



Class: MSc Sem 4

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Chapter Name: Quantifying risk

Today's Agenda

1. Risk Quantification
2. Evaluation of Risks
3. Aggregating Risks
4. Risk Measures
5. Risk Portfolios / Registers
6. Risk Reporting

1 Risk Quantification

For all risk events there are two key features to be assessed:

- the probability of the event occurring i.e. the frequency of the event
- the expected loss if the event occurs i.e. the severity of the event.

Each of these is normally a random variable, although there are some situations where the loss if the event occurs is a fixed amount rather than a random variable. This situation would normally arise in a single event insurance risk, for example an individual purchasing a term assurance policy that pays a fixed sum assured if the individual dies within the specified term.

A single event insurance risk is one where only one claim payment is made for each policy, unlike general insurance policies, where several claims can be made within the period of the cover.

1 Risk Quantification

➤ Subjective Assessment

A common approach to risk assessment used by financial institutions is to extend the risk identification 'brainstorming' approach so that the probability and cost or impact of the risk event are each estimated. These estimates would be on a five-point scale (or three-point scale). For a five-point scale the assessments would be based on: 5 = high, 4 = medium-high, 3 = medium, 2 = medium-low, 1 = low.

The product of the probability assessment and the impact assessment gives a scale of 1 to 25 (or 1 to 9 for the three-point scale) as an assessment of the risk. This risk-scoring approach provides a method for ranking risk events.

The organization could then prioritise its methods of dealing with risks with a score of higher than a certain amount. For instance a risk which is a one-off event but high potential impact or has a medium impact but a high probability of occurring.

The assessment would be carried out with and without possible risk controls, to generate a figure for the effectiveness of proposed controls. This will enable the efficiency of risk controls to be assessed against their cost.

1 Risk Quantification

➤ Using a Model

A risk event may be assessed by developing a model in which the probability of loss and the amount of loss are both treated as random variables..

To use a mathematical model, the first need is to assign a distribution both to the probability of the risk event occurring, and also to the loss if the event occurs.

For some risks occurrence isn't an on/off event, but to quantify the risk simply it is necessary to define the event.

For example, investing in equities carries market risk. The firm could set an event as a 25% fall in equity price over a year and then research historic data to determine a probability distribution of this event. The choice of parameter for the fall in the equity market would need to be consistent with the firm's risk appetite.

Another approach would be to set the frequency of the loss event in advance, and to use this to determine the size of the parameter. For example, a 0.5% probability of an equity fall might involve a market movement of 40%.

All these considerations need to be taken into account in designing an appropriate model – as to whether a stochastic or deterministic model is appropriate.

1 Risk Quantification

Obtaining the data to parameterise the model will be a crucial issue, and the availability of data may influence the decision as to what, or whether, a model is used.

This is particularly important when rare events are considered. Even in areas where there is a large volume of data, such as mortality, where developed countries have been conducting censuses for well over 100 years, there is a need to consider a pandemic event. Here one has to go back almost 100 years to the 1919 influenza epidemic, and then realise that the effects need to be adjusted for improvements in medical science (antibiotics, antivirals), lifestyle (population movement) and general population health.

2 Evaluation of Risks

➤ Scenario Analysis

Scenario analysis is a deterministic method of evaluating risk. It is useful where it is difficult to fit full probability distributions to risk events (and hence where a stochastic model would be inappropriate). This could be because the risks are not suitable for mathematical modelling, or because the distribution would need so many subjective parameters that the value of using it is eroded.

Scenario analysis is frequently used when evaluating operational risks but can also be used to assess the impact of financial risks such as a global recession.

It involves a number of steps:

- Risk exposures need to be grouped into broad categories – all risks involving financial fraud, all risks involving systems errors, for example. This step is likely to involve input from a wide range of senior individuals in the organisation.
- For each group of risks, a plausible adverse scenario is developed. The scenario needs to be plausible, otherwise it will not be possible to determine the consequences of the risk event. The scenario is deemed to be representative of all risks in the group.

