Algorithmic Trading
Session 9
Trade Implementation III
Transaction Costs

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Outline

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Introduction

Where Do We Stand in the Algo Prop Trading Framework?

- As we have seen, algorithmic proprietary trading strategies can be broken down into three subsequent steps: Signal Generation, Trade Implementation and Performance Analysis
- **Trade Implementation** happens after the Signal Generation step has triggered a buy or sell signal. It determines how the order is structured, e.g. position size and limit levels. In advanced strategies, it can also take into account cross correlation with other portfolio holdings and potential portfolio constraints
- Sessions 7 – 9 deal with the question of sizing and executing trades, incl. exit
  - **Session 7**: Order Types
  - **Session 8:** Algorithmic Execution
  - **Today's Session 9:** Transaction Costs

Introduction

Transaction Costs

- Each time an asset is bought or sold, transaction costs are incurred. They can have a significant impact on investment returns. Therefore, it is important to both measure and analyze them in order to improve execution
- Transaction costs can vary between 1bps to 250bps of the value traded, dependent on the asset class, transaction size and broker used. This wide range is partly due to the different characteristics of each asset and order, but also due to the different way transaction costs may be assigned
- One of the most common ways to examine transaction costs has been to compare the actual performance of a portfolio with its "paper" equivalent. A paper portfolio is simply a virtual portfolio traded at benchmark prices, but without accounting for any costs
- While transaction costs are inevitable, they can be minimized. Therefore, in order to maximize investment returns, it is important to accurately measure transaction costs and to anlayze them to understand how and why they occur

Introduction

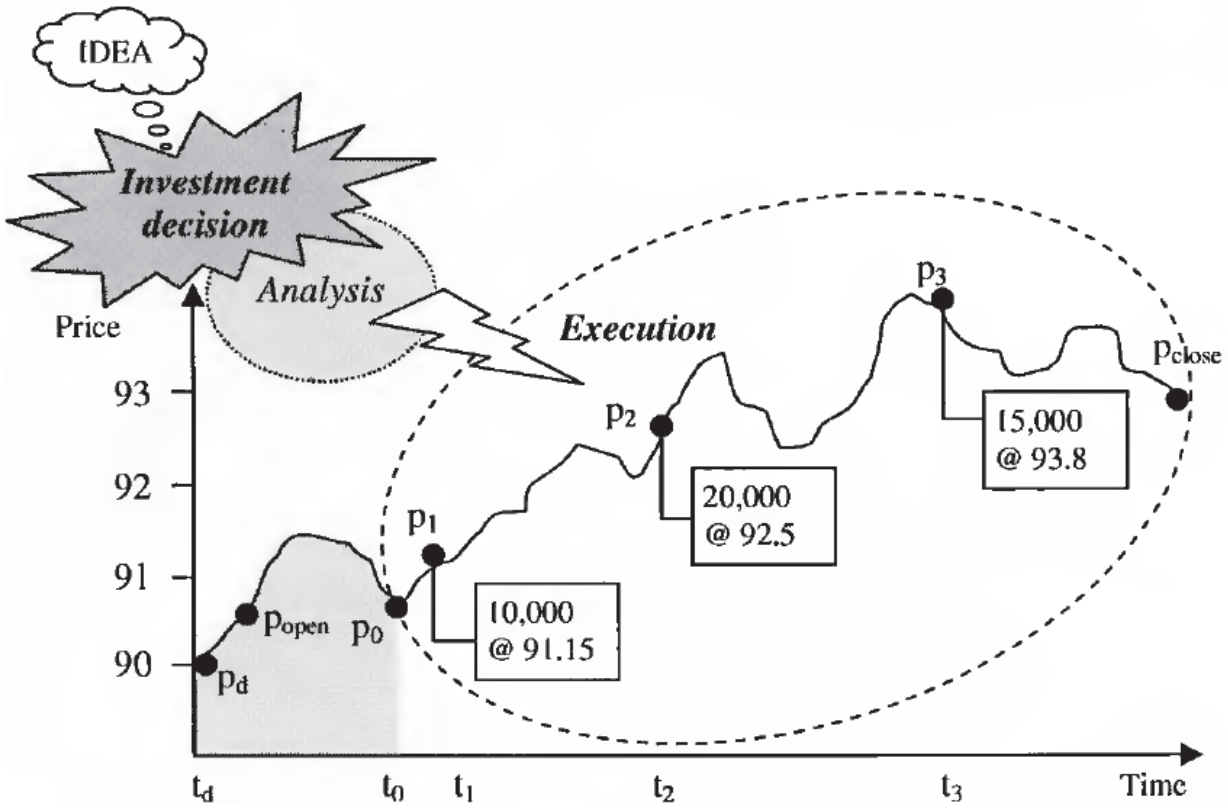
Transaction Costs in the Investment Cycle

