MATH GR 5320
Financial Risk Management and Regulation

Lecture 1: Introduction to Financial Risk Management

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If mistakes are found, please return them to hjstein@columbia.edu

Outline

Preliminaries

Overview

This is a 3 credit course in risk management and regulation, given in 13 2 hour lectures.

- Overview of the markets and the interactions of the players
- Definition and classification of financial risks — market risk, credit risk, liquidity risk, ...
- Market risk measurement — risk measures, value at risk (VaR), effective shortfall (ES), parameter estimation
- Credit modeling — reduced form models, Merton model, Black-Cox model, modeling joint default
- Counterparty risk — credit valuation adjustments (CVA) and risk mitigation
- Model validation — correctness, consistency, suitability, ...
- Regulation — balance sheet, capital and leverage ratios, regulatory objectives, overview of US and Basel regulations
- Financial failures — case studies of defaults and market crashes

I am also planning on 1 or 2 guest lectures.

Objectives

By the end of the course you should be able to:

- Classify the risks inherent in different positions and situations
- Compute VaR and ES of simple portfolios
- Work with credit spreads, default probabilities and default models
- Outline and understand the steps involved in model validation
- Identify which regulatory agencies cover which institutions, and know the nature of their regulations
- Compute capital and leverage ratios

Prerequisites

Prerequisites:

- Mathematical maturity – you should be able to read, write and understand proofs, and derive formulas.
- Probability and statistics, including conditional expectations and random variables.
- Stochastic processes and arithmetic and geometric Brownian motion.
- Arbitrage pricing theory, including Ito's formula and derivative pricing.
- Numerical methods.
- Programming.

Those lacking the background might find themselves struggling.

Also, it's not required to bring your laptops to class, but it might be useful on occasion.

If you are unsure about your background, please talk to me about it after class.

Grading

Grading will be based on:

- 50% : Homework assignments.
- 45%: Project.
- 5%: Attendance and participation.

Grading will be on a curve.

Homework:

- Weekly assignments.
- Start easy and will get harder.

Project:

- Develop a risk calculation system, including:
  - Model specification.
  - System design.
  - Test plan.
  - Implementation with test results.

Resources

Resources:

- Lectures.
- Lecture slides.
- Code samples.
- Supplementary readings – read the references!

Useful books:

- Quantitative Risk Management (Coleman [Col12], but part 1 appears to be available in Coleman [Col11]).
- Global Risk Management: A Quantitative Guide [Che13]
- Quantitative Risk Management: Concepts, Techniques and Tools [MFE15].

WARNING

WARNING WARNING WARNING WARNING WARNING WARNING

This is a risk management course. You will need to manage the risk of errors in the presentations and materials.

- ALL formulas in ALL references are subject to error!
- OPERATIONAL RISK – DO NOT copy and use!
- DO YOUR MODEL VALIDATION! – Only use a formula if you can validate the derivation!

Extra credit will be given for each error found.

WARNING WARNING WARNING WARNING WARNING WARNING

Homework

Working out problems is critical for understanding and being able to use the material.

Recommendations:

- Work on each problem until you understand everything about it.
- The homework is designed to teach you things, so think about the results!
  - Do they make sense?
  - Does anything look odd?
  - If so, study further!
- Don't rely on formulas – use and understand derivations.
- Don't rely on one source – use class time, lecture notes, book, uploaded supplementary material, internet resources, ...
- Do the work individually, but work in groups.
  - Don't kill yourself trying to figure out something that doesn't make sense. Ask others in the group.
  - Make sure you ultimately understand each step, the set of steps, the results, etc.
  - Compare notes.
  - Write up the homework yourself.

Policies

Requirements:

- Highest level of personal and academic honesty.
- Full and accurate attribution of the ideas and work of others.
- Submissions must be your own work.
- Students may collaborate on homework assignments, but must:
  - Note the names of their collaborators.
  - Write up assignments themselves.
- Students may work in groups of up to three members on the project and submit their work as a group.

Failure to adhere to these requirements will have serious consequences, up to and including dismissal from the university.