2 Evaluation of Risks

- For each scenario, the organisation must translate the scenario into assumptions for the various risk factors in the model. Again, this is likely to involve senior staff input. The consequences of the risk event occurring are then calculated. The financial consequences include redress paid to those affected, the cost of correcting systems and records, regulatory fees and fines, opportunity costs while any changes are made, etc.
- The total costs calculated are taken as the financial cost of all risks represented by the chosen scenario.

One drawback to scenario analysis is that it quantifies the severity of the scenario but not the probability of it occurring. Organisations often use their capital models to determine the probability of a particular scenario occurring.

If capital requirements can be modelled stochastically, then the probability distributions can be used to identify a confidence level for a particular outcome.

2 Evaluation of Risks



Revenue forecasting is the starting point of all financial planning, which is why sales headcount is one of the most common use cases for scenario analysis.

When creating your sales capacity model, you discover your revenue parameters based on the number of new sales representatives you plan to hire. If you set your assumption for quota attainment based on historical data, you'll have one scenario set as a base case for revenue growth. But what if your hiring plan falls short? This is where you start to develop scenarios

Let's say that you currently have two account executives with sales goals of \$600,000 each. Your baseline scenario is a \$1.2 million revenue forecast. You decide to ask, "What if we were to hire 10 more account executives with the same sales goals?" Your best-case scenario is that everyone hits 100% of quota and you boost revenue to \$7.2 million.

A base case of 80% quota attainment is more likely. So, your original sales capacity model might encompass the base case where all 12 of those reps, when fully ramped, pull in \$480,000 in revenue.

But you also have to plan for the worst case, where maybe you lose a couple of reps in onboarding, and none of those new reps hit quota when fully ramped. Where would that leave the health of your pipeline and revenue growth? And more importantly — how would your organization's financials withstand that scenario?

2 Evaluation of Risks

With these findings, you can expand into multiple scenarios with a more granular what-if analysis:

- What if we don't hit the hiring goals in our time frame?
- What if onboarding and ramp speed is slower or faster?
- What if we hired five additional representatives (above the original headcount plan)?
- What if our sales representative ramp rate is 20% longer than expected — and how does that affect overall revenue goals?

No matter how good you are at forecasting, any of these what-if questions could derail your plans. And it's finance's job to provide executives, business partners, and key stakeholders with the complete picture of all potential outcomes and future scenarios. When you can quickly update a model to answer these questions, you put yourself in a position to make more informed decisions about when to be aggressive with hiring and when it's a better time to be more conservative.

2 Evaluation of Risks

➤ Stress Testing

Stress testing is also a deterministic method of modelling risks, where the risk events are extreme. It is commonly used to model extreme market movements, but also has applications in modelling credit and liquidity risks.

The risks that are incurred by extreme events can be identified and investigated by the process of financial stress testing.

For example, in relation to market risk, this involves subjecting an asset portfolio to extreme market moves by radically changing the underlying assumptions and characteristics, in order to gain insight into the portfolio's sensitivities to predefined risk factors. In particular, both asset correlations and volatilities are often observed to increase during extreme market events.

There are two types of stress test:

- to identify 'weak areas' in the portfolio and investigate the effects of localised stress situations by looking at the effect of different combinations of correlations and volatilities
- to gauge the impact of major market turmoil affecting all model parameters, while ensuring consistency between correlations while they are 'stressed'.

2 Evaluation of Risks



A bank stress test analyzes how a bank's balance sheet will be impacted by an adverse change in the above economic variables. Stress tests run several scenarios with the variables above and others. Below are examples of common scenarios that might be run in a stress test:

- How will an X% change in interest rates impact the bank's financial position?
- What happens if unemployment rises by X% in year Z?
- What happens if the GDP falls by X% and unemployment rises by Y%?
- What happens to the bank's assets if the stock market crashes by X%?
- How does the bank's exposure change if oil/precious metal prices fall by X%?
- What happens if the FX rate with country A depreciates by X%?
- What happens if there is a housing market crash of X%?