- Historically, most of the early research on transaction costs focused on post-trade analysis. Though, over the last few years, pre-trade analysis has become ever more important. In particular, algorithmic trading is often reliant on pre-trade models to achieve a more cost efficient execution
- Pre-Trade Analysis concentrates on estimating potential transaction cost. Hence it is a key input into the choice of trading strategy and can have a substantial effect on the overall execution (and so investment) performance. Liquidity analysis might also be used to identify the best strategies and venues for trading
- Post-Trade analysis focuses on execution performance and measurement of transaction costs. It is essential for understanding the effectiveness of both the investment ideas and their implementation. In turn, this performance is an important consideration when new investment strategies are formulated. For example, an investment opportunity worth 30bps may not be worth following up if previous transaction costs for similar orders have been around this level

Introduction

Transaction Costs Example

- We will use the example from the assigned reading during this session to compare the various components of transaction costs
- Investment decision @ p_d
- 50k share buy order placed at t_0
- Child orders execute at t_1, t_2, t_3
- Pre-trade period lasts from t_d to t_0
- Execution phase lasts from t_0 to t_{close}



Pre-Trade Analysis

Overview

- Pre-trade analysis is important to ensure that best execution is achieved. These analytics help investors or traders make informed decisions about how best to execute a given order
- Four types of information are key to trading strategy selection. These four are:
  - **Prices:** Market prices, price ranges, trends / momentum
  - **Liquidity:** Percentage of avg. daily volume, volume profile, trading stability
  - **Risk:** Volatility, beta, risk exposure
  - **Cost estimates**: Market impact, timing risk
- The liquidity and risk estimates highlight the expected difficulty of trading. The cost estimates give a reasonable indication of what might be achieved. This is particularly important for algorithmic trading strategies as it gives an idea how suitable an order is for a given strategy

Pre-Trade Analysis

Price Data

- A wide range of price data is useful for pre-trade analytics. The current market bid / ask prices act as a baseline for what we might achieve. The last traded price is also useful (especially for illiquid assets), since this may be significantly different from the current quotes
- The bid ask spread is seen as an estimate for the cost of immediacy. If immediate execution is desired a seller has to sell at the bid and a buyer has to buy at the ask, incurring the spread as the cost of immediacy. A comparison to historical bid ask spreads allows us to gauge whether the current spread is unusual
- Price ranges, such as the difference between a day's high and low, give an indication of the current price volatility. Likewise, benchmarks such as today's opening price or last night's close are also useful. Trends may be reflected by daily, weekly or even monthly percentage changes

Pre-Trade Analysis

Liquidity Data

- Liquidity is closely related to transaction costs. Trading volume offers a simple way to rate the liquidity of an asset. The average daily volume (ADV) is often calculated over a period of 14, 30, 90 or 360 calendar days. The percentage of ADV represents the relative size of our order given the asset's volume. For instance, anything less than 20% should be achievable to trade within a normal trading day, whereas above not without market impact

