ESSEC

Advanced Master's in Financial Engineering

FINM32227

Financial Risk Management

CLASS HANDOUTS

SESSION 8

Peng Xu

Liquidity Risk and Model Risk

Outline

- Liquidity Risk
- Model Risk

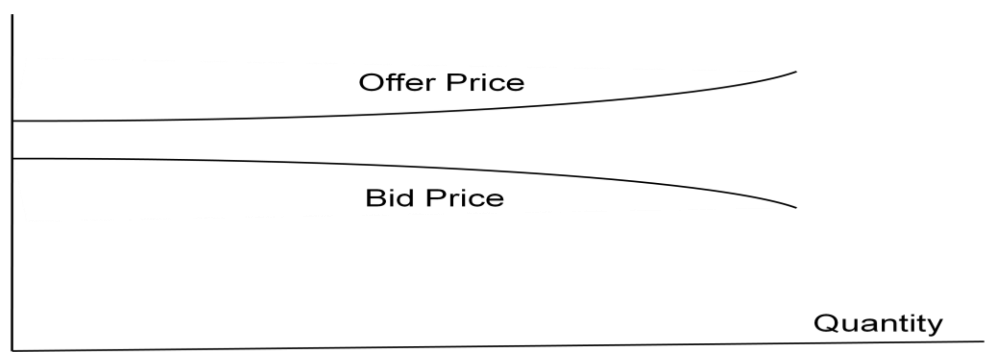
- Types of Liquidity Risk
  - Liquidity trading risk
  - Liquidity funding risk
- Liquidity trading risk
  - Price received for an asset depends on

    1) The mid market price

    2) How much is to be sold

       Bid-offer spreads depend on the size of the trade.

       In the market for large deals between sophisticated financial institutions:



       The bid-offer spreads in the retail market sometimes shows the opposite pattern

    3) How quickly it is to be sold

    4) The economic environment

- As we found in August 2007 transparency is factor that affects liquidity
- Measuring Liquidity:

The proportional bid-offer spread for an asset is defined as

$$\mathrm{s} = \frac{\text{Offer price} - \text{Bid price}}{\text{Mid} - \text{market price}}$$

where mid-market price is the average of bid and offer price. In liquidating a position of an asset, a financial institution incurs a cost equal to $\frac{1}{2}s\alpha$, where α is the dollar (mid-market) value of the position.

$$\text{Cost of liquidating (normal market)} = \sum_{i=1}^{n} \frac{1}{2} s_i \alpha_i$$

where s_i is an estimate of the proportional bid-offer spread in normal market for the ith financial instruments, α_i is the dollar (mid-market) value of the position, and n is the number of positions.

$$\text{Cost of liquidating (stressed market)} = \sum_{i=1}^{n} \frac{1}{2} (\mu_i + \lambda_i \sigma_i) \alpha_i$$

where μ_i and σ_i are the mean and standard deviation of the proportional bid-offer spread and λ_i gives the required confidence level for the spread.

Example:

Suppose that a financial institution has bought 10 million shares of one company and 50 million ounces of a commodity. The shares are bid \$89.5 and offer \$90.5. The commodity is bid \$15 and offer \$15.1. What is the cost of liquidating the two assets in a normal market?

Suppose the mean and standard deviation for the bid-offer spread for the shares is 1.0 and 2.0. The mean and standard deviation for the bid-offer spread for the commodity are both 0.1. Suppose the spreads are normally distributed. What is cost of liquidating the two assets that we are 99% confident will not be exceeded? What if the spreads are not normally distributed, but the empirical results show that the 99 percentile of the distribution for the spreads of both assets is 3.6 standard deviations above the mean?

