

# **Risk Management in Finance - Introduction**

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# *Outline of Introduction*

What is risk?

Why risk  
management?

Measurement and  
management

Types of risk

The conflict of risk  
and return

- What is risk?
- Why risk management?
- Measurement and management
- Types of risk
- The conflict of risk and return

## What is risk?

- ❖ This slide has...
- ❖ Example 1.1
- ❖ Example 1.1 continued
- ❖ Financial risks

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# What is risk?

# Risk

What is risk?

❖ This slide has...

❖ Example 1.1

❖ Example 1.1  
continued

❖ Financial risks

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- In everyday speech, the word *risk* is associated with the possibility of negative outcomes.
- For something to be risky, the final outcome must be *uncertain* and there must be some possibility that the final outcome will have *negative consequences*.

## Example 1.1

- A player (investor/speculator) is entering a casino with an initial capital of  $V_0 = 1$  million dollars.
- All initial capital is used to place bets according to a predetermined gambling strategy.
- After the game the capital is  $V_1$ .
- We denote the profit (loss) by a random variable  $X = V_1 - V_0$ .
- The distribution of  $X$  is called the *profit-and-loss distribution* (P&L) and the distribution of  $L = -X = V_0 - V_1$  is simply called the *loss distribution*.
- As the loss may be positive, this is a risky position, i.e., there is a risk of losing some of the initial capital.

# Example 1.1 continued

What is risk?

❖ This slide has...

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- Suppose the game gives 1.6 million dollars with probability  $p$  and 0.6 million dollars with probability  $1 - p$ .
- $$X = \begin{cases} 0.6, & \text{with probability } p \\ -0.4, & \text{with probability } 1 - p \end{cases}$$
- If this game is *fair*, corresponding to  $E(X) = 0$ , is  $p = 0.4$ .
- However, even if  $p > 0.4$ , the player might choose not to participate in the game with the view that not participating is more attractive than playing a game with a small expected profit together with a risk of losing 0.4 million dollars. This attitude is called *risk-aversion*.

# Financial risks

What is risk?

❖ This slide has...

❖ Example 1.1

❖ Example 1.1  
continued

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## Characteristics of financial risks:

- Randomness (deterministic results don't represent a risk)
- Negative deviations (chance vs. risk)
- Financial (in this course we only consider financial risks!)
- Ideally: measurable

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Why risk  
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- ❖ Increased trading volumes
- ❖ The fall of Barings Bank plc

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# Why risk management?



# *Increased trading volumes*

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❖ Increased trading volumes

❖ The fall of Barings Bank plc

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The trading volumes on the financial markets have increased tremendously over the last decades.

- In 1970 the average daily trading volume at the New York Stock Exchange was 3.5 million shares.
- In 2002 it was 1.4 billion shares.
- In the last few years we have seen a significant increase in the derivatives markets.
- There are a huge number of actors on the financial markets taking risky positions and to evaluate their positions properly they need quantitative tools from risk management.
- Recent history also shows several examples where large losses on the financial market are mainly due to the absence of proper risk control.

# ***The fall of Barings Bank plc***

- The British merchant bank Barings Bank plc was founded in the 18th century.
- In 1995, quasi overnight insolvency due to unauthorized speculative transactions with derivatives of a single trader of the bank. This caused a loss of 1.4 billion US dollars within only a few months.
- How was the "rogue trader" able to do business on such a large scale?
  - ◆ Add profits and losses to separate accounts and hide losses.
  - ◆ Take large risks.
  - ◆ Report high profits to supervisors, get promoted and engage in even more risk-taking.

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- ❖ Risk measurement
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- ❖ Risk management II
- ❖ Risk management process I
- ❖ Risk management process II
- ❖ Risk management process III
- ❖ Risk management process IV
- ❖ Risk management process V
- ❖ Risk management process VI

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# Measurement and management

# ***Risk measurement***

- Suppose we hold a portfolio consisting of  $d$  underlying investments with respective weights  $w_1, \dots, w_d$ .
- Change in value of the portfolio over a given holding period (the so-called P&L, or profit and loss) can be written as  $X = \sum_{i=1}^d w_i X_i$ , where  $X_i$  denotes the change in value of the  $i$ th investment.
- Measuring the risk of this portfolio essentially consists of determining its distribution function  $F_X(x) = P(X \leq x)$ , or functionals describing this distribution function such as its mean, variance or 99th percentile.
- We need a joint model for the underlying random vector of investments  $(X_1, \dots, X_d)$ .
- So risk measurement is essentially a statistical issue.

# ***Risk management I***

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**Definition:** The term **risk management** is commonly defined as the sum of all measures for the systematic identification, measurement, management, and control of risks in a firm and its relevant environment. Its primary goal is the **stabilization or increase of the shareholder value** (market value of equity).

# ***Risk management II***

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❖ Risk management I

❖ **Risk management II**

❖ Risk management process I

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- Risk management represents a **continuous process**.
- Since it is a **central management task**, a functioning risk management needs companywide strategies and objectives set by management.
- In general, it can not be delegated.