2 Evaluation of Risks



Stress tests determine the financial health of banks in periods of financial turmoil by running model simulations like the ones above. Running such scenarios is a tedious job, as a lot of variables go into such models.

The central bank of a country generally provides a basic framework for running stress tests. The three key areas stress tests focus on the most are credit risk, market risk, and liquidity risk.

Bank stress tests were introduced in 2008-2009 in response to the financial crisis. International financial authorities required all banks of a certain size to undergo periodical stress testing and publish the results. Banks that failed stress tests were required to build up their capital reserves.

A key benefit of stress testing is the improvement in **risk management**. Bank stress tests essentially add another layer of regulation, which forces financial institutions to improve risk management frameworks and internal business policies. It obliges banks to think about adverse economic environments before making decisions.

2 Evaluation of Risks

➤ Combining Stress and Scenario Testing

The principle of stress testing can be coupled with scenario testing to determine a stress scenario. Scenario analysis outlines the factors that may be affected under a given scenario, on which stress testing may be later applied. The overall stress scenario test combines the individual factor stress tests simultaneously to allow for any inter-relationships.

When constructing a stress scenario, decisions need to be made as to how other aspects of the business will react if a stress event occurs.

For example, for a provider of unit-linked investment bonds, a sustained reduction in market values will affect:

- income received from fund management charges
- persistency of existing investment bonds
- new business volumes

2 Evaluation of Risks

- the provider's regulatory capital requirements
- the value of the shareholders' interests
- the probability of any guarantees biting.

All these factors need to be built into the model.

The scenarios should be tailored to reveal weaknesses in terms of risk exposure and sensitivity, and should thus focus on the risk factors to which the business is most exposed.

2 Evaluation of Risks

➤ Reverse Stress Testing

A requirement of regulatory bodies is often that regulated firms carry out a reverse stress test. This is the construction of a severe stress scenario that just allows the firm to be able to continue to operate its business plan.

In layman's language it means formulating a scenario which impacts the business in such a manner that it is just capable of fulfilling its strategic business plan and nothing more.

Business plan failure needs to be determined by the firm and needs to consider both the short-term and the long-term plan. This might, for example, occur if the firm has insufficient capital to meet statutory requirements, or to cover its minimum risk appetite.

It might also occur from a non-financial external event that causes the firm to cease having access to its major market.

For well-capitalised firms a reverse stress test may be an extreme event, but it nevertheless needs to be a plausible scenario

2 Evaluation of Risks

➤ Stochastic Modelling

An obvious extension of stress testing is a full stochastic model with all the variables that give rise to risk being incorporated as probability distributions, and a full set of dynamic interactions between the variables specified. The model can then determine the capital necessary to (just) avoid ruin at any desired probability level.

Not only is such a model extremely complex to specify and build, the run times that result from having more than one, or possibly two, variables simulated by stochastic methods become impractical with even the most modern computing power.

It is therefore necessary to limit the ideal scope of the model by one or more of the following approaches:

- Restrict the duration of the model to two years if the risk criterion is expressed as a one-year ruin probability. Some parts of the model, such as calculation of basic policy reserves for life assurance contracts, will still require projections to run-off.
- Limit the number of risk variables that are modelled stochastically. Deterministic approaches can be used for other risk variables. Variables that only have an adverse effect when they move in one direction can be modelled using deterministic scenario analysis. For example, in a benefit scheme it is increasing longevity that will put the scheme under stress, rather than deteriorating mortality.

2 Evaluation of Risks

- Carry out a number of runs with a different single stochastic variable, followed by a single deterministic run using all the worst-case scenarios together. This will determine the effect of interactions between the various variables.

It is important to remember that the results are only as good as the model used.

3 Aggregating Risks

➤ Capital Requirements and Relationships Between Risks

In managing risk, attention needs to be paid to all risks, though the methods outlined in the previous sections indicate the key risks that merit most management involvement.

