AF4
Risk Theory and management

The milestones for this part are to understand:

- The definition of risk
- How to interpret Standard deviation and beta
- The Capital Asset Pricing Model and its limitations.
- The difference between Systematic and non-systematic risk.
- The importance of correlation in risk management
- The principles of Modern Portfolio Theory
- The efficient frontier concept.

What is Risk

Whilst you will be familiar with the different specific risks such as capital risk, inflation risk etc., these are simply ways in which external factors can affect the outcome of any investment. They do not give an objective measure of the level of risk of a specific security.

The expected or likely return can be calculated by working out the average return over 10 years. If this was 3% and every year it had delivered 3% then there would be little if any risk because it consistently delivered what you expected. This does not mean it is not exposed to other specific risks. For example if inflation was 8% its real return would be falling but it could still be considered a risk free investment.

On the other hand, suppose you had an investment where the expected return was 6% but annual returns had fluctuated between -5% and 12%. This would carry risk because there was a difference in the actual returns compared with the expected one.

Note that this difference can be good or bad. If you expected 6% and got 12% you would be very pleased. If the return was -5% you would be somewhat disappointed. So we can define risk as:

"The difference between what you expected and what you received"

Put another way **risk = volatility**

Measurement of Risk

Most individuals would claim to have a gut feeling about risk, claiming to know instinctively when something was high risk and when it was low risk. This is subjective, but risk theory and management starts with the premise that risk can be measured objectively. The two key measures that are used are an investment's:

- Standard deviation (SD)
- Beta

Both measure a security or asset's volatility but

- Standard deviation is a measure of the asset's historical volatility
- Beta is a measure of the assets against a benchmark.

Standard Deviation

The great unknown in investment is the answer to the question, "What can I expect to get in the future?" Whilst the past is not necessarily a guide to the future it is possible to take some lessons from what actually happened. If we take an analogy with the weather, whilst it is difficult, if not impossible, to predict in January what the weather will be on a certain day in July, we can look back over many years, check what the weather was like and come to a view on the **probability** of the weather being good.

Expected Return

By looking back at past 'holding period returns' for an investment, we can see the likelihood of various levels of returns taking place – we can calculate the **probability of returns** based on past experience.

In practice, this involves studying the past performance figures of an investment over many years. and seeing how often each performance result actually happened. A probability rating is applied to each possible result.

For example, an investment could have had the following returns over the past 40 years

Annual Return	Number of times this happened
5%	8
10%	14
15%	12
20%	6

From this we can calculate the **probability** of similar returns being achieved in the future

A 5% return was achieved in 8 of the last 40 years so we can say that there is an 8 in 40 chance of this being achieved. The probability is 0.2 (8/40)

The probability of getting a 10% return is 0.35 (14/40)
The probability of getting a 15% return is 0.3% (12/40)
The probability of getting a 20% return is 0.15% (6/40)

Note that all probabilities must add up to 1

We can now calculate the **weighted probability** by multiplying the annual return by the probability of it happening. Using this method, we get:

Return r	**Probability** p	**Weighted Probability** r x p
5%	0.2	1.0
10%	0.35	3.5
15%	0.3	4.5
20%	0.15	3.0
Total		12.0

The **mean** or **expected return** is 12%

This measure doesn't though measure the **risk** of the investment. It would not be appropriate recommend an investment just because its expected return met the client's target. If you think about it, it's possible for two investments to have the same expected return but have quite different levels of volatility as in the following table.

Year	Security A	Security B
1	5%	8%
2	-15%	10%
3	35%	9%
3	0	10%
5	25%	10%
6	-10%	12%
7	50%	9%
8	5%	10%
9	10%	9%
10	-5%	12%
Average	10%	10%

In this table both A & B have returned an average 0f 10% over 10 years. However

A has been much more volatile with a return of 50% in year 7 but -15% in year 2.
B has never been lower than 8% but never higher than 12%.