# ***Risk management process I***

The above definition of risk management shows the central tasks of a risk manager, which have to be fulfilled within the framework of the **risk management process**:

- Risk identification ("Which risks have an impact on the company?")
- Risk assessment ("How (much) do these risks affect the company?")
- Risk management ("How do I deal with the relevant risks?")
- Risk control ("How well have the risks been handled? What needs to be changed")
- Risk communication ("Which information must be communicated to internal and external addressees?")

# ***Risk management process II***

## **Risk identification:**

- First step in the RM-process: Identification of possible risks.
- Differentiation between **internal** (e.g. illegal behavior of employees) and **external** risks (e.g. changes in exchange rates).
- Decision of the risk management, which risks are **relevant** to the company and would have a **significant** adverse effect on the company's financial situation.
- Numerous risks are likely to be **known** beforehand (for example, banks are always subject to the risks that granted loans may default), often, however, this is not the case.



# ***Risk management process III***

## **Risk measurement:**

- Second step in the RM-process: **Measurement or evaluation** of all previously identified risks.
- Methods of **quantitative risk management** often use statistical, financial, and actuarial methods.
- However, **qualitative risk management** procedures are also used, particularly for risks that occur rarely or are difficult to measure (e.g., in the form of expert judgements).

# ***Risk management process IV***

## **Risk management:**

- Third step in the RM-process: Determination of **how** to deal with the risks.
- Choosing suitable countermeasures/actions by the risk manager **in coordination with the management**.
- Possible **strategies** for dealing with risks:
  - ◆ Risk avoidance (e.g. by not closing a deal).
  - ◆ Risk reduction (e.g. by hedging or by diversification in several asset classes).
  - ◆ Risk transfer (e.g. to an insurance company).
  - ◆ Risk mitigation (e.g. by setting up limits).

# ***Risk management process V***

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## **Risk control:**

- Fourth step in the RM-process: **Review** of the identified risks, the adequacy of the models used to measure risk, as well as measures taken to manage the risk.
- If necessary, **improvement** of measurement methods and control instruments.
- The measures taken have to be checked regularly whether their benefits justify their costs.

# ***Risk management process VI***

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## **Risk control:**

- One part of the last step in the RM-process:  
**Communication** of the results of risk management and risk control.
- Addressees:
  - ◆ Managing board.
  - ◆ Supervisory board, etc.
  - ◆ Supervisory authorities, etc.
  - ◆ Auditors, actuaries, etc.

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- ❖ Financial vs. real economic risks
- ❖ Financial risk
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# Types of risk

# Financial vs. real economic risks

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There is a differentiation between financial and real economic risks. Financial risks are such risks, which have their origin in the investment and financial activities of the firm, and therefore in its interaction with financial markets.

- In particular, such risks that arise from changes in **market prices**.
- Similarly, **defaults** of trade receivables or granted credit can lead to financial losses.
- Finally, insufficient **liquidity** of the company or individual assets can also jeopardize the existence of the company.

# Financial risk

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- All these subcategories of financial risk have in common that they do not arise **directly from the business activities of the firm**, but cash flows connected to them.
- Another common feature of these risks is that they represent a **potential loss** for the firm. Therefore, **risk management will seek to reduce potential losses**.
- A typical starting situation in **quantitative risk management**:
  - ◆ Risk = loss distribution of an investment.
  - ◆ Risk management = determining the distribution of the loss  $L$  and deriving a hedging strategy (e.g. reducing the variance of  $L$ ).

# ***Real economic risk***

- Contrary to financial risk, **real economic risk** represents such risks that arise from the **production of goods and services** by the firm or those that concern them directly.
- As a consequence, they involve a number of very different threats to the success of company.
- Examples:
  - ◆ The entrepreneurial risk that products (or services) cannot be sold. The result: slumps in sales and profits.
  - ◆ Disruption of the production of goods due to accidents, fires, disasters, and similar incidents. slumps in sales and profits.
- Many of these types of risk have been summarized by the banking regulation, within the framework of the Basel II project, under the concept of **operational risk** (later more on this topic).



# *Main types of risk*

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❖ Financial vs. real economic risks

❖ Financial risk

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Many sorts of risks can be categorized into one of the following three groups:

- Market risk
- Credit risk
- Liquidity risk
- Operational risk

# Market risk I

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**Definition:** **Market risk** represent such risks that arise from **changes in relevant market prices** and can lead to losses as a result of unfavourable price developments. They arise whenever a good, produced/required by a company, is traded on one (or more) market(s) and the price of that good is subject to fluctuations. Depending on the type of goods, different forms of market price risk can be further distinguished, which are briefly outlined below.

# *Market risk II*

## **Market risk - a modern concept?**

The management of **market risk** has been a concern of merchants for centuries. The simple realization that whenever goods' prices fluctuate, the purchase and sale of these goods has a potential for loss, has already led merchants in ancient Mesopotamia, India, and Greece to perform simple **hedging** strategies and transactions (cf. Swan, 2000). In many cases these referred to **raw materials and especially agricultural products**, whose prices are subject to natural, seasonal fluctuations (and therefore weather as well as harvesting and sowing times). Due to the demand for corresponding hedging transactions, the first **commodity futures and derivatives exchanges** were established over time, on which trading is still conducted today (of course on a larger scale and with more complex securities) in particular for the purpose of risk management.