Introduction

A way of life

In the broadest scope, risk management is an essential part of decision making:

- Project management
- Buying a car
- Choosing a medical treatment
- Choosing a major
- Picking a restaurant for dinner
- Crossing the street

Every decision involves analyzing pros and cons.

Risk management is analyzing and mitigating the cons.

Definitions of risk management

http://en.wikipedia.org/wiki/Risk_management

> *Risk management is the identification, assessment, and prioritization of risks (defined in ISO 31000 as the effect of uncertainty on objectives) followed by coordinated and economical application of resources to minimize, monitor, and control the probability and/or impact of unfortunate events or to maximize the realization of opportunities.*

http://www.sra.org/vision-statement

> *Risk analysis is broadly defined to include risk assessment, risk characterization, risk communication, risk management, and policy relating to risk, in the context of risks of concern to individuals, to public- and private-sector organizations, and to society at a local, regional, national, or global level.*

See also http://www.theirm.org/about/risk-management/

Risk management steps

We have that:
Risks = possibilities that things won't go as planned

Risk management game plan:

- Identification
  - What can go wrong?
- Assessment
  - Impact.
  - Probability of occurrence.
- Mitigation
  - Minimize impact.
  - Reduce probability.
  - Monitor.

Financial risk management

http://www.prmia.org/faq/risk-management-overview

Risk management is the discipline of minimizing an organization's exposure to things which could negatively impact their business. Risk managers minimize exposure to risk through careful analysis of pertinent information, trends and history.

http://en.wikipedia.org/wiki/Financial_risk_management

Financial risk management is the practice of economic value in a firm by using financial instruments to manage exposure to risk, particularly credit risk and market risk. Other types include Foreign exchange, Shape, Volatility, Sector, Liquidity, Inflation risks, etc. Similar to general risk management, financial risk management requires identifying its sources, measuring it, and plans to address them.

Analysis

For financial risk management, we systematically analyze a financial business or the financial markets as a whole

- The players
  - Banks
  - Investors
  - Hedge funds
  - Regulators
- The pieces
  - Bonds
  - Stocks
  - Loans
  - Savings
  - Derivatives — futures, options, structured products, ...
- The moves
  - Trading
  - Execution
  - Management

The goal of this analysis is to understand the potential losses that can be incurred.

Identification

Given the portfolio and infrastructure, we need to characterize the events that can impact the business

- Market moves
- Idiosyncratic moves
- Political events
- System failures
- Oversight failures
- Legal issues
- Moral hazards

Impact

Given the business and the events that impact it, we need to gauge their impact

- Quantitatively
- Qualitatively

To characterize the relevant events and their impact, a risk manager must have an intimate knowledge of the workings of the entire firm.

Mitigation

Once risks are identified, they need to be mitigated

- Reduce positions
- Hedge
- Hold capital
- Realign compensation
- Install controls
- Change culture

Quantitative financial risk management

In finance, we can analyze some risks quantitatively.

Investors and managers are concerned with returns and gains:

- Expected future value: $E^P[V_t]$
- Potential rewards: $P[V_t > X] = E^P[1_{V_t>X}]$
- Expected returns: $E^P[\log(V_t/V_0)] = E^P[\log(V_t)] - \log(V_0)$

Risk managers are concerned with losses:

- CDF of V_t: $F(X) = P[V_t \leq X] = E^P[1_{V_t \leq X}]$
- Value at Risk (VaR): $V_0 - F^{-1}(1-p)$

In this respect, the issue is exploring the high end of the distribution of V_t vs the low end of the distribution.

The credit side

On the other hand, when considering credit, gains are important — a large amount owed is a large potential loss:

- CDF of V_t: $F(X) = P[V_t \leq X] = E^P[1_{V_t \leq x}]$
- Potential Future Exposure (PFE): $F^{-1}(p)$
- Expected Exposure (EE): $E^P[\max(V_t, 0)]$

So risk managers are actually concerned about both the extreme highs and the extreme lows of the distribution of V_t (but only because for credit we separately consider the exposure and the loss).