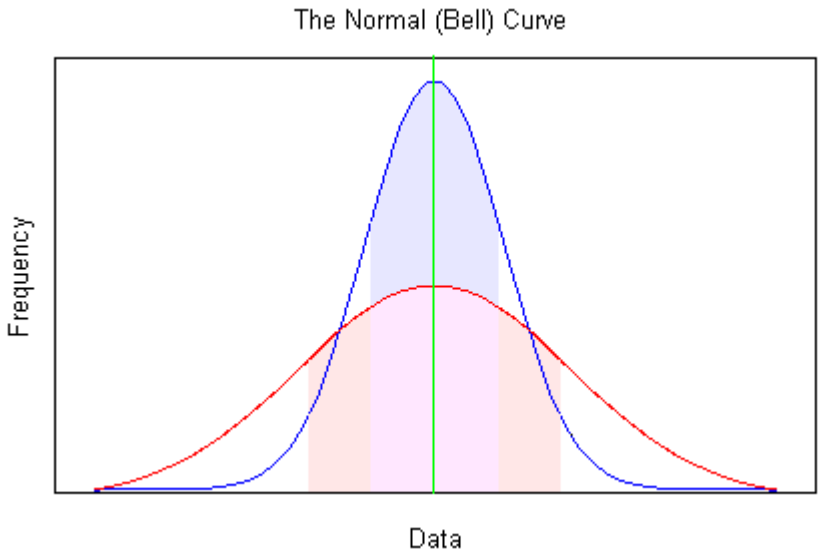
It’s obvious that A carries more risk than B but we still need a way to objectively measure this which is done by calculating the Standard Deviation of both A & B which are 20.68% and 1.29% respectively.

What is Standard Deviation?

SD is a mathematical calculation that shows how wide the actual results in a sample differ from the average or mean. The good news is that you won't be expected to calculate it but you must know its significance and how to interpret it.

The problem with calculating the average of a sample is that it does not tell the whole story and can be misleading. What we also need to know is how the results varied from the average. Going back to our table both delivered an average of 10% but the range of results was much wider in A. This is captured by the SD so the first key point about it is:

- The higher the SD the wider the actual results varied from the average. In the case of investments the higher the SD the more volatile future performance will be.



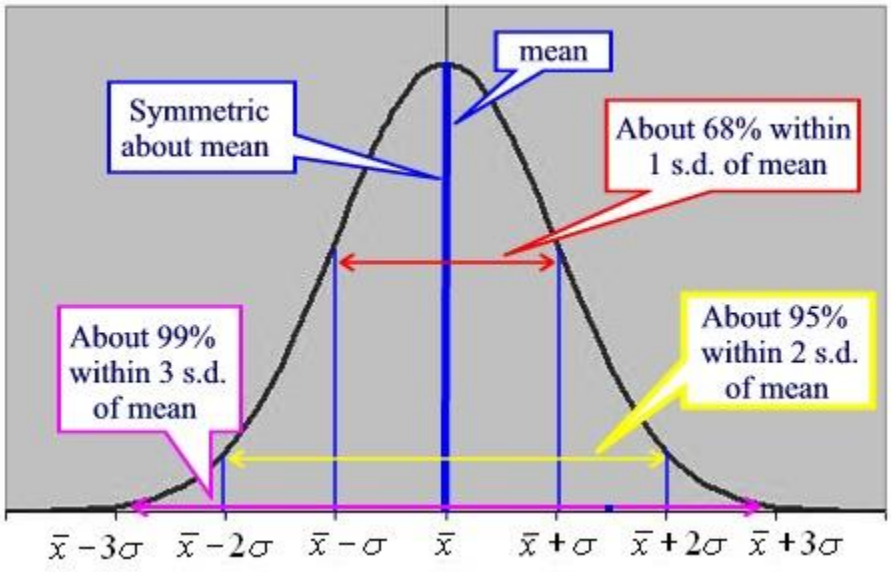
This can be illustrated in the above chart. As the range of outcomes becomes wider the curve becomes flatter and the SD increases.

SD is a key tool in statistics and forms the basis of opinion polling. These typically interview a random selection of say 200 people and extrapolate that over the whole population. This is possible because mathematically the probability of future returns or events can be predicted as follows:

68% of the time the actual return is expected to be between the mean +/- 1 SD
95% of the time the actual return is expected to be between the mean +/- 2 SD
99% of the time the actual return is expected to be between the mean +/- 3 SD

This is not predicting the precise return nor the minimum or maximum return, it is simply predicting the range of possibilities.

This can be shown in the diagram below:



Don't worry too much about some of the symbols.

Applying this to our original investment A, it means that over a 100 year period:

- in 68 years we would expect the return to be between -10.68% and 30.68%
- in 95 years we would expect the return to be between -30.86% and 50.68%
- in 99 years we would expect the return to be between -50.86% and 70.68%

Clearly no individual investor will have a 100 year investment horizon and we could scale it down to a 10 year view. However, it's also worth looking at this in another way. If this theory is true in practice there should only be a return worse than -50.68% once in every 100 years. That might be sufficiently rare to make it worth accepting.