# Market risk III

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## Futures exchanges

Futures exchanges are exchanges on which forward transactions are concluded and settled. Contrary to **spot markets**, the execution of obligations (delivery and payment) from the financial contract occurs only in the future.

# Commodity risk

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- **Commodity risk** comprises potential losses arising from price fluctuations of **raw materials**.
- Similarly, losses can also result from the fact that required raw materials are delivered too late, not in the required quantity, only at higher prices than the prices calculated or even not at all delivered.
- In the first case, commodity risk generally arises, if the prices for a commodity develop adversely in the future, i.e., if a relevant commodity price rises on the procurement side or if a relevant price decreases on the sales side.
- Depending on the type of raw material or commodity, the respective market prices can fluctuate to different degrees and are subject to **seasonalities**.

# Foreign exchange risk I

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- Closely linked to commodity risk of a company is its **foreign exchange risk**.
- Currency risk covers such risks of a firm arising from transactions in a **foreign currency**.
- For example, if an automobile manufacturer produces its models in Germany and sells them in China, the production costs in Euros are opposed to sales in Chinese Yuan.
- If the exchange rate of the Euro to Yuan (i.e. the market price of the foreign currency Yuan) changes, the car manufacturer receives higher or lower sales in Euros for its products sold in China.

# Foreign exchange risk II

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- As one can easily see, **commodity and foreign exchange risk often occur together**, namely whenever raw materials are purchased in a foreign currency. For both, commodity and foreign exchange risk, the risk manager has quite similar methods available to avoid or reduce these risks.
- Thus, a simple strategy for the complete avoidance of foreign exchange risk is to relocate the production site to the foreign market (in a similar way, a firm could also relocate the production near raw material suppliers). Finally, both types of risk can be reduced by concluding **hedging transactions** with opposite value development.

# *Securities risk I*

- Securities, as long as they are freely traded on a market, are in general subject to the risk that their respective **market price will develop unfavorably for the holder of the security**.
- All securities traded on securities exchanges, such as stocks, corporate bonds, but also certificates on stock indices, are subject to this risk, which on the one hand is expressed in **falling prices**, on the other hand, however, in a **volatile** and therefore in a **dprice development that is difficult to predict**.
- As a consequence, the common statistical procedures for modeling these risks usually aim for an **accurate estimation of the present** and for a forecast of the future price volatility of the security, or the estimation of potential future (downward) losses.



# Securities risk II

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- Note that in the case of certain securities, it is difficult to draw distinction between securities risk and **interest rate risk** which is yet to be described. In particular, this is the case when a security is subject to price changes solely due to fluctuations in market interest rates.
- Similarly, at the time of the purchase of a bond, there can be an additional risk that the issuer of a bond defaults and the buyer does not get back the invested nominal amount. In this case, however, the incipient price decline (to an amount close to zero) is usually understood as **credit risk** and not as market risk.

# Securities risk III

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## Careful!

Market risk, as well as all other types of risk, should never be considered **in isolation**! An asset position of a company is regularly exposed to several risks at the same time, e.g., in the case one owns a share denominated in a foreign exchange risk.

# Interest rate risk I

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**Definition:** **Interest rate risk**, or more precisely the risk of changing interest comprises losses in assets, resulting from changes in the market interest rates relevant to that asset position.

- Prerequisite: Asset value **depends on an interest rate**.
- Examples are interest-bearing securities, loans granted, and securities whose value is determined by a net present value calculation.
- If these asset positions offer **fixed interest payments**, fluctuating market interest rates also lead to an indirect interest rate risk in the form of **opportunity costs**.

# Interest rate risk II

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## Example 1.2:

For example, a **bank** could have issued a **loan** at a higher interest rate than agreed. In this case, the **resale value of the loan** would change unfavorably for the bank. On the other hand, if the bank does not sell or assign the loan until maturity, the change in market interest rates will not lead to an immediate loss.

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## Example 1.3:

In contrast, market interest rate changes in **interest bearing securities** directly lead to **decreasing prices**. The reason for this is that the price of a fixed-interest security, in the end, is equal to the present value of the expected future interest payments plus the nominal investment amount, and thus directly reflects interest rate changes in the form of fluctuating prices.

# Interest rate risk IV

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- If interest payments are **variable**, e.g, when interest payments are based on a market interest rate such as the 3-month LIBOR, fluctuating market interest rates usually result in lower losses stemming from price changes.
- Reason: changes in the expected (variable) interest payments are compensated by the resulting **changes in discount factors**.

# Interest rate risk V

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## Example 1.4: Falling market interest rates

Let there be two **risk-free zero-coupon bonds** with nominal amount of  $N = 100$  and a current risk-free interest rate of  $r=10\%$ :

	Bond 1	Bond 2
Bond price $P_i$	90.90	75.13
CF in $t = 1$	100	0
CF in $t = 2$	—	0
CF in $t = 3$	—	100

An increase of the interest rate to  $r=12\%$  leads to **falling bond prices** ( $P_1 = 89.29$ ,  $P_2 = 71.18$ ).