- The required trading horizon can be based on the ADV, together with factor α representing our trading participation rate:

$$Horizon = \frac{Size}{ADV \ * \ \alpha}$$

- For example, given an order size of 50k as in our example, an ADV of 1m, and a trading participation rate of 10% leads to the following horizon:

$$Horizon = \frac{50{,}000}{1{,}000{,}000 \ * 10\%} = 0.5 \ days$$

- For such estimates to reliable, it is important that the actual trading volume behaves similar to the historical one. This can be measure by the coefficient of variation (CV), based on the standard deviation σ of ADV. As trading stability is inversely related to this coefficient, a high CV value implies sizable deviations from the historical volume

$$CV = \frac{\sigma \ ADV}{ADV}$$

Pre-Trade Analysis

Risk Data

- Volatility is a key variable for estimating how much risk we may be exposed to. It is based on the standard deviation of price returns (not prices, this is a common mistake), often for the last 1, 3, 6 or 12 months. As we have seen with the CV, a high volatility implies a considerable amount of timing risk. Therefore, the more volatile the asset, the more aggressive trading strategies (hence liquidity demanding strategies) are generally used to counteract the timing risk
- Market risk could be measured using an asset's beta, which is a measure of its sensitivity to market returns (CAPM). A positive value means that the asset price moves in the same direction as the market whilst a negative one means it behaves in a contrarian fashion. A beta of 1 means that the asset moves in line in direction and size with the market. A beta above 1 signifies a more pronounced price response, whilst an asset with a beta of below 1, e.g. 0.5, moves only half as much as the market

Pre-Trade Analysis

Transaction Cost Estimates

- Transaction cost models generally provide an estimate for the overall cost as well as detailing major cost components such as market impact and timing risk. We will investigate both in more detail later in this presentation
- The basis for most transaction cost models is the framework of Almgren and Chriss (2000), where they detailed the optimal execution of portfolio transactions. They use random walk models to estimate the current market price in terms of permanent market impact, price trending and volatility
- In terms of asset selection, given two assets with similar expected returns it is logical to trade the one that has the lower expected transaction costs. Exactly the same applies for comparing different trading strategies, one should use the one with the lowest expected transaction costs. Although detailed pre-trade analysis is required, historical information can be used as a guideline
- Cost estimates are also an important guide to the difficulty of an order. For instance, if the timing risk estimate is significantly larger than the market impact forecast, one should apply a more aggressive trading strategy. Conversely, a larger market impact may suggest adopting a more passive style

Post-Trade Analysis

Overview

- The historical results of post trade analysis act as a measure of broker/trader performance. They may also inform both investment and execution decisions
- Clearly, there is a lot more to transaction costs than fees and commissions. Past performance is therefore an important tool for comparing the quality of execution of both brokers and individual traders. Unbundling research fees has also made it easier for investors to link costs to the execution, and so use post trade analysis to accurately compare broker performance
- Breaking down the costs into their components allows us to see where and how the costs (or slippage) occurred. Detailed measurement helps to ensure that future efforts for cost reduction are focused on the correct stage of the investment process. It may also be used to guide the execution method selection
- Performance analysis is an important tool for post trade comparison of broker/trader/algorithm results. This is mostly done via benchmark comparison or as a relative performance measurement
- The post trade transactions costs can be determined via Perold's implementation shortfall. This measures the difference between the idealized paper portfolio and the actually traded one

Post-Trade Analysis

Benchmarks

- A good benchmark should be easy to track and readily verifiable, it should also provide an accurate performance measurement. Johnson lists the following benchmarks for the example in the book

Benchmark		***Results for Example 6-1***	
Type	*Name*	*Benchmark Price*	*Relative performance (bps)*
Post-Trade	Close	93.00	37
	Future Close (next day)	94.00	137
Intraday	OHLC	92.00	-63
	TWAP	92.20	-43
	VWAP	92.40	-23
Pre-Trade	Previous Close	90.00	-263
	Opening Price	90.50	-213
	Decision Price	90.00	-263
	Arrival Price	90.65	-198
Average execution price		92.63	n/a

- Post trade benchmarks, such as the closing price, are only known once the trading day is over. Intraday benchmarks, such as VWAP, need constant updates as the trading day progresses. Other intraday measures such as OHLC need the whole trading day to be completed to be known. Pre trade benchmarks, such as the previous close or open, are known before the start of the trading day