Note: 1) the above calculation of the cost of liquidation assumes that spreads in all instruments are perfectly correlated. 2) Since the bid-offer spread depends on how quickly a position is to be liquidated, the cost of liquidation is likely to be a decreasing function of the time period assumed for the liquidation

- Liquidity-adjusted VaR:

  Assume that the mark-to-market process values all instruments at the mid-market price,

$$\text{Liquidity} - \text{adjusted VaR} = VaR + \sum_{i=1}^{n} \frac{1}{2} s_i \alpha_i$$

$$\text{Liquidity} - \text{adjusted Stressed VaR} = VaR + \sum_{i=1}^{n} \frac{1}{2} (\mu_i + \lambda_i \sigma_i) \alpha_i$$

- Unwinding a Position Optimally:

A trader, when faced with the problem of unwinding a large position in an asset, has a trade-off between the bid-offer spread and market risk.

Suppose the size of a position is V units and a trader wants to liquidate it over n days. q_i is amount traded on day i and x_i is amount held at the end of day i ($x_i = x_{i-1} - q_i$ and $x_0 = V$)

Suppose trading happens at the beginning of a day and the price changes at the end of a day

Suppose dollar bid-offer spread as a function of units traded is $p(q)$. Suppose standard deviation of mid-market price changes per day is σ

Trader's objective might be to choose the q_i to minimize

$$\lambda\sqrt{\sum_{i=1}^{n}\sigma^2 x_i^2} + \sum_{i=1}^{n}\frac{1}{2}q_i p(q_i)$$

subject to $\sum_{i=1}^{n} q_i = V$

Example:

A trader wishes to unwind a position in 100 million units over 5 days. $p(q) = a + be^{cq}$ with $a = 0.1$, $b = 0.05$, and $c = 0.03$

The standard deviation of the price change per day is 0.1

With 95% confidence level the amounts that should be traded on successive days is 48.9, 30.0, 14.1, 5.1, and 1.9

With 90% confidence level the amounts that should be traded on successive days is 45.0, 29.1, 15.6, 7.0, and 3.3

- Liquidity funding risk
  - Liquidity is not the same as solvency. E.g., Northern Rock
  - Cash needs may arise from
    - bond coupon payment
    - depositor withdrawals
    - draw-downs on line of credit
    - guarantees that have been made
    - defaults by counterparties

- margin requirement from a derivatives contract used to hedge illiquid asset
- Reserve Requirements

o Sources of liquidity

- Liquid assets such as cash or Treasury bills
- Ability to liquidate trading book positions
- Ability to attract wholesale and retail deposit at short notice
- Ability to securitize assets (such as loans) at short notice
- Central bank borrowing

– Basel III requirement on Liquidity Risk:

➢ Liquidity Coverage Ratio (LCR)

$$\text{Liquidity Coverage Ratio} = \frac{\text{High Quality Liquid Assets}}{\text{Net Cash Outflows for 30 day period}} \geq 100\%$$

for an acute 30 - day stress period (3 notch downgrade, partial loss of deposits, loss of unsecured wholesale funding, increased haircuts on secured funding, increased collateral requirements, drawdowns on lines of credit, etc)

- Net Stable Funding Ratio (NSFR)

$$\text{Net Stable Funding Ratio} = \frac{\text{Amount of Stable Funding}}{\text{Required Amount of Stable Funding}} \geq 100\%$$

For a period of longer term stress.

Each category of funding (capital, deposits, etc) is multiplied by an available stable funding (ASF) factor to form numerator.

Each category of required funding (assets, off - balance sheet exposures) is multiplied by a required stable funding factor (RSF) to form denominator

Following the liquidity crisis of 2007, bank regulators issued a list of 17 principles describing how banks should manage their liquidity and indicated that they would be monitoring the liquidity management procedures of banks more carefully in the future

– Liquidity Black Holes
  - A liquidity black hole occurs when most market participants want to take one side of the market and liquidity dries up
  - Positive and Negative Feedback Traders

- A negative feedback trader buys after a price decrease and sells after a price increase
- A positive feedback trader buys after a price increase and sells after a price decrease
- Positive feedback trading can create or accentuate a black hole
- Reasons for Positive Feedback Trading

1) Computer models incorporating stop-loss trading

   When the price of an asset falls below a certain level, it is automatically sold to limit loss

2) Dynamic hedging a short option position

   Hedging a short option position (call or put) involves buying after a price rise and selling after a price decline

3) Creating a long option position synthetically

   Hedging a short position in an option is equivalent to creating a long position in the same option synthetically.