# Interest rate risk VI

## Example 1.5: Prices of bonds with different maturities

Let there be four **risk-free coupon bonds** with a nominal amount of  $N = 100$ , a coupon of  $K=2\%$  and a current risk-free market interest rate of  $r=1.5\%$ :

	Bond 1	Bond 2	Bond 3	Bond 4
Bond price $P_i$	100.49	100.97	101.45	101.92
CF in $t = 1$	102	2	2	2
CF in $t = 2$	—	102	2	2
CF in $t = 3$	—	—	102	2
CF in $t = 4$	—	—	—	102

Everything else equal, the **price of a coupon bond** decreases as the maturity of the nominal amount approaches.



# Credit risk I

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## Credit risk

If a firm holds **receivables** from private persons or another firm (usually these will be clients of the firm), the firm is exposed to the possibility that the claims are **not or only partially** (and thus not as contractually agreed upon) **settled**. This risk of (debtor) default is generally referred to as **credit risk** or counterparty default risk.

## ***Credit risk II***

- For **banks**, credit risk is therefore the most important type of risk, as their business model is fundamentally based on granting **credit/lending**.
- It should be noted, however, that in the end **almost each firm is exposed to credit risk**, provided that the goods and services offered, are sold under granting a term of payment.
- In contrast to the credit risk of banks, industrial companies are subject to **debtor risk**. Depending on the industry in which a company operates, debtor risk will be more or less important for the company's risk management.
- For example, credit risk in the retail sector will play a subordinate role. In the case of energy suppliers who have receivables from electricity and gas bills from thousands of retail consumers, debtor risk management will be regularly conducted in the scope and style of a bank.

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## Credit risk in a strict sense

Credit risk in the strict sense, describes the risk that a debtor actually **defaults** and can no longer completely satisfy his debt. In this case, the creditor will write down his claim and take measures to settle it.

## Credit risk in a broader sense

Contrary to credit risk in the strict sense, **credit risk in the broader sense** is understood as the risk that only **the probability of default** of a debtor **worsens**. The actual default of the debtor is therefore not required. While credit risk in the strict sense is often present in standardized retail business, credit risk in the broader sense is predominantly found in business with large, wholesale and business customers.

# Credit risk IV

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## Counterparty risk

The types of credit risk described above relate to business relations between a company and its customers. If a firm enters into a contractual business relationship with another professional market participant (one speaks in this case of a **counterparty**), against which the firm has a payment claim, the default risk of this payment is considered a **counterparty risk**.

# *Credit risk V*

## Subtypes of credit risk

- **Replacement risk from derivatives:** default of the counterparty in a derivative transaction and risk of additional costs when concluding a comparable transaction with another counterparty.
- **Issuer risk:** default of issuers of tradable debt or equity securities (bonds, shares, etc.).
- **Fulfillment risk:** risk that one contractual partner will not perform while the other already has performed.
- **Country risk:** Risk of default of a foreign state (also: sovereign risk) and/or risk of prohibition of payments in (or to) the foreign country.

# *Credit risk VI*

- Counterparty risk has a special importance in the **non-exchange** (so-called OTC) **trading** of securities.
- Here, transactions take place **directly between two market participants** and not via an intermediary of a stock exchange.
- An advantage of OTC trading is that both contracting parties can negotiate arbitrary conditions, while on a **stock exchange**, only standardized products/contracts are traded.
- However, one disadvantage is that in the event of a default of the contracting party (the counterparty), the settlement of the transaction and in particular the settlement of financial receivables is not guaranteed by a stock exchange.
- A possibility for the **removal of counterparty risk** consists in the establishment of a **central counterparty** which takes over the so-called **clearing** for all market participants.

# Credit risk VII

What is risk?

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Types of risk

- ❖ Financial vs. real economic risks
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- ❖ Model risk I

The conflict of risk and return

## Clearing

**Clearing** is the entire procedure of settling a financial transaction. In particular, this includes: the determination and settlement of mutual claims, liabilities, and delivery obligations as well as the transmission and reconciliation of information relevant for the settlement. As in OTC trading with central counterparties, market participants do not enter into transactions directly with each other, but always indirectly via the central counterparty, and thus, there should not be any counterparty risk.

# Credit risk VIII

What is risk?

Why risk management?

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The conflict of risk and return

## Industry example: the AIG case

*[...]. For one thing, banks and mutual funds are major holders of AIG's debt and could take a hit if the insurer were to default. In addition, **AIG was a major seller of "credit-default swaps"**, essentially insurance against default on assets tied to corporate debt and mortgage securities. Weakness at AIG could force financial institutions in the U.S., Europe and Asia that bought these swaps to take write-downs or losses. **AIG's millions of insurance policyholders appear to be considerably less at risk.***



# Liquidity risk I

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The conflict of risk and return

- The types of risk presented up to this point only had an **indirect impact** on the survival of a company.
- One reason for the **insolvency** of a firm is (as the term already implies) the **missing ability** to regularly **meet its short-term payment obligations**.
- Although market risk and credit risk could lead to financial losses, they only become a threat to the company, if the losses simultaneously lead to **liquidity risk** (i.e, the firm can no longer sustain any additional losses).

