Securities Trading: Principles and Procedures

Trading/transaction cost analysis (TCA)
Chapter 14

How do we evaluate trading outcomes and processes?

Basic perspective

- To actually implement any investment or hedging strategy, we need to trade.
- In a perfectly competitive, perfectly efficient market, these trades could be accomplished effortlessly.
- Reality: trading is difficult and costly
- Trading costs cut into our investment profits.
  - If trading costs are large enough, the investment profits may turn into losses.

Example: Commissions

- Brokers charge commissions for executed orders.
- If we buy XYZ at 10.00 and sell at 10.10, we've made a 0.10 profit.
- If we pay a $0.02 per share commission, our profits net of commission are

$$0.10 - 2 \times 0.02 = 0.06$$

- It is easy to factor in commission costs: they are clearly reported and identified.
- Commission costs are explicit.
- Other trading costs are implicit: they are not clearly identified.

Example: testing and implementing an investment strategy.

- First we use statistical analysis or machine learning on historical data to find a rule that looks like it might be profitable.
- Then back-test the rule
  - Simulate the strategy on past data: what would the profits have been?
- Limitations
  - Statistical estimation error
  - Evolution of the market: the future may not be like the past.
  - Accounting for trading costs.
- Our trial strategy:
  - If a stock has closed higher for two days in a row, buy it. If it closes lower for two days in a row, sell it."

Back-testing on a sample of market closing prices

Day 1	…							
$20	$21	$22	$23	$24	$25	$26	$25	$24
	↑	↑	↑	↑	↑	↑	↓	↓
		Buy						Sell
		−22						+24

- In this test, we bought at 22 and sold at 24.
  - The *paper* profit is 2.
- When we try the rule in practice, profits are much lower. What happened?

Our error

- In testing, we assume that we can trade at closing prices.
- But we only observe closing prices at close of trading.
  - When the closing auction has been run.
  - After the auction, these prices aren't available any more.
- When we actually buy/sell we're either trading in
  - After-hours sessions, or
  - The next day's opening auction.

In a real market, our strategy might have worked out like this:

Day 1	…							
\$20	\$21	\$22	\$23	\$24	\$25	\$26	\$25	\$24
	↑	↑	↑	↑	↑	↑	↓	↓
		Buy						Sell
		−22.10						+23.80

- Usually, when we buy in this situation, we pay above the closing price …
  - And when we sell, we receive a lower price.
- Our actual profit is \$1.70

The difference

- The paper profit and actual profit differ by:
$$\$2.00 - \$1.70 = \$0.30$$
- Andre Perold (1988) calls this difference the *implementation shortfall*.
- The closing prices that we used to compute our paper prices are ideal/imaginary prices that we can't actually attain.

The implementation shortfall for each trade.

- We assumed that we could buy at \$22; we actually bought at \$22.10.
  - The implementation shortfall for our purchase is (per share)

$$\text{IS} = 22.10 - 22.00 = 0.10$$

- We assumed that we could sell at \$24; we actually sold at \$23.80
  - The implementation shortfall for our sale is

$$\text{IS} = 24.00 - 23.80 = 0.20$$

Benchmark prices

- In this computation of the implementation shortfall, we used the prior closing price as a refence price.
- A reference price is sometimes called a benchmark price.
  - Benchmark (definition)
    - a standard or point of reference against which things may be compared or assessed.
    - a surveyor's mark cut in a wall, pillar, or building and used as a reference point in measuring altitudes.

The implementation shortfall (IS) for an execution

- For an buy/purchase order that is executed at a single time:
$$IS = execution\ price - benchmark$$
- For a sale order that is executed at a single time:
$$IS = benchmark - execution\ price$$
- Some orders are executed in multiple trades or multiple prices.
  - Orders that walk through the book.
  - Orders that the trader splits up across different times.
  - Replace execution price by share-weighted average execution price (over all executions).