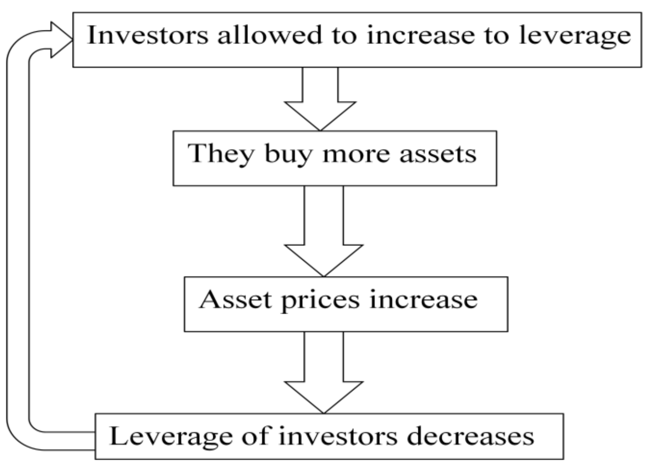
4) Margin calls

A big movement in market variables, particular for traders who are highly leveraged, may lead to margin calls that cannot be met. This forces traders to close out their position. This is a form of positive feedback trading.

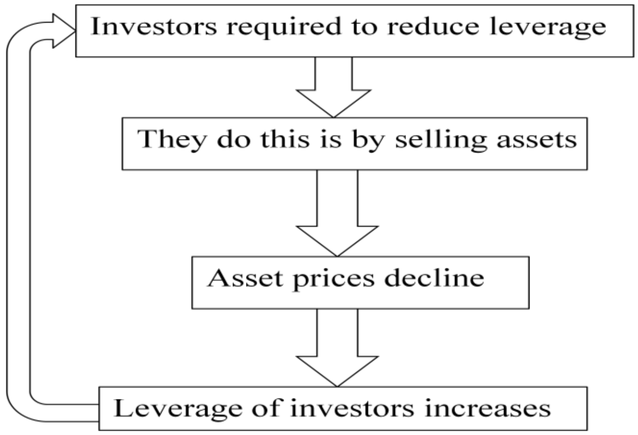
5) Predatory trading

Traders short the asset when they know that the price of the asset is likely to decrease

- Leveraging and Deleveraging
  - The Leveraging Cycle



  - The Deleveraging Cycle



- The Impact of Regulation

  If all financial institution were regulated in the same way, they would tend to react in the same way to market movements. This has the potential to create a liquidity black hole

- Irrational Exuberance

  Traders working for many different financial institutions become irrationally exuberant about a particular asset class or a particular market variable, overexposing themselves to a particular risk

- What is needed is more diversity in the trading strategies followed by market participants.

I. Liquidity Risk

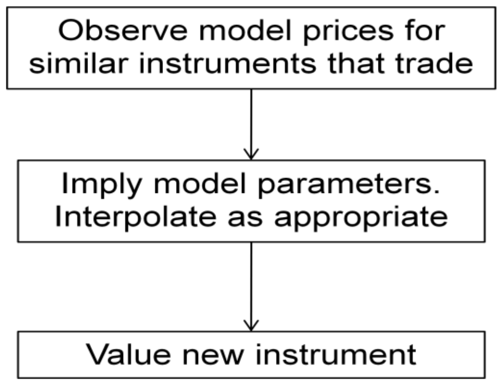
Traders that have long-term objectives should avoid allowing themselves to be influenced by the short-term overreaction of markets.