Post-Trade Analysis

Relative Performance Measure

- Kissell introduced the relative performance measure (RPM) as an alternative to price based benchmarks. It is based on a comparison of what the trade achieved in relation to the rest of the market. In terms of volume, RPM represents the ratio of the volume traded at a less favorable price to the total market volume:

$$RPM(volume) = \frac{Total\ volume\ at\ price\ less\ favorable\ than\ execution}{Total\ market\ volume}$$

$$RPM(trades) = \frac{Number\ of\ trades\ at\ price\ less\ favorable\ than\ execution}{Total\ number\ of\ trades}$$

- Transaction cost is dependent on many factors: the asset's characteristics (liquidity, volatility), market conditions (price trends, momentum), trading strategy etc. Therefore, when comparing the performance of two separate orders, we need to take these various factors into account and just comparing our executed price to one of the price based benchmarks might not be enough
- One of the main advantages of the RPM metric is that is that it is normalized, as the percentage rates the trade relative to all other trades that occurred that day

Post-Trade Analysis

Post-Trade Transaction Costs

- The total transaction costs of a trade may be determined by using Pernol's implementation shortfall (IS) measure. This is the difference in value between the idealized paper portfolio and the actually traded one. The theoretical return depends on the price when the decision to invest was made (p_d), the final market price (p_N) and the size of the investment (X). The real returns depend on the actual transaction costs. So, if x_j represent the sizes of the individual executions and p_j are the achieved prices:

$$IS = X(p_N - p_d) - (Xp_N - \sum x_j p_j - fixed) = \sum x_j p_j - Xp_d + fixed$$

- Note this assumes that orders are fully executed. Hence, Kissell and Glantz extended it by an opportunity cost factor as not every order will be fully executed. $(X - \sum x_j)$ represents the unexecuted position

$$IS = \sum x_j p_j - (\sum x_j)p_d + (X - \sum x_j)(p_N - p_d) + fixed$$

- For our example, we get an IS of 297bps + fixed costs, calculated as (133.5k / 4.5m)

  Execution cost: (10k * 91.15 + 20k * 92.5 +15k* 93.8) – (45k * 90) = 118,500

  Opportunity cost: (50k – 45k) * (93 – 90) = 15k

  Order Value: 50k * 90 = 4.5m

Breaking Down Transaction Costs

Overview

- There has been a considerable amount of research focused on breaking down trading costs. The table below suggests one way of classifying the different constituents:

Cost type		Classification				Focus for:	
		Explicit	*Implicit*	*Fixed*	*Variable*	*Algorithms*	*Execution Tactics*
Investment	Taxes	✓			✓		
	Delay Cost	✓ [5]			✓		
Trading	Commission	✓		✓			
	Fees	✓		✓		○	○
	Spreads		✓ [6]		✓		●
	Market Impact		✓		✓	●	○
	Price Trend		✓		✓	●	
	Timing Risk		✓		✓	●	○
	Opportunity Cost		✓		✓	○	

● often ○ sometimes

- Differentiating between investment and trading related costs is useful since it helps identify who best can control them. Investment related costs occur before the order is placed with the broker / execution trader, whereas trading related costs account for all costs thereafter. Explicit costs can easily be measured, whereas implicit costs are much harder to quantify

Breaking Down Transaction Costs

Investment Related Costs – Taxes and Delay

- Investment related costs can be a significant proportion of overall transaction costs. They primarily consist of delay cost and taxes. The delay reflects the time from the investment decision being made (t_d) to when an order is actually dispatched (t_0)
- Taxes must be incorporated in any investment strategy. They depend on asset class, legal form of the investor and jurisdiction. For example, some countries levy capital gains taxes, whereas others do not. The same applies for stamp duty on share purchases
- The delay cost is caused by any price change from the initial decision to invest to when an order has actually been received by a broker

Breaking Down Transaction Costs

Trading Related Costs - Overview

- The explicit trading related costs comprise of **commission** and **fees**, which are usually known in advance and open for negotiation
- The most significant costs are the implicit trading related costs, primarily market impact and timing risk, but also spread, price trend and opportunity cost
- **Spread cost** is also an implicit cost since although being visible it is not always as easily measurable as commissions or fees
- **Market impact** represents a payment for liquidity (or immediacy) and a cost due to the information content of the order.
- The **price trend** represents the added burden caused by a trending market
- **Timing risk** is primarily associated with the volatility of an asset's price, as well as its liquidity
- **Opportunity costs** represent the risk from not fully executing the order, possibly because the trading strategy was too passive

