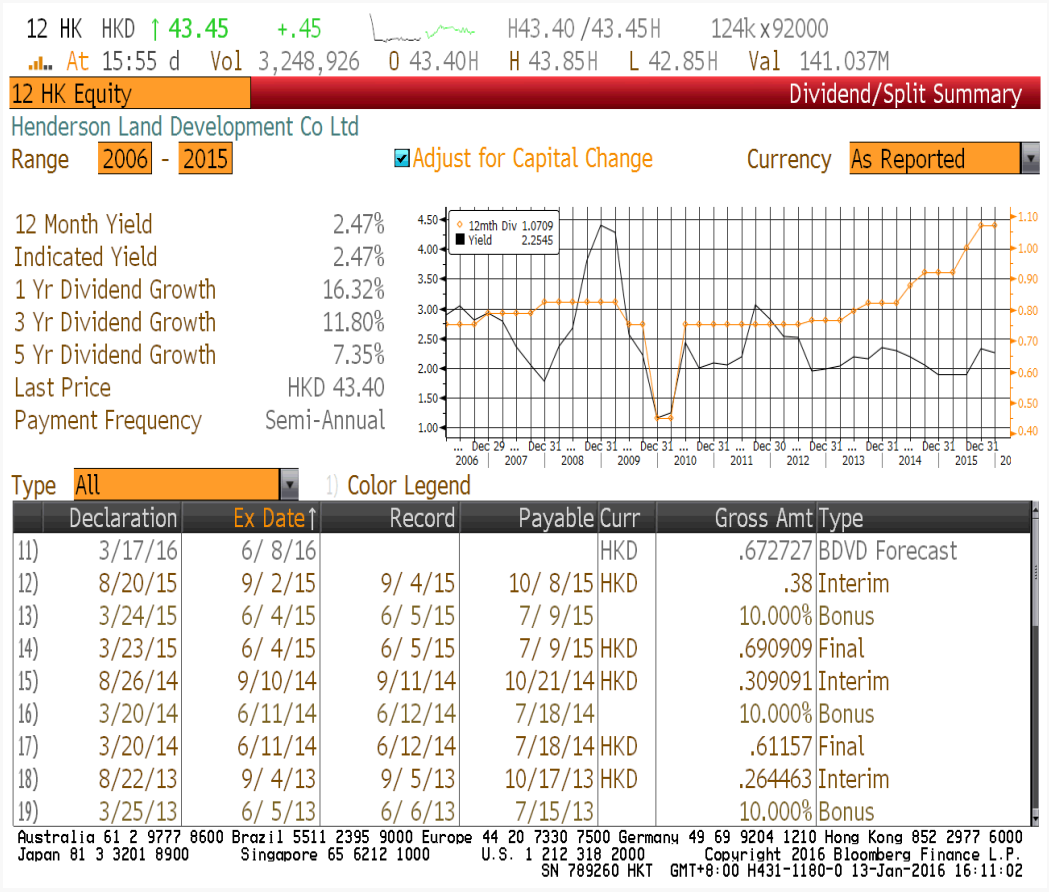
Dividends example



- The closing price of Link REIT on Nov 24, 2014 was $48.75
- Price before market opened on Nov 25, 2014 would be $48.75 – 0.8956 = $47.8544
- The closing price on Nov 25, 2014 was $47.90, which should be considered as **going up**, rather than coming down

Source: Bloomberg LP

Dividends example: bonus shares



Source: Bloomberg LP

- If you hold 1000 shares of Henderson Land (0012.HK) on 6/3/15, you would have 1100 shares on 6/4/15
- Closing price on 6/3/15 was HKD 63.30
- Closing price on 6/4/15 was HKD 56.95
- 1 bonus share for 10 shares held; after the ex-dividend date, share price should drop to 10/11 of the previous day's close

Listing issues

- Dual listing; e.g. HSBC is listed in Hong Kong and London Stock Exchanges
  - different group of investors
  - different listing rules

- American Depositary Receipt (ADR)
  - similar to dual listing
  - denominated in the local currency (USD)
    - e.g. China Mobile ADR traded in New York Stock Exchange; 1 ADR = 5 ordinary shares
- Specific rules concerning the conversion from one to the other
- Different market hours