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Alternative benchmark prices

- The previous day's closing price.
- The NBBO midpoint at the time the order was submitted. *Very common*
  - Also called "BAM" (Bid-Ask Midpoint)
- Both of these are pre-trade benchmarks: they are determined before there are any executions.
- Post-trade benchmarks
  - The NBBO midpoint five minutes after the trade.
  - The next day's opening price
- Average price benchmarks
  - Time-weighted average price (TWAP, "Tee Wap") over the day or duration of the trading horizon.
  - Volume-weighted average price (VWAP, "Vee Wap") over the day/duration. *Very common*

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Example: A buy of 10,000 shares, benchmarked to the BAM

- At the time the order is sent, the NBB is 20.02; the NBO is 20.05. The order is filled in three executions.
  - 3,000 shares @ 20.05
  - 2,000 shares @ 20.06
  - 5,000 shares @ 20.08
- The NBBO midpoint is 20.035.
- The share-weighted average execution price is
  - $\frac{3{,}000}{10{,}000} \times 20.05 + \frac{2{,}000}{10{,}000} \times 20.06 + \frac{5{,}000}{10{,}000} \times 20.08 = 20.067$
- The implementation shortfall is $20.067 - 20.035 = \$0.032$ per share.

Uses of the implementation shortfall

- Track the difference between paper and actual profits.
- Measuring trading costs to satisfy legal/regulatory requirements.
- Allocating profits/losses across different teams or individuals.
- Evaluation of …
  - Order placement strategies
  - Market centers, trading venues, exchanges
  - Brokers
  - Individual traders

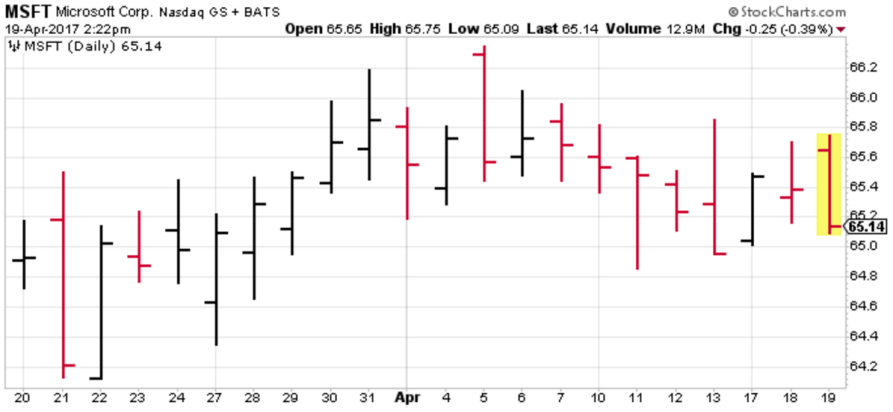
Example: Allocating performance at the Northstar hedge fund.

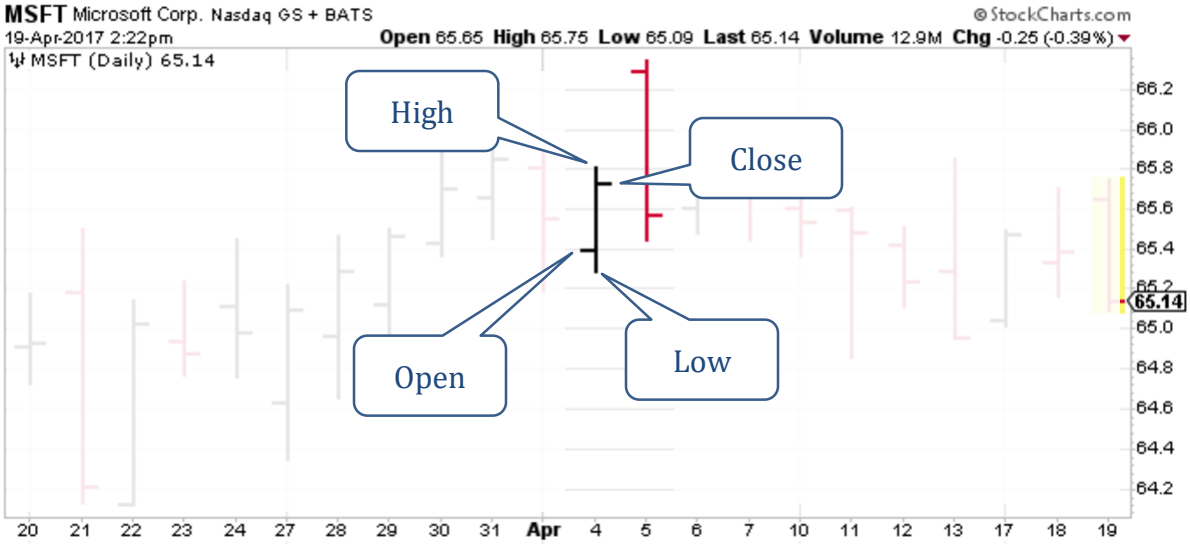
- At Northstar:
  - Portfolio managers make investment decisions.
  - Traders implement their decisions.
- Priyansh, the portfolio manager, directs that MSFT should be bought and (a few days later) sold.
  - She makes her decisions at the start of the day before the open.
- Tom, the trader submits the orders.
  - He decides when (during the day) and how to trade.