## *Liquidity risk II*

- Usually, the **liquidity of firm** is understood as its **ability to fulfill all due obligations** at a given time.
- The company obtains the ability to settle its short-term debt by **retaining sufficient** cash or short-term disposable assets, i.e., sufficient **liquid funds**.
- The liquidity of the company is a basic prerequisite for its continued existence on the market, and illiquidity coupled with the maturity of short-term liabilities, generally results in the insolvency of the company.
- If the insolvency is not filed with the insolvency court despite a lack of liquidity, this can qualify as a criminal offence of **delay in filing insolvency**.

# Liquidity risk III

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The conflict of risk and return

## Liquidity risk

Liquidity risk is the risk that a company has insufficient liquid funds to settle all short-term liabilities. The liquidity risk can arise in two ways within a company. On the one hand, a large outflow of liquid assets from the enterprise can occur, so that the servicing of liabilities that are due in the near future is questionable. On the other hand, even if liquid funds remain unchanged, the maturity of liabilities might decrease, so that the short-term demand for liquid funds increases unexpectedly. It is also possible that expiring loans may not be extended or replaced by new loans. The liquidity risk of a company is therefore often referred to as refinancing risk.

# *Liquidity risk IV*

- Liquidity risk is of particular importance for **banks**.
- Since banks engage in maturity transformation in their core business (i.e., taking short-term deposits from customers and granting these funds in form of long-term loans), a massive withdrawal of short-term deposits (so-called **bank run**) can lead to the insolvency of a bank.
- Bank runs represent a central research field in banking research and are one of the main reasons for regulating banks.
- For insurance companies, liquidity risk usually plays a minor role, since a) insurance companies have a comparatively constant inflow of cash via premiums and b) massive withdrawals of liquid funds are less likely than for banks.

# Liquidity risk V

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The conflict of risk and return

- Closely related to the concept of liquidity risk for a firm is the concept of **liquiditating** an asset (or its **market liquidity**).

## Market liquidity

**Market liquidity** is understood as the ease with which an asset can be bought or sold without the transaction having any influence on the market price of the asset. Ideally, an asset can be purchased or sold at its fair market value immediately and without affecting the market price. If, on the other hand a security is not liquid, the seller must either accept a price reduction (haircut) for the immediate sale or wait for a certain period of time before the sale takes place at the desired price.

# Liquidity risk VI

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The conflict of risk and return

## Liquidity risk vs. market liquidity

The liquidity risk of a firm and market liquidity are **directly connected with each other**. A decline in the liquidity of assets and securities held by a company can increase the company's liquidity risk or trigger illiquidity.

# Operational risk I

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- **Common denominator of all risk types discussed up to this point:**
  - ◆ **Exogenous character** of the cause of risk (e.g., exchange rate changes).
  - ◆ Risks related only to the **core business of the firm** (e.g., lending to banks).
- However, financial risks can also arise from
  - ◆ **exogenous influences** on areas of a firm that **do not belong to the core business**, or from
  - ◆ **endogenous** sources of risk (own employees, internal processes, etc.).

# *Operational risk II*

- Especially in the first case (e.g., natural catastrophes, disasters), unexpected major losses can arise, if risk management has previously only monitored and controlled risks in the course of business.
- These risks were in the past considered as a residual of the overall risk of a firm and its more precisely quantifiable risks (such as market risk or credit risk).
- Within the framework of the **Basel II capital adequacy regulations for banks** from 2007, however, operational risk was separately defined and, for banks, the measurement and backing of these risks with equity capital was required.
- In some countries, these regulations have been transposed into law.



# Operational risk III

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## Definition

**Operational risk** is the risk of losses arising as a result of the inadequacy or failure of internal procedures and systems, people or as a result of external events. This definition includes legal risks.

# Operational risk IV

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The conflict of risk and return

## WARNING!

The definition of operational risk **does not contain strategic risks or reputational risks**. Reputational risk, risks arising from strategic decisions, and risks actively assumed in the context of business activities are not covered by operational risk (similar to Basel II).

# *Operational risk V*

- The most important difference to the earlier conception of operational risk: the definition is **no longer based on a distinction from other types of risk**, but on an **explicit listing of the most important causes** for a resulting loss.
- Many operational risks are characterized by the following characteristics:
  - ◆ **High claims amount** (e.g., caused by a flood, storm, IT failure, etc.)
  - ◆ **Very low probability of occurrence.**
  - ◆ Therefore: **difficult to measure!**

# Operational risk VI

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## Collapse of Barings Bank plc:

- The interaction of various risk factors led to an operational risk.
- Lack or failure of internal control procedures.
- As a result: illegal behavior of a single (rogue) trader.
- Occurrence of an external event (the Great Hanshin earthquake in Kobe, 1995).

# Model risk I

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The conflict of risk and return

## Example: Inadequate modeling of possible losses:

- One central task of financial risk management is to estimate and forecast potential future losses as accurately as possible before entering into financial contracts.
- However, losses may not only arise from changing market prices or increasing credit default probabilities, but also because of inadequate risk modeling.

# Model risk II

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The conflict of risk and return

- In a simple example, the risk manager could have chosen a model that is fundamentally unsuitable for estimating losses.
- But even a model that is well suited for the intended purpose can still be **falsely calibrated or estimated with erroneous (i.e., incorrectly measured) data** so that as a result the quality of the risk assessment is seriously impaired.