Risk management vs option pricing

Risk management:

- VaR: $V_0 - F^{-1}(1-p)$, where $F(X) = P[V_t \leq X] = E^P[1_{V_t \leq X}]$.
- EE: $E^P[\max(V_t, 0)]$.

This is distinct from option pricing. The price of a call option on V_t with zero strike is:

- Price: $E^Q[\max(V_t, 0)/N_t]N_0$

Key distinction:

- real world measure P, vs
- a risk neutral measure Q with respect to a numéraire N.

Note also the normalization by the numéraire.

This is confusing when V_t itself is calculated:

- EE: $E^P[\max(V_t, 0)] = E^P[\max(E^Q[V_T/N_T|\mathcal{F}_t]N_t, 0)]$

Systemic risk

Post crisis, in addition to far greater scrutiny of the individual risks that banks are bearing, we also have concern about *systemic risk*.

http://en.wikipedia.org/wiki/Systemic_risk

> *In finance, systemic risk is the risk of collapse of an entire financial system or entire market, as opposed to risk associated with any one individual entity, group or component of a system, that can be contained therein without harming the entire system.*

Not concern with levels of various risks at individual institutions, but of risk to financial markets as a whole.

Summary

The rest of the course will be exploring these ideas in detail, with the key issues being:

- What factors impact the prices?
- What is the joint distribution of these factors?
- How do the factors impact the portfolio value?

To do this, we need to know the behavior of:

- The positions being held.
- The people in the firm.
- The markets.

But keep in mind:

http://www.murphys-laws.com/

What can go wrong, will go wrong.

Also:

D.J. Hand. *The Improbability Principle: Why Coincidences, Miracles, and Rare Events Happen Every Day*. Farrar, Straus and Giroux, 2014. ISBN: 9780374175344. URL: http://books.google.com/books?id=e1iNAgAAQBAJ

Risk classification

Types of risks

Classically, financial risk analysis is divided into specific categories:

- Market risk — Impact of market moves
- Credit risk — Impact of credit events (defaults, rating changes) on debt obligations
- Idiosyncratic risk — Impact of changes in individual companies
- Counterparty risk —Impact of credit events on OTC derivatives
- Model risk — Impact of faulty models
- Liquidity risk — Inability to unwind
- Operational risk — Weaknesses in controls, protocols and/or systems
  - Legal risk — Potential for lawsuits
- Compliance and regulatory risk — Following regulations and the impact of changing regulations
- Reputational risk — Potential for and impact of bad press
- Moral hazard — Rewarding bad behavior
- Systemic risk — Market crisis analysis and crisis avoidance

Market risk

Market risk – impact of market changes:

- Market up/down, such as:
  - Equities
  - Credit
  - Interest rates
  - Exchange rates
  - Commodities
- Sector up/down, such as:
  - Industrials
  - AAs
  - Greece
- Spreads up/down, such as:
  - Long rates vs short rates
  - Credit vs equity

Market risk

Think of impact of exogenous market changes vs company specific changes

$$dS_i = \beta_i dM + d\epsilon_i$$

or

$$dS_i = \sum_j \beta_{ij} dM_j + d\epsilon_i$$

Market risk is typically concerned with the impact of changes in M and M_i, not with ϵ_i.

- VaR is used
- Risk of oversimplifying (linear factor model)
- Critical to understand portfolio composition:
  - Long/short portfolio vs long only
  - Spread trades
  - Carry trades
- Much more complicated when derivatives are involved

Credit risk

Credit risk — impact of credit changes:

- Defaults.
- Credit migrations.

Consider:

- Individual events.
- Default clustering.
- Recovery rate R, the part of the value that we will receive in the event of a default.