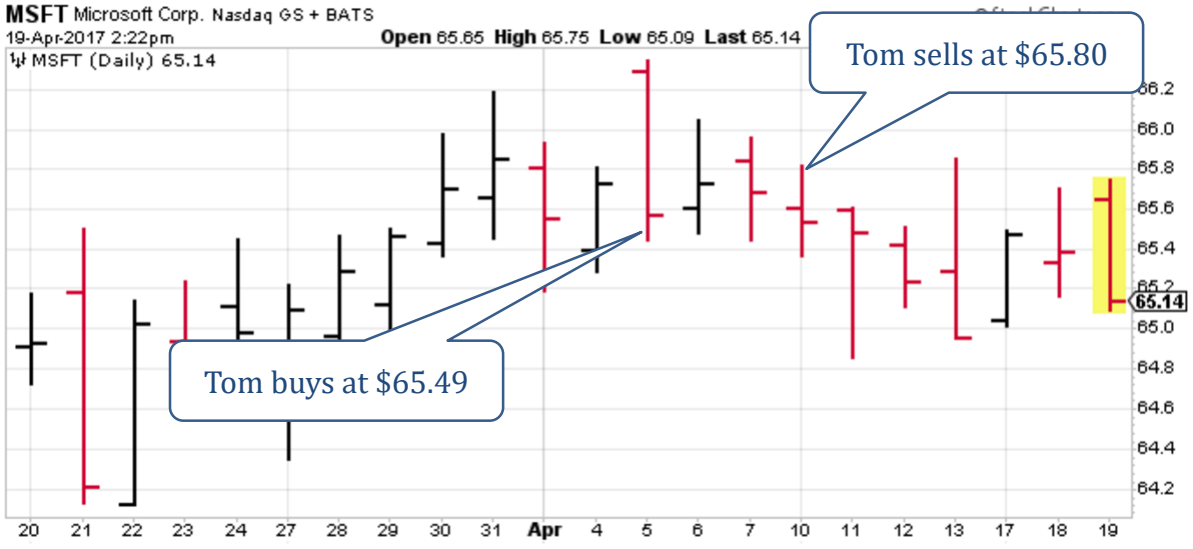
- Wednesday, 5 April 2017
  - At 9am, Priyansh: "Buy 10,000 MSFT, today." Tom buys at $65.49
- Monday, 10 April
  - At 9am, Priyansh: "Sell 10,000 MSFT, today." Tom sells at $65.80
- The fund's profit: $\$658{,}000 - \$654{,}900 = \$31{,}000$ $(\$0.31/share)$
- Priyansh: "The profit came from my stock selection."
- Tom: "The profit is due to my trading ability."