In many regulatory regimes for financial product providers, the capital requirement is set in respect of an event occurring within 12 months with a probability 0.5%.

This is frequently called the capital requirement for a '1 in 200-year event'. This phrase can be misleading to non-experts, as it implies that if an event has just occurred, it will be another 200 years before they need to worry about the next one. In practice, rare events, such as stock market crashes and extreme weather events, appear to be happening more frequently than the assumed probability indicates.

The technique of stochastic modelling can be used to determine capital requirements for a firm for all risks to which it is exposed. Stochastic modelling can provide a complete distribution of outcomes to calculate capital required at a pre-determined probability level.

A stochastic model should allow for correlations between risk events for every simulation.

4 Risk Measures

➤ Liability Risks

The most common way of measuring liability risks is the analysis of experience – in other words, the ratio of the actual occurrences of an event to the occurrences expected when the risk was accepted.

It is important to stress the need for consistent classification and measurement not only of the risk events, but also of the population exposed to risk.

Apart from analysing mortality, expenses and withdrawal experience, correspondence in the exposed to risk analysis is also important.

➤ Value at Risk

Value at Risk (VaR) generalises the likelihood of underperforming by providing a statistical measure of downside risk. VaR represents the maximum potential loss on a portfolio over a given future period with a given degree of confidence.

4 Risk Measures



Examples

A 99% one-day VaR is the maximum loss on a portfolio over a one-day period with 99% confidence, ie there is a 1% probability of a greater loss.

For example, if the 95% one-month VAR is \$1 million, there is 95% confidence that over the next month the portfolio will not lose more than \$1 million.

VaR can be measured either in absolute terms or relative to a benchmark.

VaR is based on assumptions that may not be immediately apparent. In particular, it is frequently calculated assuming a normal distribution of returns. If the distribution of returns is 'fat-tailed', or skewed, tracking error (with its focus on the standard deviations of returns) may be misleading.

Unfortunately, portfolios exposed to credit risk, systematic bias or derivatives may exhibit non-normal distributions. The usefulness of VaR in these situations depends on modelling skewed or fat-tailed distributions of returns, either in the form of statistical distributions or via Monte Carlo simulations. Lack of sufficient data observations within the 'tails' of the distributions means there is increasing subjectivity in the choice of the underlying probability.

4 Risk Measures

Another shortcoming of VaR is that it does not give a value to the loss that may occur. Hence, another measure known as Tail VaR is used. It gives the value of the expected shortfall, given that the shortfall has occurred.

For example, if we believe that our average loss on the worst 5% of the possible outcomes for a portfolio is \$5 million, then the Tail VaR is \$5 million for the 5% tail.

5 Risk Portfolios

➤ Risk Categorisation and Quantification

It is advisable for an individual or company exposed to risk to establish a risk portfolio or risk register. The risk portfolio categorises the various risks to which the business is exposed.

Against each risk would be recorded a quantification of:

- impact
- probability

The product of the impact and the probability measures gives an idea of the relative importance of the various risks.

5 Risk Portfolios

➤ Risk Response

The risk portfolio can then be extended to indicate how the risk has been dealt with. Whether the risk has been :

- Avoided – by not taking th risk at all, eg an insurance company rejecting a client for a term life assurance whose medical underwriting claims he is a chain smoker
- retained (and how much capital is needed to support it)
- diversified (and a revised assessment of the remaining combination of risks)
- mitigated (and a revised assessment of the remaining risk) by opting for a reinsurance policy

5 Risk Portfolios

➤ Additional Details

For risks that are retained, the risk portfolio becomes a more detailed risk register. It would also include:

- details of control measures
- reassessment of value and impact after controls
- the risk owner
- the Board committee or senior manager with oversight of the risk (key strategic risks overseen by the full Board)
- identification of concentrations of risk and the need for management action in these areas.