# Model risk III

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## Definition:

**Model risk** is the risk that a company suffers a financial loss from the use of a model that shortens reality or the incorrect calibration, estimation, or use of a model.

# ***Model risk IV: types of model risk***

- Use of the **wrong** model.
  - ◆ Model has a different purpose or is generally unsuitable for the intended purpose.
  - ◆ Model is incorrectly specified.
- Model is incorrectly implemented.
  - ◆ Programming error.
  - ◆ Technical errors and coarse approximations (e.g. assumption of a non-existent linear correlation).
- Wrong use of the model.
  - ◆ Data problems, overfitting/underfitting.
  - ◆ Incorrect model calibration.
  - ◆ Overinterpretation of the results (What is the model capable or not capable of?).



# *Model risk V*

## Sources of model risk in FRM:

- Wrong pricing model for securities, especially derivatives.
- Inaccurate estimation of market indices (e.g., volatility, correlation, variation of these indices over time, etc.).
- Forecasting period is too long.
- Simplifying assumptions in capital market models (no transaction costs/liquidity costs, a risk-free interest rate, random walk assumption for equity returns, etc.).
- Data errors (e.g., in high frequency data).
- General overstraining of models and excessive complexity of certain tasks (e.g., models for forecasting tail events or for determining systemically relevant financial institutions).

# *Model risk VI*

## Approaches for limiting model risk in FRM:

- Use of multiple models, interpretation of the differences found in the models, worst case-/ model averaging approaches.
- Quantification of model risk using a benchmark.
- Consideration of limiting cases, extreme scenarios, review of model assumptions.
- **Parsimony**: If there are several models to explain a phenomenon, the model with the **least (or most economical) assumptions should be chosen**. Specific example: time series model with less parameters to be estimated.
- Back- and stresstesting.

# Model risk VII

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## Backtesting:

**Backtesting** refers to the process of **evaluating a risk model** by applying the model on **historical data** and checking for the adequacy of the model. The model is then adapted and corrected on the basis of the results and identified weaknesses.

**Example:** Forecasting of share price returns and backtesting the forecast model with historical data.

# Model risk VIII

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## Stresstesting:

**Stresstesting** is the investigation of the effects of changes in risk factors using scenario technique on specific key figures of a firm (e.g., equity ratios, profitability, probability of insolvency, etc.). A distinction can be made between micro (individual institute) and macro stress tests (total financial sector).

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# The conflict of risk and return

# ***Risk vs Return***

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- There is a trade off between risk and expected return
- The higher the risk, the higher the expected return

# Example

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Suppose Treasuries yield 5% and the returns for an equity investment are:

Probability	Return
0.05	50%
0.25	30%
0.40	10%
0.25	-10%
0.05	-30%

# Example continued

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- We can characterize investments by their expected return and standard deviation of return
- For the equity investment:
  - ◆ Expected return = 10%
  - ◆ Standard deviation of return = 18.97%



# Combining Two Risky Investments

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❖ Example continued

❖ Combining Two Risky Investments

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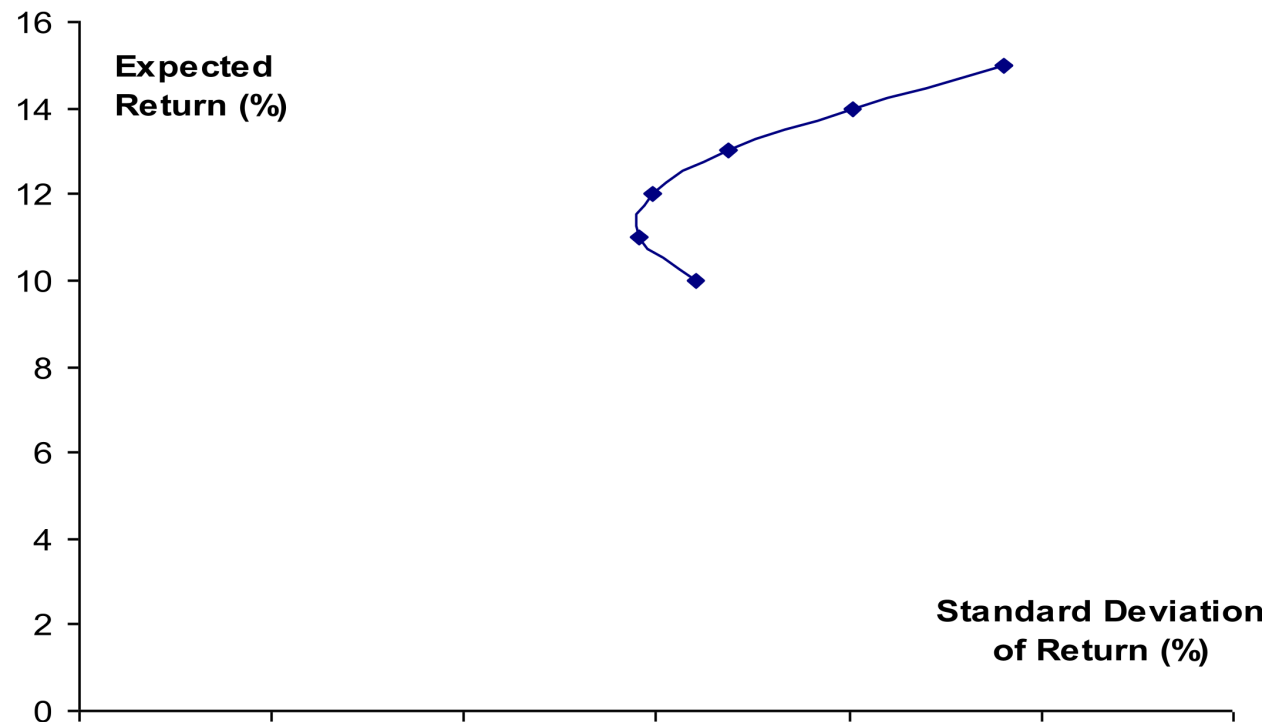
❖ Risk vs Return for Companies