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
						1
2	3	4	5 MSFT bought	6	7	8
9	10 MSFT sold	11	12	13	14	15

The Open-High-Low-Close (OHLC) chart for MSFT, April 2017







Tom's IS, benchmarked to the previous day's closing price

- MSFT closing prices
  - April 4, ~$65.75
  - April 7, ~$65.70
- On the purchase, $IS = 65.49 - 65.75 = -0.26$
  - The sign conventions used for IS measure it as a cost.
  - IS<0 shows a trading profit.
- On the sale, $IS = 65.70 - 65.80 = -0.10$
  - Also a profit.

Allocating the overall profit

- $IS = Paper\ profit\ - Actual\ profit$
- $Actual\ profit = \underbrace{Paper\ profit}_{Priyansh} - \underbrace{IS}_{Tom}$

$$= \underbrace{65.70 - 65.75}_{Priyansh} - \left(\underbrace{-0.26}_{Tom(purchase)} \quad \underbrace{-0.10}_{Tom(sale)}\right)$$

$$= \underbrace{-0.05}_{Priyansh} + \underbrace{0.36}_{Tom}$$

$$= 0.31$$

Embedded problem 1

- MSFT open prices
  - April 5, ~$66.30
  - April 10, ~$65.60
- Compute Tom's implementation shortfalls and the profit allocation relative to these (opening) benchmark prices.

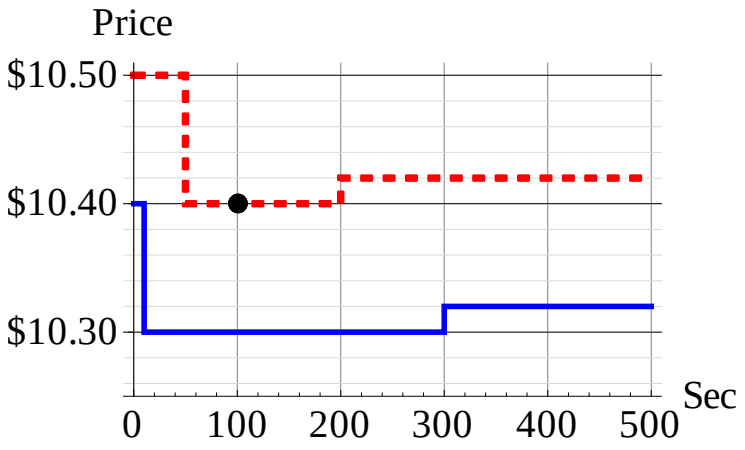
Standard TCA for marketable orders

- Marketable: the order can be executed immediately.
- The standard measures are:
  - Effective cost
  - Realized cost
  - Price impact
  - Price improvement

The effective cost

- Effective cost = IS using the NBBO midpoint at the time of submission as a benchmark.
- p is the trade price; m is the prior NBBO midpoint.
- $$Effective\ Cost = \begin{cases} p - m, \text{ for a marketable buy order} \\ m - p, \text{ for a marketable sell order} \end{cases}$$
- For a buy order: "How much did I overpay, relative to the NBBO midpoint?"

Example: A buy order executes at the NBO



Calculation details:

$m = 10.35; m_5 = 10.37; p = 10.40$

$Eff\ Cost = 10.40 - 10.35 = 0.05$

$Rlzd\ Cost = 10.40 - 10.37 = 0.03$

$PrImpact = 0.05 - 0.03 = 0.02$

The realized cost

- The realized cost is the IS using a post-trade benchmark.
- $Realized\ Cost = \begin{cases} p - m_5, \text{ for a marketable buy order} \\ m_5 - p, \text{ for a marketable sell order} \end{cases}$
  - Where m_5 is the NBBO midpoint 5 minutes (300 seconds) after the trade.
- Sometimes interpreted as the profit of the "dealer" who took the other side of the order.
  - Example: a customer hits the dealer's bid ("p")
  - Dealer: "Five minutes ago I bought from the customer at p; the stock is now worth m_5: my profit is $m_5 - p$."