Breaking Down Transaction Costs

Trading Related Costs – Commissions, Fees and Spreads

- **Commissions** are charged by brokers for agency trading to compensate them for their cost. They are generally quoted in basis points or cents per contract. They have decreased significantly over time as most execution tasks have been fully automatized so that less employees are needed
- **Fees** represent the actual charges from trading. These may be from floor brokers, exchange fees as well as clearing and settlement costs. Often brokers include them into their commission charge so that a client doesn't necessarily know the exact breakdown between fees and commissions. Note that some exchanges and ECNs assigns costs only to aggressively priced orders in order to encourage liquidity provision
- **Spread cost** represents the difference between the best bid and ask prices at any given time. The spread compensates those who provide liquidity. Clearly, aggressive trading styles will result in higher spread costs than passive ones. Unsurprisingly, large cap and liquid stocks as well as liquid futures have lower spreads. More volatile assets tend to have higher spreads

Breaking Down Transaction Costs

Trading Related Costs – Market Impact and Price Trends

- **Market impact** represents the price change caused by a specific trade or order. Generally, it has an adverse effect, for instance helping drive prices up when are trying to buy. The exact market impact is the difference between the actual price chart and the hypothetical one if our orders had not been created, hence it is difficult to measure. Market impact can be broken down into temporary and permanent impact, where temporary reflects the cost of demanding liquidity and permanent corresponds to the long term effect of our order, representing the information content that it exposed to the market

- **Price trends** describe the status when asset prices exhibit broadly consistent trends. This price drift, or momentum, is also known as short-term alpha. An upward trend implies that prices will increase when buying and vice versa. The price trend cost may be determined based on the difference between this trend price and the arrival price. Reducing trend cost may be achieved by shortening the trading horizon and so increasing market impact costs. So, for larger orders, one has to strike a balance between the two

Breaking Down Transaction Costs

Trading Related Costs – Timing Risk and Opportunity Costs

- **Timing risk** is used to represent the uncertainty of the transaction cost estimate. The two main sources of this uncertainty are volatility in the asset's price and traded volume. Price volatility is arguably the most important risk. The more volatile an asset, the more likely its price will move away and so increase transaction costs. The liquidity risk represents the uncertainty with respect to the market impact cost. Generally, market impact costs are estimated based on historical volumes, so if the actual trading volumes differ significantly, this may result in a shift in market impact

- **Opportunity cost** reflects the cost of not fully executing an order. This may be because the asset's price went beyond the price limit or could just be due to insufficient liquidity. Either way, it represents a missed opportunity, since the next day prices may move even further away. The overall cost may be determined as the product of the remaining order size and the price difference between the final price and the arrival price:

$$(X - \sum x_j)(p_N - p_0)$$

- Unlike the other cost components, opportunity cost represents a virtual loss rather than a physical one and is only realized if a new order makes up the remainder at a less favorable price

Summary and Questions

- Transaction costs can have a significant impact on investment returns. Therefore, it is important to both measure and analyse them if best execution is to be achieved
- Implementation shortfall or "slippage" is the difference in performance between an actual portfolio and its theoretical "paper" equivalent
- Pre trade analysis concentrates on estimating the expected difficulty of trading and potential transaction costs
- Post trade analysis focuses on execution performance and cost measurement
- Transaction costs can be decomposed into a wide range of different components. Among them are broker costs, spread costs, delay costs, market impact, timing risk and opportunity costs
- Transaction costs are closely related to market liquidity and volatility. They become cheaper with higher liquidity and lower volatility

- Questions?

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Sources

- Algorithmic Trading and Direct Market Access by Barry Johnson
- Optimal Execution of Portfolio Transactions by Robert Almgren and Neill Chriss, published in Journal of Risk, 2000, vol. 3, p. 5 - 29