There are limitations to this approach.

- It is a difficult concept for the average client to grasp.
- It is based solely on past data and as advisers always make clear, "the past is not necessarily a guide to the future." However, the past is our only guide and if an asset has consistently returned between 3% and 5% why should it be expected to suddenly produce a return of 18%?
- For the extrapolation of the range of future returns as shown above, the sample must be selected at random. Opinion pollsters go to great lengths to ensure that their interviewees have been selected at random and there is no selective bias. It can be argued that past investment returns aren't purely random. Each step up in the table above is called a sigma event so the possibility of getting a result between mean +/- 3 SD is called a 3 sigma event. As we have seen that is a rare event that should happen once in a 100 years. In the run up to the 2008 banking crisis financial mathematicians had constructed a trading formula that stated that the chances of catastrophic loss on

any one day would be a 6 sigma event. That is one day in 4,039,906 years. A catastrophic event then happened several days in a row and wiped out the bank.

Beta

SD measures the volatility of a security against past results. Beta measures volatility against a benchmark.

The most common benchmark used in the UK is the FTSE 100 index. That is given a Beta of 1. If a security reflects absolutely the performance of the index its beta would also be 1. If a security is less volatile the beta is less than 1 and is expressed as 0.xxxx. If it is more volatile than the index its beta is more than 1 and expressed as 1.xxx.

Here are some examples as at August 12 2014 and January 28 2018 sourced from the FT

	August 2014	January 2018
Tesco	0.728	0.9651
Barclays	1.78	0.779
BP	1.67	1.2213
Marks & Spencer	1.07	1.1096
Glaxo	0.4914	1.1629

The main use of beta is to identify volatility and therefore select securities that match the client's attitude for risk. It can also be used to extrapolate future performance.

Following this theory, based on the 2018 figures, if the index went up by 10%:

- Tesco shares to rise by 9.65%.
- Glaxo shares would rise by 11.62%

If the index fell by 10%

- Tesco shares would fall by 9.65%.
- Barclay's shares would fall by 11.62%%

As with SD, beta is based purely on past performance and there is no agreed method of calculating it particularly the period of past performance that is used. As can be seen from this table the beta of Barclays and Glaxo have changed significantly over four years

Beta is also the key factor in the **Capital Asset Pricing Model (CAPM)**

Capital Asset Pricing Model (CAPM)

CAPM is a tool that aims to predict the possible return on an investment. It should not be seen as an accurate predictor but rather as some way investors can assess whether it is likely to deliver the return they require.

The starting point is that no rational investor would invest in anything that delivered a return that was lower than a "risk free" return. What that rate should be is open to debate but is usually taken as being in the UK, short term Treasury Bills. It follows that an investment must have to offer the potential of a better return and that is termed the risk premium. In CAPM that is taken to be the return delivered by the London Stock market

So far then we have two factors:

- Risk free return
- Market return

The level of market return will also be a matter of debate because this varies from year to year. However, in any CAPM calculation these two are fixed amounts. The final factor and the one variable is the beta of the security.

Formulas tend to frighten many candidates as they seem to be written by mathematicians to intimidate everyone else. Therefore, it will probably be easier if it is written in full rather than using abbreviations or symbols:

Expected return = risk free return + Beta (market return less risk free return)

Here's how it would be calculated.

Risk free return = 1%
Market return 7%
Beta = 0.75

ER = 1% + 0.75(7% -1%)
ER = 1% + 0.75 x 6%
ER = 1% + 4.5%
ER = 5.5%

Therefore, if the investor was looking for a return of 7.5% this share might not be suitable.

CAPM has been criticised as being too simplistic and because it is based on unrealistic assumptions. These are:

- All investors are rational making decisions on the basis of risk and reward
- All investors have identical holding periods
- There are many buyers and sellers and no one can influence the price
- There are no transaction costs.

- Information is free and available to all
- All investors can borrow, and unlimited amounts can be borrowed at the risk free rate
- Liquidity of any asset can be ignored

Studies have also shown that the actual returns made by different securities do not reflect what was predicted by CAPM. A further objection to CAPM is that it is a single factor model in which the only thing that changes is the beta of the security. Other models such as the **Arbitrage Investment Theory** are multi models since the return on an asset is not just determined by its beta but also by inflation, risk premium, industrial production and interest rates.