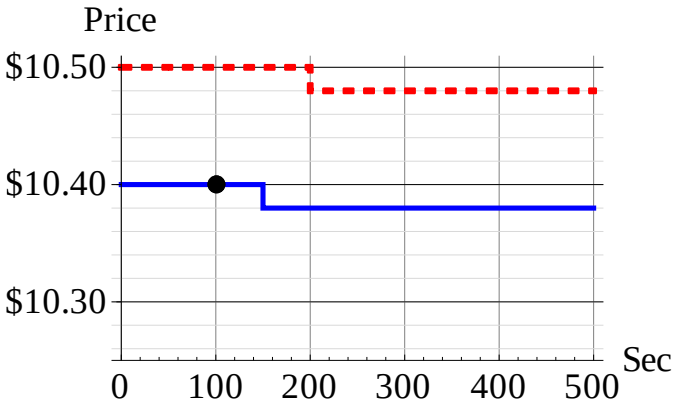
Price impact

- $Price\ impact = Effective\ cost - Realized\ cost$
  - For a buy, $price\ impact = (p - m) - (p - m_5) = m_5 - m$
  - For a sell, $price\ impact = m - m_5$
- Price impact measures the movement of the quote midpoint (over five minutes) in the direction of the trade.
  - "If we bought, how much did the midpoint rise?"
  - "If we sold, how much did the midpoint fall?"

Why "five minutes after the trade"?

- For the realized cost and the price impact, want to measure the effect of the trade on the security *value*.
  - Quotes immediately after a trade might be noisy.
  - Others submit or cancel orders in reaction to the trade.
  - The five-minute delay allows the quotes to stabilize.
- Why not a 60-minute delay?
- Why exactly five minutes?
  - SEC chose five minutes in implementing Rule 605.

A sell order executes at the NBB



Calculation details:

$m = 10.45; m_5 = 10.43; p = 10.40$

$Eff\ Cost = 10.45 - 10.40 = 0.05$

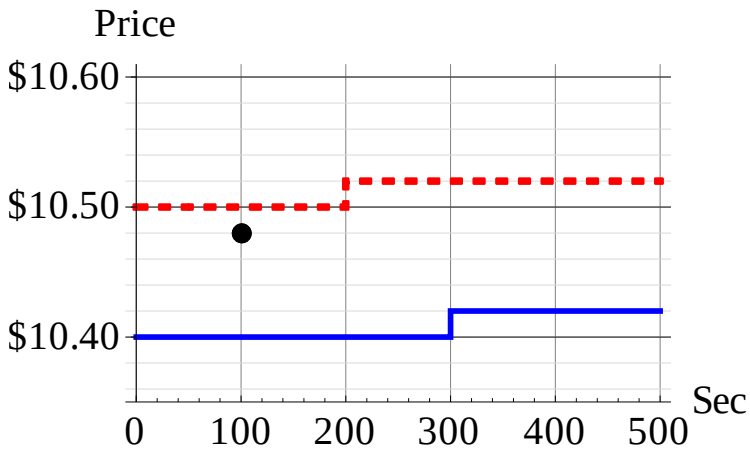
$Rlzd\ Cost = 10.43 - 10.40 = 0.03$

$PrImpact = 0.05 - 0.03 = 0.02$

Price improvement

- We expect a marketable order to be executed at the quote (NBB or NBO)
- If we trade at a better price, the difference is price improvement.
- $Price\ improvement =$
  $\begin{cases} NBO - p, & \text{for a marketable buy order} \\ p - NBB, & \text{for a marketable sell order} \end{cases}$

A buy order executes at $10.48 with price improvement



Calculation details:

$m = 10.45; m_5 = 10.47; p = 10.48$

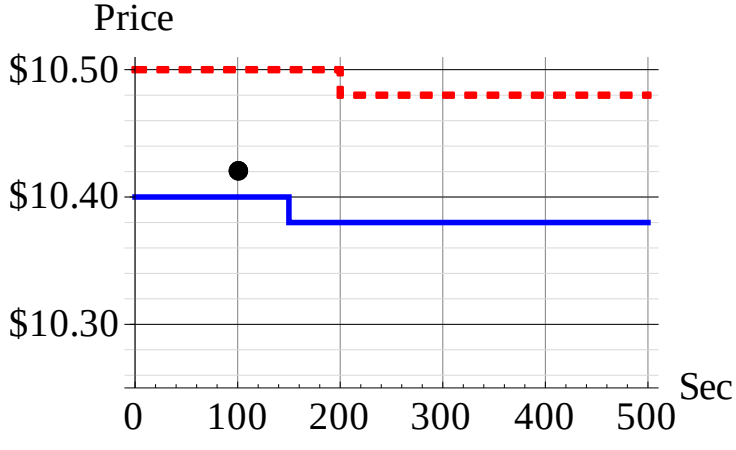
$EffCost = 10.48 - 10.45 = 0.03$

$RlzdCost = 10.48 - 10.47 = 0.01$

$PrImpact = 0.03 - 0.01 = 0.02$

$PrImprove = 10.50 - 10.48 = 0.02$

A sell order executes at $10.42 with price improvement



Calculation details:

$m = 10.45; m_5 = 10.43; p = 10.42$

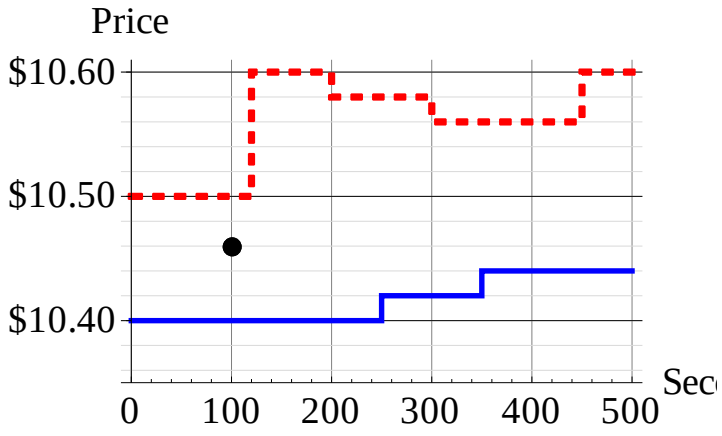
$EffCost = 10.45 - 10.42 = 0.03$

$RlzdCost = 10.43 - 10.42 = 0.02$

$PrImpact = 0.03 - 0.02 = 0.01$

$PrImprove = 10.42 - 10.40 = 0.02$

A more complicated buy order



Calculation details:

$m = 10.45; m_5 = 10.50; p = 10.46$

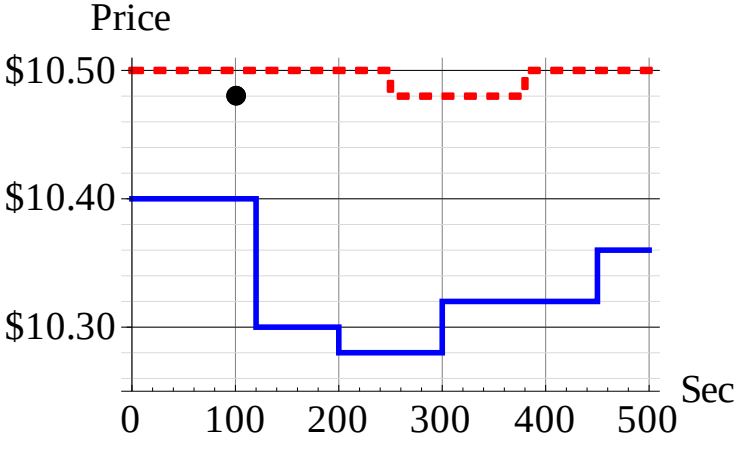
$EffCost = 10.46 - 10.45 = 0.01$

$RlzdCost = 10.46 - 10.50 = -0.04$

$PrImpact = 0.01 - (-0.04) = 0.05$

$PrImprove = 10.50 - 10.46 = 0.04$

A more complicated sell order



Calculation details:

$m = 10.45; m_5 = 10.41; p = 10.48$

$EffCost = 10.45 - 10.48 = -0.03$

$RlzdCost = 10.41 - 10.48 = -0.07$

$PrImpact = -0.03 - (-0.07) = 0.04$

$PrImprove = 10.48 - 10.40 = 0.08$

Embedded problem 2

- The NBBO is 35.40 bid, offered at 35.50.
- A buy order is executed at 35.49.
- The NBBO five minutes later is 35.41 bid, offered at 35.55.
- Compute:
  - Price improvement
  - Effective cost
  - Realized cost
  - Price impact

SEC Rule 605.