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❖ Bankruptcy Costs

$$\mu_P = w_1\mu_1 + w_2\mu_2, \quad \sigma_P = \sqrt{w_1^2\sigma_1^2 + w_2^2\sigma_2^2 + 2\rho w_1w_2\sigma_1\sigma_2}$$

$$\mu_1 = 10\% \quad \mu_2 = 15\%, \quad \sigma_1 = 16\%, \quad \sigma_2 = 24\%, \quad \rho = 0.2$$



# Efficient Frontier of Risky Investments

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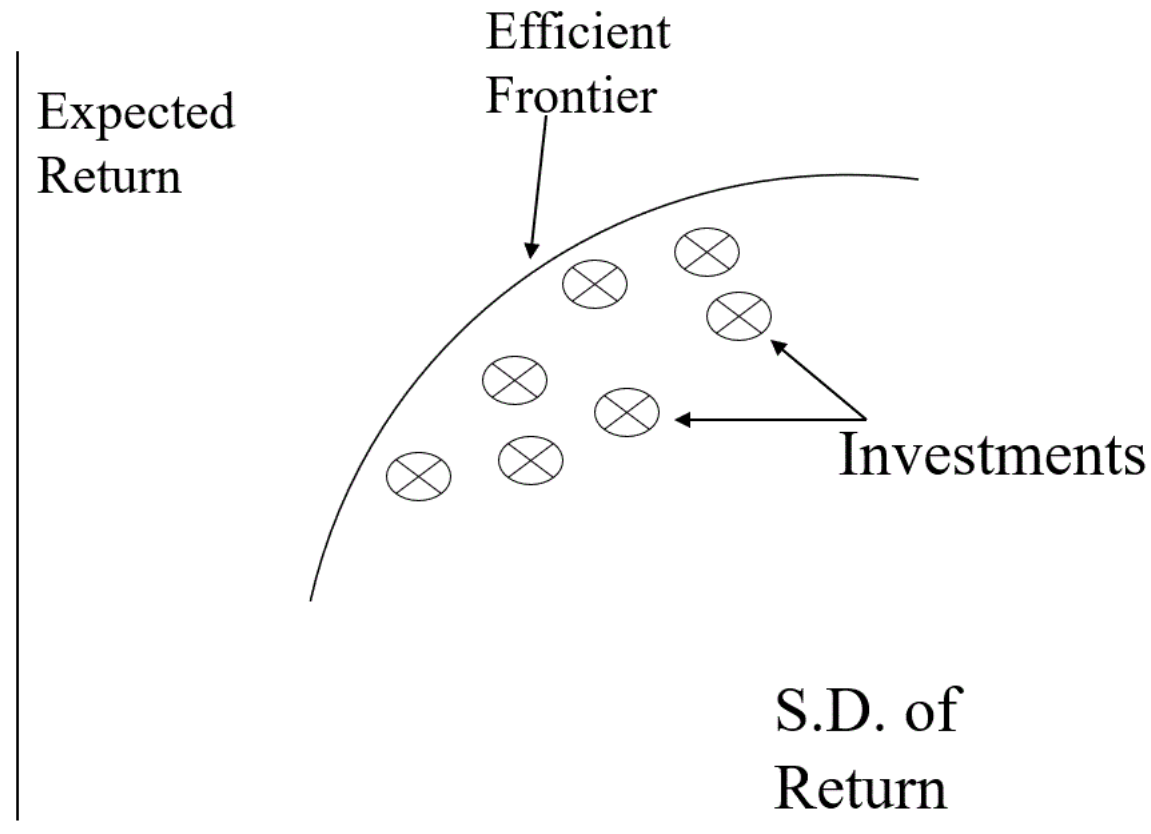
❖ Efficient Frontier of All Investments