One final point. So far the examples of SD and beta have been confined to single securities such as individual shares but they can also be applied to an individual portfolio or an OEIC fund.

Control and management of Risk

So far we have established that:

- Risk is the difference between what is expected and what is achieved.
- Risk is the same as volatility.
- It is measured by standard deviation and beta.
- SD takes into account how the past performance has varied against the mean.
- Beta compares the historical volatility of the security with a benchmark.

The next step is to look at how volatility can be managed and controlled.

Common sense tells us that the obvious way to reduce risk is to diversify, in other words “don’t put all your eggs in one basket”. However, there is good and bad diversification. The value of all assets, other than cash, will always fluctuate. This volatility arises from:

- Systematic Risk
- Non-systematic Risk

These should not be confused with systemic risk. That is defined as an event that could trigger a collapse in an industry or economy.

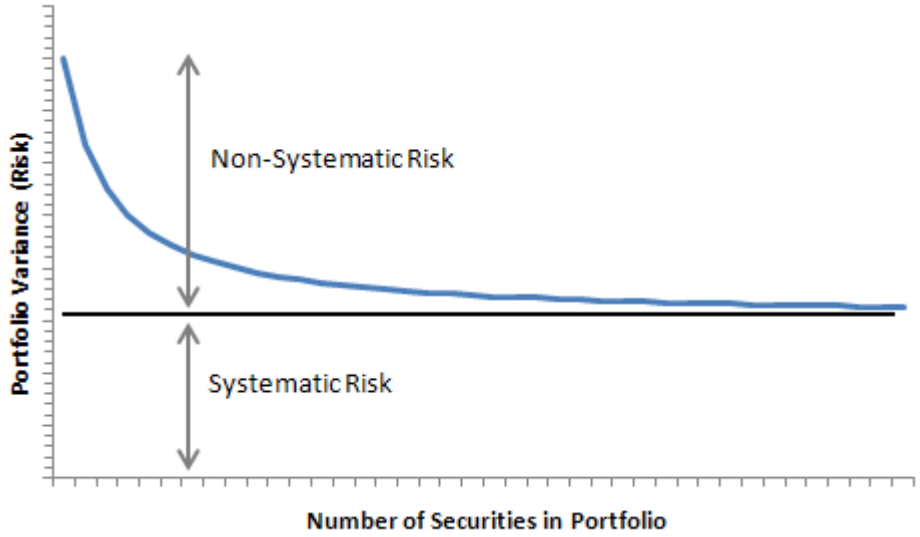
Systematic risk, also known as market risk, is the inherent risk of being in assets that fluctuate in value. Non-systematic risk is the risk to a particular security. Some examples are:

- A drugs company had to withdraw its best-selling drug because of reported side-effects.
- A food manufacturer is prosecuted for poor hygiene standards
- A mining company reports that one of its mines has less potential than predicted.

All of these would tend to reduce the company's share price, but it would not affect the share price of any other company. This distinction is important because it shows the limitations of diversification

Systematic risk cannot be reduced by diversification. A portfolio could hold every share listed on the London Stock Exchange but it would still be vulnerable to falls in the market.

Diversification can though reduce non-systematic risk.



In this chart the vertical axis represents the risk of the portfolio and the horizontal axis the number of securities in the portfolio. As the number of securities in the portfolio increases the level of Systematic risk stays the same because no matter how many shares are held in the portfolio this risk cannot be reduced.

The downward curved line represents non-systematic risk which does reduce as the number of securities in the portfolio is increases. Note that the reduction in risk is very high when the first securities are added but as more are added the reduction becomes less. Some argue that the optimum number of securities should be 25 to 35 as there is no reduction in risk after that point. Finally note that the total risk in any portfolio is the sum of systematic and non-systematic risk

How diversification can be measured

The way that two assets move in relation to each other is called **correlation**. This can be:

- **Positive correlation:** This is when different stocks are affected by similar factors and tend to move up and down together.
- **Negative correlation:** This is the opposite and means that stocks tend to move in opposite directions in response to economic factors.
- **No correlation:** This is where the returns on different investments are not connected and we are unable to make a direct comparison as to how they react to economic factors.

For example, shares in an oil company and a transport company would be negatively correlated. If the price of oil goes up that is good for the oil company and bad for the transport company.