- A market center (exchange or broker who executes orders) must report standard execution statistics.
  - These statistics must be reported on the market center's website.
- Compliance is usually minimal: the data are simply dumped in raw form.
- Interactive Brokers reports in an easy-to-understand layout.
  - *interactivebrokers.com → About IB → Performance Reports → … Monthly Rule 605 … Reports*

IB 605 Report, Agilent Technologies, November, 2013

Symbol	Type	Size	Orders	Shares	CancShr	McExecShr	AwyExShr
A	Mrkt	100- 499	38	8326	0	8326	0
A	Mrkt	500-1999	14	9884	0	9884	0
A	mktL	100- 499	49	10262	0	10262	0
A	mktL	500-1999	9	8050	0	8050	0
A	mktL	2000-4999	1	2000	0	2000	0
AA	Mrkt	100- 499	281	48661	0	48661	0

- Mrkt - Market orders
- mrkL - marketable Limit Orders
- CancShr - Canceled Shares: Cumulative number of shares of covered orders canceled prior to execution.
- McExecShr - Market Center Executed Shares: Cumulative number of Shares of Covered Orders executed.
- AwyExShr - Away Executed Shares: Cumulative number of Shares of Covered Orders routed to another market by Interactive Brokers ATS and then executed.

Type	Size	Orders	Shares	ARS	AES	ImprShr	ImprAmnt
Mrkt	100- 499	38	8326	-0.0514	0.0154	3277	0.0100
Mrkt	500-1999	14	9884	-0.0384	0.0118	1000	0.0100
mktL	100- 499	49	10262	0.0438	0.0123	2358	0.0100
mktL	500-1999	9	8050	0.0941	0.0084	1300	0.0100
mktL	2000-4999	1	2000	-0.9300	0.0300	2000	0.0100

- ARS is the Average Realized Spread ($= 2 \times average\ realized\ cost$)
- AES is Average Effective Spread ($= 2 \times average\ effective\ cost$)
- ImpShr is Price Improved Shares: The cumulative number of shares of covered orders executed with price improvement
- ImpAmnt is (for the shares that had price improvement) the average price improvement ($/sh)

Analysis of market orders, 100-499 shares

- $Avg\ price\ improvement = \frac{3{,}277}{8{,}326} \times \$0.01 = \$0.0039$
- $Avg\ effective\ cost = \frac{\$0.0154}{2} = \$0.0077$
- Recall:
  - $Price\ improvement + effective\ cost = \frac{1}{2} \times bid/ask\ spread$
  - $Implied\ spread = 2 \times (\$0.0039 + \$0.0077) = \$0.0232$
- $Avg\ realized\ cost = -\frac{\$0.0514}{2} = -\$0.0257$
- $Avg\ price\ impact = effective\ cost\ - realized\ cost$
  $= \$0.0077 + \$0.0257 = \$0.0334$

Opportunity costs

- All of our IS calculations have been for orders that were actually executed.
- What is the "cost" of an order that *doesn't* execute?
- Example: Sometimes order strategies use limit orders; sometimes limit orders don't execute.
- If we say, "no execution, no cost," we're pretending that we were indifferent whether or not the order executed.

Example of an opportunity cost.

- The market is MSFT is 95.00 bid, offered at 95.10.
- We enter a limit order to buy at the bid (95.00).
- The bid is never hit; at the end of day MSFT is trading at 100.
- If our order had been executed, we would have had a $5 profit.
- The non-execution cost us $5.