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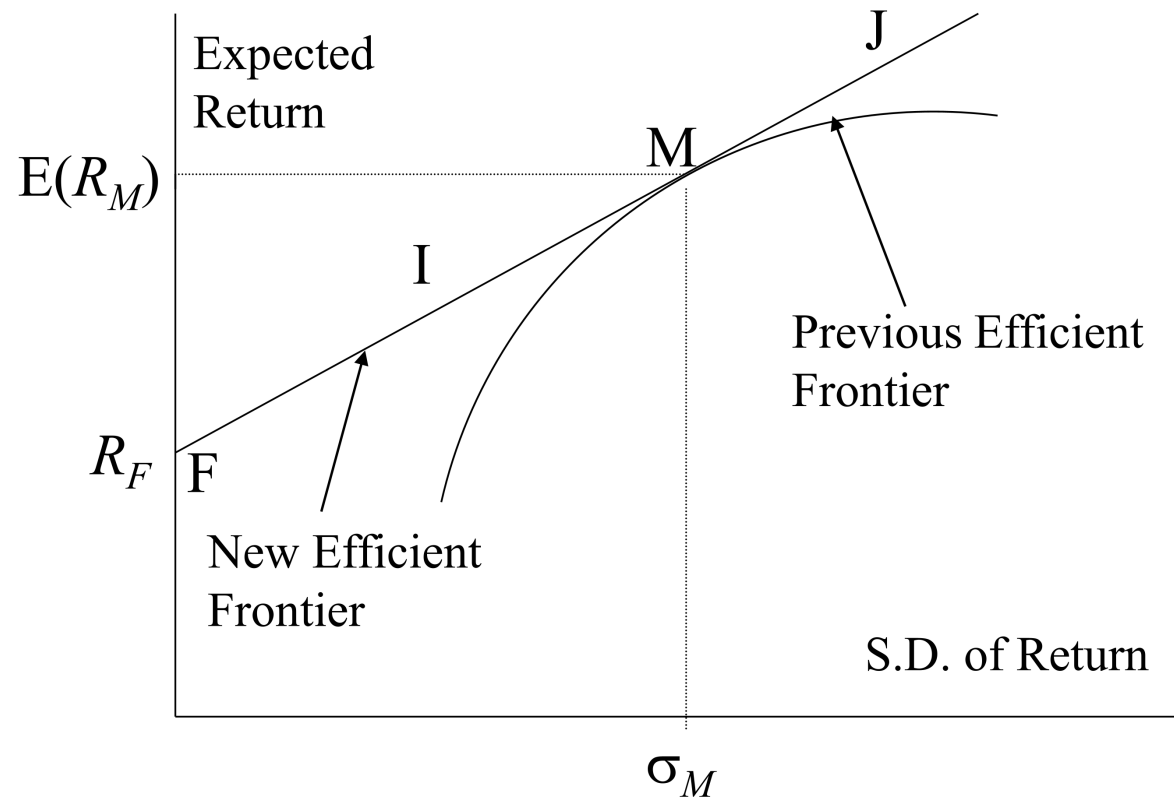
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❖ Bankruptcy Costs



# Efficient Frontier of All Investments



- The optimal investments are those on the line  $FJ$
- In these investments on  $FJ$ , the relative weights of risky assets are the same, i.e., as in the portfolio represented by  $M$

# Assumptions

The analysis we have presented leads to the surprising conclusion that all investors want to **hold the same portfolios of risky assets** (the portfolio represented by  $M$ ). This is clearly **not true**.

In presenting the arguments, we implicitly made a number of assumptions:

- Investors care only about expected return and SD of return
- Investors focus on returns over one period
- All investors can borrow or lend at the same risk-free rate
- Tax does not influence investment decisions
- All investors make the same estimates of expected returns, standard deviations of returns, and correlations between returns for available investments

# ***Risk vs Return for Companies***

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❖ Bankruptcy Costs

- In practice companies are concerned about total risk
- Earnings stability and company survival are important managerial objectives
- The regulators of financial institutions are primarily interested in total risk
- “Bankruptcy costs” arguments show that that managers may be acting in the best interests of shareholders when they consider total risk

# ***What Are Bankruptcy Costs?***

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- Lost sales (There is a reluctance to buy from a bankrupt company.)
- Key employees leave
- Legal and accounting costs

**The Hidden Costs of Bankruptcy** Several years ago, a company had a market capitalization of \$2 billion and \$500 million of debt. The CEO decided to acquire a company in a related industry for \$1 billion in cash. The cash was raised using a mixture of bank debt and bond issues. The price paid for the company was justified on the basis of potential synergies, but key threats to the profitability of the company were overlooked.

Many of the anticipated synergies were not realized. Furthermore, the company that was acquired was not profitable and proved to be a cash drain on the parent company. After three years, the CEO resigned. The new CEO sold the acquisition for \$100 million (10% of the price paid) and announced that the company would focus on its original core business. However, by then the company was highly leveraged. A temporary economic downturn made it impossible for the company to service its debt and it declared bankruptcy.

The offices of the company were soon filled with accountants and lawyers representing the interests of the various parties (banks, different categories of bondholders, equity holders, the company, and the board of directors). These people directly or indirectly billed the company about \$10 million per month in fees. The company lost sales that it would normally have made because nobody wants to do business with a bankrupt company. Key senior executives left. The company experienced a dramatic reduction in its market share.

After two years and three reorganization attempts, an agreement was reached among the various parties, and a new company with a market capitalization of \$700,000 was incorporated to continue the remaining profitable parts of the business. The shares in the new company were entirely owned by the banks and the bondholders. The shareholders got nothing.