Shares in a bank and a property company will tend to have positive correlation. Property companies borrow heavily from banks but if the property company fails that will mean the bank will have to write off those loans.
The most effective diversification comes from combining investments whose returns ideally move in the opposite direction to one another, or if in the same direction, at least not to the same extent.

There is published data to show the correlation of different assets. This is based on past performance which may not of course be repeated in the future.

- Perfect positive correlation is shown as +1
- Perfect negative correlation is shown as -1

If you had two assets that had perfect positive correlation then if the first increased by 10% then the second would also rise by 10%. If there was perfect negative correlation then if the first increased by 5% the second would fall by 5%.

As you might expect most correlations fall somewhere between these two points as in this table

	X	Y	Z
X		0.4	- 0.3
Y	0.4		-0.7
Z	-0.3	-0.7	

X is positively correlated to Y but negatively correlated to Z
Y is negatively correlated to Z

The numbers help us to predict how the change in one might result in a change to the other so:

If X increases by 10% we would expect Y also to increase by 4%
If Y increases by 10% we would expect Z to fall by 7%
If Z fell by 10% we would expect X to increase by 3%

Modern Portfolio Theory

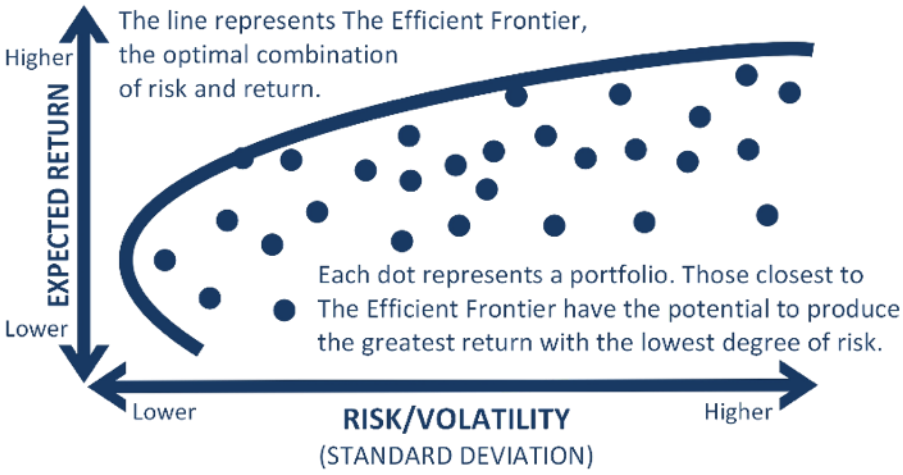
Whilst this is called “Modern Portfolio Theory” it dates back to 1952. The key principles are:

- The key to achieving good returns is identifying the best asset allocation rather than selecting individual stocks. In other words the starting point should be to identify what percentage of a portfolio should be in cash, bonds, equity or property.

- Given that we can identify the client's risk appetite it is possible to construct a portfolio that will give the highest level of return. Alternatively given a client's desired return, a portfolio can be constructed that will deliver this at the lowest level of risk
- Portfolios should mainly consist of assets that have negative correlation

Efficient Frontier

In assessing individual assets or portfolios the two key elements are expected return and risk measured by its standard deviation. As the risk increases we would expect the return to increase. Shown on a graph it would look like this.



The efficient frontier is the curve that rises as the amount of risk increases. The expected return rises rapidly at first but as risk increases the subsequent gain in expected return becomes less.

The optimal portfolio will be the one that lies on the efficient frontier. A portfolio can be considered efficient if it is not possible to obtain a higher return without increasing the risk.

The basis of MPT is that the combined effect of the assets in a portfolio is what matters, not the risks and returns of the individual investments within the portfolio.

Although this theory uses rigorous and proven mathematics it does have its drawbacks:

- Models rely on past risk and correlation data and therefore may not predict the optimum portfolio for the future.
- It relies on investors being able to decide on the exact level of risk they are prepared to take.
- An optimized portfolio only takes account of risk and reward. It does not cater for any other client's needs such as income

That concludes this part so you should now understand:

- The definition of risk
- How to interpret Standard deviation and beta
- The Capital Asset Pricing Model and its limitations.
- The difference between Systematic and non-systematic risk.
- The importance of correlation in risk management
- The principles of Modern Portfolio Theory
- The efficient frontier concept.