Example: comparing effective costs.

- Suppose that the average spread in a stock is $0.10.
  - The half-spread is $0.05
- A hedge fund tries an experiment to measure order costs.
  - Submit 100 buy market orders.
  - Submit 100 buy limit orders priced at the bid.
- Compare average effective costs for each strategy.

Outcome

- All of the market orders will execute, paying (on average) \$0.05 above the midpoint.
  - Average effective cost = \$0.05
- *Some* of the limit orders will execute.
  - Those that *do* execute pay (on average) \$0.05 *below* the midpoint.
  - Average effective cost = −\$0.05
- Conclusion: "we should use more limit orders."
- What is the cost of limit orders that don't execute?

Adjusting for opportunity costs

- For orders that don't execute, impute (assume) an execution price.
- One rule: if a limit order has not been executed by the end of the day, assume that it is executed at the close.
- Example
  - The bid-ask midpoint is 50.10. This is our benchmark.
  - We enter a limit order to buy at 50.
  - If the order executes, $IS = 50.00 - 50.10 = -0.10$
  - If the order does not execute, and the price in the closing auction is 52, then $IS = 52.00 - 50.10 = 1.90$.
- Note: the Funari order on the Tokyo Stock Exchange will actually deliver this outcome.
  - A Funari order starts as a limit order, but if it hasn't been executed by the end of the trading session, it converts to "market on close".

Delay costs

- When a large order is being worked over time, the price generally moves away from the order, even ignoring the price impact of the executions.
  - This increases the trading cost.
  - If we could have done the full trade immediately, we'd have avoided this cost.
- Example
  - 10,000 sh to buy. Split as 2,000 per hour over next five hours.
  - Over the five hours, the price tends to rise.
- By some estimates, the cost of delay is very high.

Why does the price move away from the order?

- Money managers complain:
  - The brokers handling our orders leak our intentions.
  - Other traders watching the market figure out what we're doing and buy ahead of us.
- Another possibility
  - We usually think that we're the only ones who had the idea to buy in the first place.
  - What if other funds are watching the same indicators and putting in the same trades?

Which benchmark?

- Simple (easy to observe or compute).
  - VWAP or TWAP just require trades (prices and volumes)
  - Bid-ask midpoints are very data intensive and can be affected by errors in time-stamps.
- Fair (to the people being evaluated).
  - At Northstar, previous day's close or same day open are close to when Priyansh can formulate her decisions and pass them on to Tom.
- Reliable (can't be gamed or manipulated)

Gaming the benchmark

- "Buy 10,000 XYZ over the next week. You'll be judged relative to VWAP on day you start trading."
- To look good, wait until the end of a day where the price has been falling.
  - Current price is low.
  - Trades that happened earlier in the day were at higher prices. → VWAP is high.

Answer to embedded problem 1

- MSFT open prices
  - April 5, ~$66.30
  - April 10, ~$65.60
- Compute Tom's implementation shortfalls and the profit allocation relative to these (opening) benchmark prices.
- Priyansh's paper profit minus Tom's IS should equal the total profit (0.31).
- Answer:
  - On the purchase, Tom's $IS = 65.49 - 66.30 = -0.81$
  - On the sale, Tom's $IS = 65.60 - 65.80 = -0.20$
  - Priyansh's paper profit is $65.60 - 66.30 = -0.70$
  - Check: $-0.70 - (-0.81 - 0.20) = 0.31$

Solution to embedded problem 2

- The NBBO is 35.40 bid, offered at 35.50.
- A buy order is executed at 35.49.
- The NBBO five minutes later is 35.41 bid, offered at 35.55.
- Compute:
  - Price improvement $= 35.50 - 25.49 = 0.01$
  - Effective cost $= 35.49 - \frac{35.40+35.50}{2} = 35.49 - 35.45 = 0.04$
  - Realized cost $= 35.49 - \frac{35.41+35.55}{2} = 35.49 - 35.48 = 0.01$
  - Price impact $= 35.48 - 35.45 = 0.03$