- Two main types of model risk:
  - The model can give the wrong price at the time a product is bought or sold
  - A wrong model can produce wrong Greek letters and the hedging is liable to be incorrect
- Models for Linear Product
  - Very little disagreement about the right model
  - But mistakes do happen. For example…
    - Kidder Peabody
    - LIBOR-in Arrears Swaps
- Models for Standard Nonlinear Product
  - Difference between the models of physics and finance
    - The models of physics describe physical processes and are highly accurate. Their parameters do not change through time.
    - The models of finance describe human behavior. They are at best approximations. Parameters change through time.

Models of finance are *calibrated* to market prices daily

As a result parameters change from day to day

The way models are usually used in finance:



- We do not need usually a model to know the price of an actively traded product. The market tells us the price.
- The model can be used as a tool to ensure that the non-actively traded instrument is priced consistent with the observed market prices of similar instruments
- Example: BS-M model implied volatility surfaces

	Strike Price				
	0.90	0.95	1.00	1.05	1.10
1 month	14.2	13.0	12.0	13.1	14.5
3 month	14.0	13.0	12.0	13.1	14.2
6 month	14.1	13.3	12.5	13.4	14.3
1 year	14.7	14.0	13.5	14.0	14.8
2 year	15.0	14.4	14.0	14.5	15.1
5 year	14.8	14.6	14.4	14.7	15.0

- Some of the points in the surface are calculated from observed price, others calculated through interpolation.
- When a new option has to be valued, traders look up the appropriate volatility in the table using interpolation
- The volatility surface are updated at least once a day
- The Black-Schole-Merton model is very popular despite the fact that the key parameter can easily change by a factor of 3 (from 10% to 30%) or even more, because
  1. It can be used in conjunction with a volatility surface to ensure that prices are consistent with observed market prices
  2. The model is a communication tool (e.g., implied volatilities are quoted for options because it is more stable than option prices)
  3. The model is sufficiently simple that a trader can develop intuition about the model and use it to structure his thinking about option markets

        - Another reasonable model, if used a similar way to Black-Scholes-Merton model, would probably lead to similar prices in markets where options trade actively
    - It is important to distinguish between Official and Research Models
        - A financial institution's official model is used for valuing trade every day. It should be designed to track market prices as closely as possible
        - Research models are designed to develop trading strategies
- Models for Nonstandard Nonlinear Product
    - Nonstandard products are products that are tailored to the needs of specific clients or are not yet sold in sufficient quantity for a standard model to have been established. Sometimes referred to as exotic or structured products
    - In the case of nonstandard product, models play a key role in both pricing and hedging. So the model risk is much higher

  - It is a good idea to use more than one model whenever possible
  - Model audit groups within a bank
    - Check that a model has been implemented correctly
    - Examine whether there is a sound rationale for the model
    - Compare the model with others that can accomplish the same task
    - Specify limitations of model
    - Assess uncertainties in prices and hedge parameters given by model
- Hedging
  - Models are used in a more significant way for hedging than for pricing
  - We can distinguish “within model” hedging from ”outside model” hedging

    Within model hedging deals with the risk of changes in variables that are assumed to be uncertain by the model

Outside model hedging deals with the risk of changes in variables that are assumed to be constant by the model

- If a model used to calculating the hedge is a poor representation of reality, there may be unexpected gain or loss. However, on average, the gain or loss from hedging using the wrong model may be small due to diversification across a large portfolio.
- To evaluate the effectiveness of hedging, many financial institutions decompose the day-to-day change in a portfolio value into: *(P&L Decomposition)*
    - P&L changes from risks that were unhedged
    - P&L changes from the hedging model being imperfect
    - P&L changes from new trades done during day

– Dangers in Model Building

- The art of model building is to capture what is important for valuing and hedging without making the model more complex than necessary

  - Should avoid overfitting and overparametrization
- Detecting Model Problems
  - Monitor types of trading a financial institution is doing with other financial institutions
  - Monitor profits being recorded from trading of different products
  - How competitive it is in bidding for different types of structured transactions