6 Risk Reporting

➤ Importance of Risk Reporting

The production of regular risk reporting is vital so that management can understand and successfully manage the risks within its business. The production of regular risk reporting allows the management of a business to:

- identify any new risks faced by the business
- obtain a better understanding of the risks faced by the business in terms of quantifying the materiality and financial impact of individual risks
- determine appropriate risk and control systems to manage specific risks
- proactively monitor and manage the effectiveness of risk and control systems within its business
- assess whether the risks faced by a business are changing over time
- assess the interaction between individual risks
- appropriately price, reserve and determine any capital requirements for its business.

6 Risk Reporting

Regular risk reporting is likely to be helpful for other stakeholders as well. For example, it could:

- give shareholders or potential shareholders in a business a greater understanding of the attractiveness of that business for investment
- help credit rating agencies determine an appropriate rating for the business
- give a regulator a greater understanding of the areas within a business which could require more scrutiny.

Risk governance discusses the advantages of managing and budgeting for risk at the enterprise level. By budgeting for risk across the whole enterprise, maximum use can be made of diversification benefits, and thus the minimum capital required to support the risks undertaken.

One of the consequences of this approach is that it is necessary to have a system of risk reporting across the whole enterprise. It is important for the Chief Risk Officer to be aware of whether all business units are using the risk allocation that they have been given.

Risk allocation is the maximum level of risk exposure that each business is permitted to accept.

6 Risk Reporting

If two business units are allocated risk exposures that diversify away at the enterprise level, but one of the two units does not take on the risk exposure allocated, this could increase the capital requirements of the enterprise. Risk exposures will not be matched, and additional capital will need to be held to cover the unbalanced risks taken on.

Where diversification between business units is used to minimise group capital requirements, the individual business units will need to report data at a much more granular level than their own total capital requirement to the group. Analysing the data from diverse business units can be a costly task, especially for multinational operations. There is a trade-off between the costs of the additional analysis required to minimise capital requirements in this way and the cost of holding additional capital if risk diversification between business units is not assumed.

➤ Issues Relating to Reporting Risk Externally

The usual way for a financial product provider to report on risk is by quantifying the capital required to protect against ruin at a given ruin probability.

The annual report may only address risk issues in a qualitative manner, leaving the quantification of risk capital and solvency requirements to be covered in a separate report.

6 Risk Reporting

This is normally carried out using a combination of stochastic and deterministic modelling techniques. A common approach is to use a stochastic model to determine the risk event at the required ruin probability, and then to run a deterministic projection using that risk event.

For example, a stochastic asset model might be used to determine that a fall in the domestic equity market of 45% in one year occurs with a 0.5% probability. In assessing a market risk capital requirement with a ruin probability of 0.5%, the company's projection models might be run assuming an equity fall of 45% on day one.

The main issues facing providers of financial benefits in completing the assessment are:

- Should the ruin probability be expressed over a single year or over the whole run-off of the business? In the latter case the ruin probability will be a much higher figure than in the former.
- A stochastic model with more than two stochastic variables will be impractical to run. Thus, a means of assessing the correlation between the risks assessed needs to be developed. The most common technique uses a correlation matrix. Populating the correlation matrix is a largely subjective exercise.
- Interactions between risks may mean that the effect of multiple risk events is greater or less than the sum of the individual risks. A practical technique needs to be developed to address this.

6 Risk Reporting

- Some risks, particularly operational risk, are still highly subjective in their assessment, particularly when it is necessary to construct a plausible adverse scenario that occurs at a very low probability. The temptation is to think only of risk events that have occurred, which are likely to be more common than the required ruin probability.
- Using past data to estimate future consequences of rare events needs to be undertaken with caution. For example, the 1918-1919 Spanish 'flu pandemic has been assessed as an event with a probability of between 0.5% and 1%. However, because of advances in medical science, particularly the discovery of antibiotics, it is estimated that the same number of deaths as in 1918-1919 would now occur only from a much rarer event, perhaps one with 0.1% to 0.2% probability.