Examples of different ways of making money in the stock market

- Take a long position in stocks, and share price goes up
- Take a short position in stocks, and share price goes down
- Construct a "synthetic" position in stocks, and hopefully the market view is correct
  - E.g. take a long position in a stock index (say Hang Seng Index or the Tracker Fund (2800)) and short most of the shares in the index

A simple example

- HSBC shares, stock price was HKD 64 per share when you enter into a position
- Consider the following positions and scenarios

Position (shares)	P&L	
	Share price = $60	Share price = $70
Long 10000	–$40000	+$60000
Short 4000	+$16000	–$24000

- If you are **bullish** (i.e. you think the shares would go up), then you should go long
- If you are **bearish** (i.e. you think the shares would go down), you should go short

Risk and return

- Which strategy would you choose?
  - *Strategy A*:
    - *50% chance of earning a 10% return*
    - *50% chance of losing 5%*
  - *Strategy B*:
    - *50% chance of earning a 15% return*
    - *50% chance of losing 12%*
- Expected return of A is 2.5%; B is 1.5%

- Higher absolute return may not always be the best strategy; need to consider the expected return AND risk together

Rational and irrational behaviour

- A rational investor always wants to achieve *the highest return with the minimum risk*
- Many important finance theories are based on the fact that people make rational decisions
- But is this assumption correct?

Rational and irrational behaviour

- Situation 1:
  - Expected return of a lottery is $10; there is a small chance that you would earn nothing
  - Each ticket costs $9
  - How many times would you want to play?
- Situation 2:
  - Expected return of an investment is $1 Million; there is a small chance that you would earn nothing
  - Initial costs are $900k
  - How many times would you want to invest?

St. Petersburg Paradox

- Proposed by Daniel Bernoulli in 1738
- A coin is tossed until the first head appears; let n be the number of times a tail appears before the first head is tossed
- Payout is 2^n
  - E.g. if there are 3 tails before a head appears, the payout is 2^3 = $8
- How much money would you want to pay to play the game?

St Petersburg Paradox

No. of tails before a head appears	Probability	Payoff	Expected payoff
0	$(½)^1$	$\$2^0 = \$1$	½ x \$1 = \$½
1	$(½)^2$	$\$2^1 = \$2$	$(½)^2$ x \$2 = \$½
2	$(½)^3$	$\$2^2 = \$4$	$(½)^3$ x \$4 = \$½
3	$(½)^4$	$\$2^3 = \$8$	$(½)^4$ x \$8 = \$½
n	$(½)^{(n+1)}$	$\$2^n$	$(½)^{(n+1)}$ x $\$2^n$ = \$½

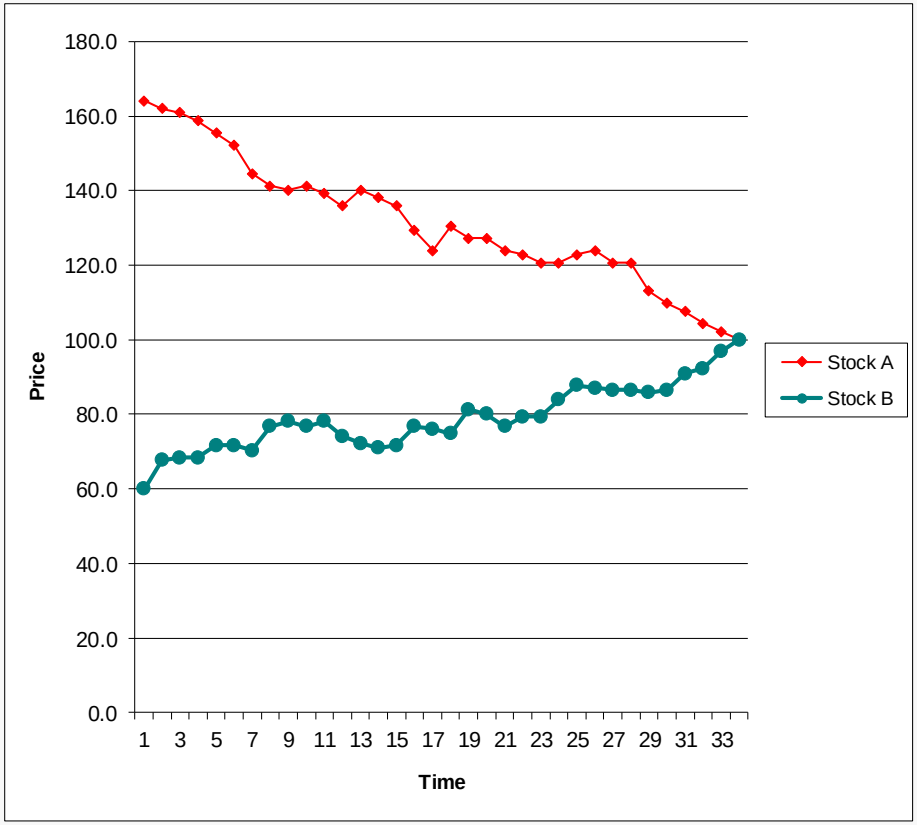
- Mathematically correct answer:
  - Expected payoff = Σ(probability x payoff) = ∞
- But most people would not pay a lot of money to play this game
- Lesson: actual trading decision is more complex!