With a recovery rate of R, default at time T causes loss of

$$(1 - R) \times V_T$$

Hence, on a per name basis, consider

- CDF of V_t: $F(X) = P[V_t \leq X] = E^P[1_{V_t \leq X}]$
- Potential Future Exposure (PFE): $F^{-1}(p)$
- Expected Exposure (EE): $E^P[\max(V_t, 0)]$

Idiosyncratic risk

Idiosyncratic risk — impact of changes in individual companies

If

$$dS_i = \beta_i dM + d\epsilon_i$$

or

$$dS_i = \sum_j \beta_{ij} dM_j + d\epsilon_i$$

then the impact of changes in ϵ_i instead of M.

- Risk that can be diversified away.
- Magnified by spread trades, long/short strategies, etc.

Counterparty risk

Counterparty risk — the exposure to loss due to a specific counterparty failing to meet contractual obligations, i.e. defaulting.

Restricts to credit risk from counterparties on derivatives contracts. Ignores fact that if a counterparty defaults, all of their contracts are affected:

- OTC derivatives
- bond issues
- stock issues
- debts, loans, ...

Compartmentalization of risks should be based on the type of risk, not the type of security, but practice disagrees.

The cost of embedded default risk = the CVA:

$$E^Q[(1-R)\max(V_\tau, 0)/N_\tau]N_0$$

where τ is default time. References: Stein and Lee [SL11], Canabarro and Duffie [CD03] and Pykhtin and Zhu [PZ07]

Liquidity risk

Liquidity risk — potential for loss due to inability to trade

- Most difficult quantitative risk to gauge
- Often final event triggering default
  - Unable to liquidate assets in time to make necessary payments
  - Missing a margin call
  - Loss of line of credit
  - Run on the bank
- Typically factored into market risk and credit risk
  - Price at exit price/sale price
  - Assume time delay between default and liquidation

Examples:

- LTCM [Mac00], [PRM09c], [Shi03]
- Northern Rock [Lle08]
- Fannie Mae and Freddie Mac [PRM09b]

Reference: Banking Supervision [BS08]

Model risk

Model risk — potential for loss due to faulty models.

Model validation

- Testing of models against market behavior — 99% VaR is exceeded 1% of the time.
- Comparison of implementations to specifications.
- Analyzing and testing model assumptions.
- Looking for missing factors.

Examples:

- LTCM is an example [Mac00], [PRM09c], [Shi03]

Operational risk

Operational risk — the risk of loss resulting from inadequate or failed internal processes, people and systems or from external events. This def inition includes legal risk, but excludes strategic and reputational risk [Bas11]

- Second biggest cause of defaults
- "Other risks"
- Settlement risk — failure to settle one of a pair of offsetting trades
- Enron
- Subprime mortgage lawsuits
- Clients suing banks when they incur losses
- Rogue traders

Difficult to quantify, yet Basel tries:

Basel Committee on Banking Supervision. *Operational Risk — Supervisory Guidelines for the Advanced Measurement Approaches*. Tech. rep. Bank for International Settlements, June 2011. URL: http://www.bis.org/publ/bcbs196.htm

Operational risk examples

Examples:

- Rogue traders
  - Barings collapsed because of losses incurred and covered up by Nick Leeson [PRM09a]
  - Jérôme Kerviel and Société Générale
- London Whale and JP Morgan Chase (http://www.bloombergview.com/quicktake/the-london-whale)
- Orange county bankruptcy because of lack of controls on county treasurer Bob Citron [Jor11; Sun01]
- Knight Capital near death experience due to moving bad code (http://www.bloomberg.com/news/2012-10-17/knight-capital-reports-net-loss-as-software-error-take html)

Compliance and regulatory risk

Compliance and regulatory risk — Following regulations and the impact of changing regulations

Compliance includes:

- Model validation
- Processing regulator issues:
  - Observations
  - Matters Requiring Attention (MRAs)
  - Matters Requiring Immediate Attention (MRIAs)

Regulatory risk analysis:

- Are laws changing?
- Chances of government stepping in.

Compliance and regulatory risk

Risk management is the largest post-crisis growth area in the financial markets, with compliance being one of the fastest growing subareas.