Theory and practice

- Today, price of stock A = price of stock B = $100
- Expected standard deviation of price movement of stock A = expected standard deviation of price movement of stock B
- Tomorrow, is it more likely for stock A or stock B to move to $102?
- Efficient Market Hypothesis (EMH) claims that all currently known information is captured by the stock price, and price movements follow a "random walk" unless new information arrives

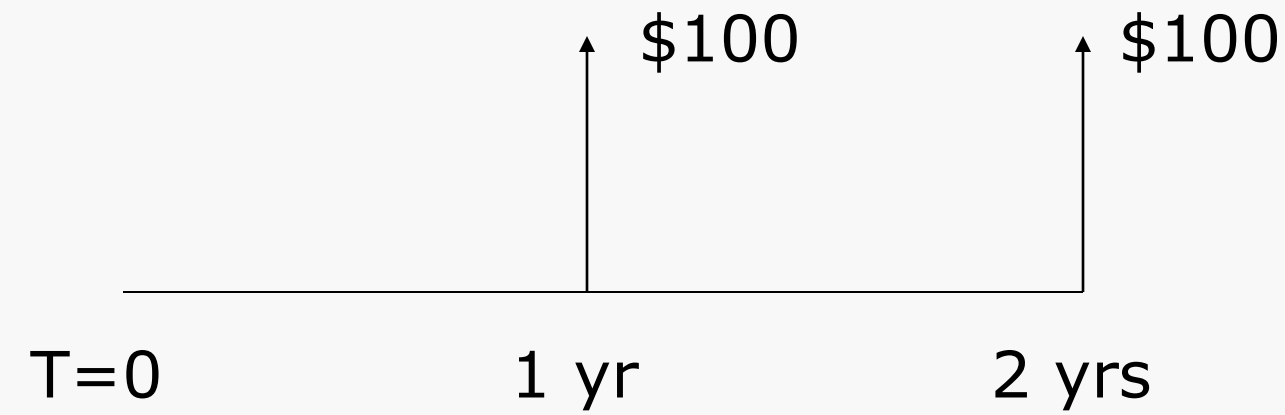
Theory and practice

- Would your answer be different if you are shown the following graph?



Fundamental financial concept: Time value of money

- How do we compare cashflows occurring at different times?



  - Assume annual interest rate of 5% p.a.

Present value and discount factor

- You need \$P to get \$100 in 1 yr:

$$100 = P \times (1+5\%)^1, \text{ or } P = \frac{100}{(1+5\%)} = 95.24$$

- You need \$Q to get \$100 in 2 yrs:

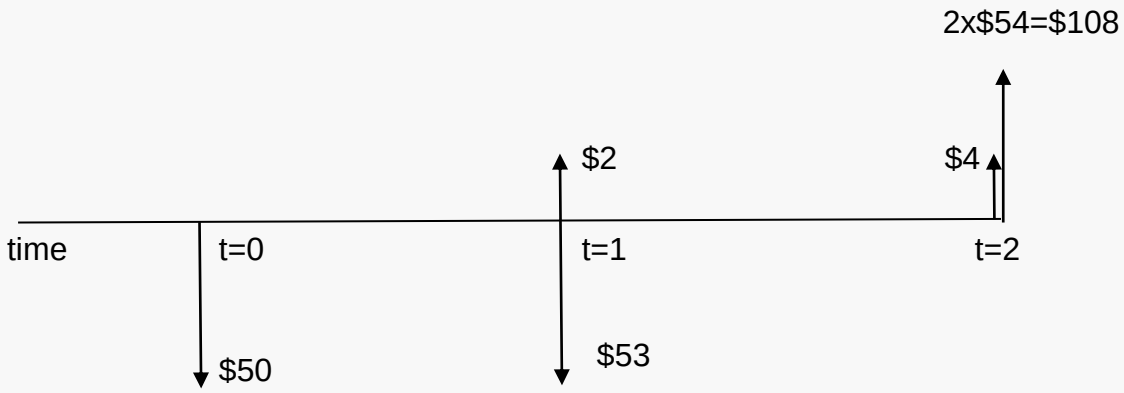
$$100 = Q \times (1+5\%)^2, \text{ or } Q = \frac{100}{(1+5\%)^2} = 90.70$$

- In general

$$P = 100 \times df \text{ where } df = \frac{1}{(1+r_t)^t}$$

Calculation of returns: example

- Bought 1 share at $50 at time 0
- Bought 1 share at $53 at time 1-year
- Sold 2 shares at $54 at time 2-year
- Receive $2 dividend at time 1-year
- Receive $4 dividend at time 2-year



Dollar-weighted return

- Also known as the Internal rate of return (IRR) of an investment
- Represent the economic reality in terms of the cash flows

$$50+\frac{53}{1+r}=\frac{2}{1+r}+\frac{(108+4)}{(1+r)^2}\Rightarrow r=7.117\%$$

Time-weighted return

- Ignore number of shares held in each period
- In the previous example, the return in year 1 = (53+2)/50 – 1 = 10%; return in year 2 = (54+2)/53 = 5.66%
- Arithmetic average of the 2-year return = (10%+5.66%)/2 = 7.83%
- Geometric average return = $[1.10 \times 1.0566]^{0.5} - 1 = 7.81\%$
- Note that the geometric average must be smaller than the arithmetic average
- Extreme example: stock price starts at $100, goes up 100% in year 1 to $200, and drop 50% to $100 in year 2; arithmetic average return is +25%, geometric average return is 0

Calculation of returns

- Dollar-weighted return takes into account of the timing of the cash flows, but a fund manager usually does not have any control on this timing (depending on investors' subscriptions)
  - Therefore time-weighted return can be more relevant to the fund manager's skills
- Geometric return takes into account of the holding period, and it calculates the historical performance accurately
- However, for the prediction of future 1-period performance, the arithmetic average is the unbiased estimator
  - In the extreme example given earlier, if there is a 50% chance for each scenario, the expected stock price is (200+50)/2 = 125, which represents a return of 25%, as indicated by the arithmetic average return

Quiz question

- Country A produces a game console called YBOX
- Country B produces a game console called QT4
- Initially, the price of 1 YBOX = 1 QT4
- 1 year from now, there are two equally probable scenarios (50% probability in each case)
  - 1 YBOX = 2 QT4 (because QT4 has dropped in price)
  - 1 YBOX = 0.5 QT4 (because YBOX has dropped in price)
- Question: what is the expected relationship between the prices of YBOX and QT4 in 1 year?

Quiz question

- If you live in country A, your calculation may be:
  - Expected price = sum(probability x payoff) = 0.5 x 2 + 0.5 x 0.5 = 1.25, i.e. 1 YBOX = 1.25 QT4

- If you live in country B, you may argue
  - 1 YBOX = 1 QT4 => 1 QT4 = 1 YBOX
  - In 1 year, 1 QT4 = 0.5 YBOX or 1 QT4 = 2 YBOX
  - Expected price = 0.5 x 0.5 + 0.5 x 2 = 1.25
  - i.e. 1 QT4 = 1.25 YBOX

Quiz question

- Or you may argue (especially if you have studied physics), since the problem is symmetric, the expected relationship should be 1 YBOX = 1 QT4

- Is there anything wrong with the calculations above? Which answer is correct?