- Consulting firms
- Clearing houses
- Banks

Economist [Eco12]:

> *The law that set up America's banking system in 1864 ran to 29 pages; the Federal Reserve Act of 1913 went to 32 pages; the Banking Act that transformed American finance after the Wall Street Crash, commonly known as the Glass-Steagall act, spread out to 37 pages. Dodd-Frank is 848 pages long.*

And that's just the law, which (among other things) grants each regulatory agency particular rights. Each right then leads to hundreds of pages of rules from the regulators. The *Bank Holding Company Supervision Manual* is over 1,900 pages [FRS14].

Reputational risk

Reputational risk — Potential for and impact of bad press

- New Coke — substantial loss of brand value
- UK Phone hacking scandal — $8 billion loss in shareholder value
- Tylenol scare
- Barclays and the Libor scandal
- JP Morgan and the London Whale
- Exxon Valdez
- BP oil spill
- Bankers Trust — [Sun], [Kha08]

Often becomes more a matter of emergency response than prevention.

Moral hazard

Moral hazard – rewarding bad behavior – misalignment of rewards with goals.

Examples:

- Tenure?
- Theft insurance?
- Health insurance?
- Rewarding returns, not risk adjusted returns.
- Too big to fail.
- Performance based bonuses.

Last crisis:

- Compensation packages that encouraged risk taking were blamed.
- Governments taxed away bonuses.
- Now have slowly vetting compensation, clawback clauses, etc.

Systemic risk

Systemic risk — Market crisis analysis and crisis avoidance.

- Can an institution's default cause others to default?
  - Credit crisis was due to such worries.
  - Second credit crisis due to Greece.
- How fragile is the financial system?
- New and growing field.
- Much research.
- Many proposed risk measures.
- Too big to fail.
- Too interconnected to fail.
- Too hard to quantify.

Systemic risk

Systemic risk disagreements

- Overall our findings indicate that emerging economy equity markets are much more integrated to global equity markets than the integration of emerging bond markets with global bond markets and the integration of emerging currency market with global currency markets – Beirne and Gieck [BG14]
- Our results imply that it is relatively difficult to generate contagion solely through spillover losses in a network of payment obligations – Glasserman and Young [GY14]
- Risk to the financial system is possible even without firms that are deemed too big to fail, Federal Reserve Governor Daniel Tarullo said – Katz [Kat14]

Sell-side vs buy-side risk management

Bank risk management

Bank risk management – purview of the risk management team.

- Analyze
  - VaR
  - Stress tests
  - Exposure calculations
  - Sensitivities (change in portfolio value with respect to each risk factor)
- Mitigate
  - Reduce positions
  - Hold capital – 8% of risk weighted assets
  - Additional capital – Risk charges against various risk measures
    - CVA VaR
    - Incremental Risk Charge(IRC) – against default and migration VaR
    - Specific Risk (SR) – against idiosyncratic risk, etc
  - VaR limits

Characteristics:

- Separate risk management team and risk managers
- Lots of regulation

Mutual fund risk management

Buy side risk management – mutual funds

- Analyze
  - Index tracking error (volatility of excess return)
  - Performance attribution
  - VaR (less)
  - Stress testing (less)
  - Scenario analysis (less)
- Mitigate
  - Position limits
  - VaR limits – often baked into portfolio construction
  - Index tracking error limits

Characteristics:

- Portfolio construction is considered to have a risk management aspect
- Relies more on portfolio managers

Hedge fund risk management

Buy side risk management – hedge funds

- Analyze
  - VaR
  - Stress testing
  - Scenario analysis
- Mitigate
  - Position limits
  - VaR limits

Characteristics:

- Lots of operational risk in hedge funds
- Firms that use leverage more likely to have sophisticated risk management practices
- Portfolio construction is considered to have a risk management aspect
- Relies more on portfolio managers
- Large HF RM look more like bank RM, but without the risk manager

Summary

Summary

Lesson 1:

- Overview of risk management
- Types of financial risks
- Different approaches of different financial institutions

Future – financial risk management in detail

- Value at Risk
- Market Risk
- Credit risk
- Counterparty risk
- Regulation
- Case studies

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