Deutsche Bank
Global Equities

DB Quant Research – Americas

Execution Excellence

Extended Transaction Cost Analysis (TCA)

Extended post-trade analysis is essential for understanding how to reduce slippage

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In this note:

In a standard post-trade TCA we define trading cost as slippage vs a conventional benchmark, such as Arrival Price, VWAP, PWP. We compute statistics using variables that are considered explanatory to illustrate the causes of slippage (i.e. order size, participation rate, duration, spread/volatility, capitalization/turnover, etc.)

- This is sufficient to explain where slippage is coming from, but not detailed enough to understand how to reduce it.
- Few of the above explanatory variables correspond to algorithmic controls.
- A more efficient way to improve performance is to analyze slippage, based on the tactics/intentions of the algorithm.
- Since tactics can change during the life of the order, we also need to understand the evolution (build-up) of slippage as the execution unfolds.

The main idea is to extend TCA beyond its traditional role of execution reporting, and use it for collecting data about the behavior of the algorithm under various parameter settings and market conditions. Specifically, we discuss three extensions

1. The usage of Volume-Weighted Average Duration (VWAD) as a measure of overall order duration, and for specific classes of fills (dark, passive, aggressive, auction).
2. The relative contribution of each tactic to the fills of an order as execution proceeds.
3. The monitoring of participation rate and arrival slippage during order execution, where the lifetime of an order is measured by its fill percent.

We present these extensions in the context of two specific case studies. This is to demonstrate how the extensions can be used for analyzing orders of a specific client, or for comparing samples across clients and time.

Case Study 1: VWAP

The strategy is designed to pace executions to match the historical volume distribution curve within the user's specified time horizon. Typically, interval VWAP is used as the primary benchmark. However, it is important to also consider slippage versus Arrival Price, both in basis points or as a fraction of the bid-ask spread. There is a trade-off between price impact and tracking error around the historical volume curve. Tight volume tracking becomes much more costly as order size increases. It may make sense to adjust the algorithm in order to minimize price impact over the day, while accepting more variance versus the primary benchmark.

1. Orders

VWAP Sample statistics by order size. Slippage is in terms of n*otional* weighted averages.

Size (% ADV)	#Ords	Notl (mln)	ADV (%)	Pcp (%)	Arrival (bps)	Arrival (sprd)	VWAP (bps)	VWAP (sprd)	PWP 10% (bps)
< 0.25	2206	1118.6	0.13	3.0	-6.3	-1.37	-0.6	-1.24	-4.9
< 1	2519	3270.5	0.59	5.4	-10.8	-3.90	-0.5	-0.33	-8.2
< 4	2582	6023.9	2.24	10.6	-15.9	-4.29	-1.0	-0.19	-7.6
≥ 4	1127	5003.7	9.74	22.0	-22.9	-5.29	-1.4	-0.30	-4.4
Total	8434	15416.7	4.17	12.5	-16.4	-4.32	-1.0	-0.33	-6.5

2. Tactics

Each fill is labeled from the corresponding order placement tactic as **Dark** (*dark seeking*), **Taker** (taking liquidity, i.e. *spread crossing*), **Supp** (supplying liquidity, i.e. *passive posting*), or **Other** *(e.g. Auctions, Finish Up, and/or Oddlots)*. For each order, we take the fills of a specific type and compute their arrival slippage, as if the order consisted of this type of fills alone. Then we average the slippage across orders. We use this statistic as a cost measure for the specific tactic. Tactics within an order are not independent, of course. By favoring one we necessarily reduce another. The following table shows the decomposition of fill rate and the average arrival slippage by tactic.

VWAP sample statistics by order placement tactic. Per-tactic arrival slippage is in terms of notional weighted averages.

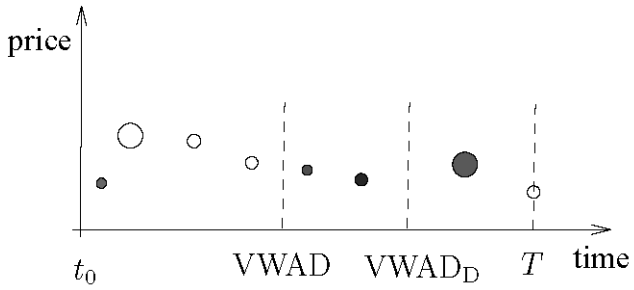
Tactic	Fill (%)	VWAD (mins)	Arrival (bps)	Arrival (sprd)
Supp	55.66	99.92	-15.0	-4.02
Taker	20.63	112.01	-18.1	-4.88
Dark	17.70	125.45	-14.7	-4.01
Other	6.01	193.74	-14.7	-3.75
Total	100.00	105.92	-16.4	-4.32

The quantity VWAD (mins) is the **Volume Weighted Average Duration** in minutes. It is defined similar to VWAP, but instead of fill prices we use fill times. An order with arrival time t_0 that received n fills, each of size q_i and at time t_i, has a VWAD given by

$$\text{VWAD} = \frac{\sum_{i=1}^{n} q_i \cdot (t_i - t_0)}{\sum_{i=1}^{n} q_i}$$

Likewise, the VWAD of a particular type of fills (dark, aggressive, passive) is computed by using only fills of that type in the numerator and denominator of the above expression. For example, the VWAD of dark fills (VWAD_D in the figure below) can be compared with the VWAD of all fills, to gauge if dark fills arrive earlier or later in the life of the order.

White represents those lit aggressive and passive fills, while grey corresponds to dark fills.



From the above tables we note the following

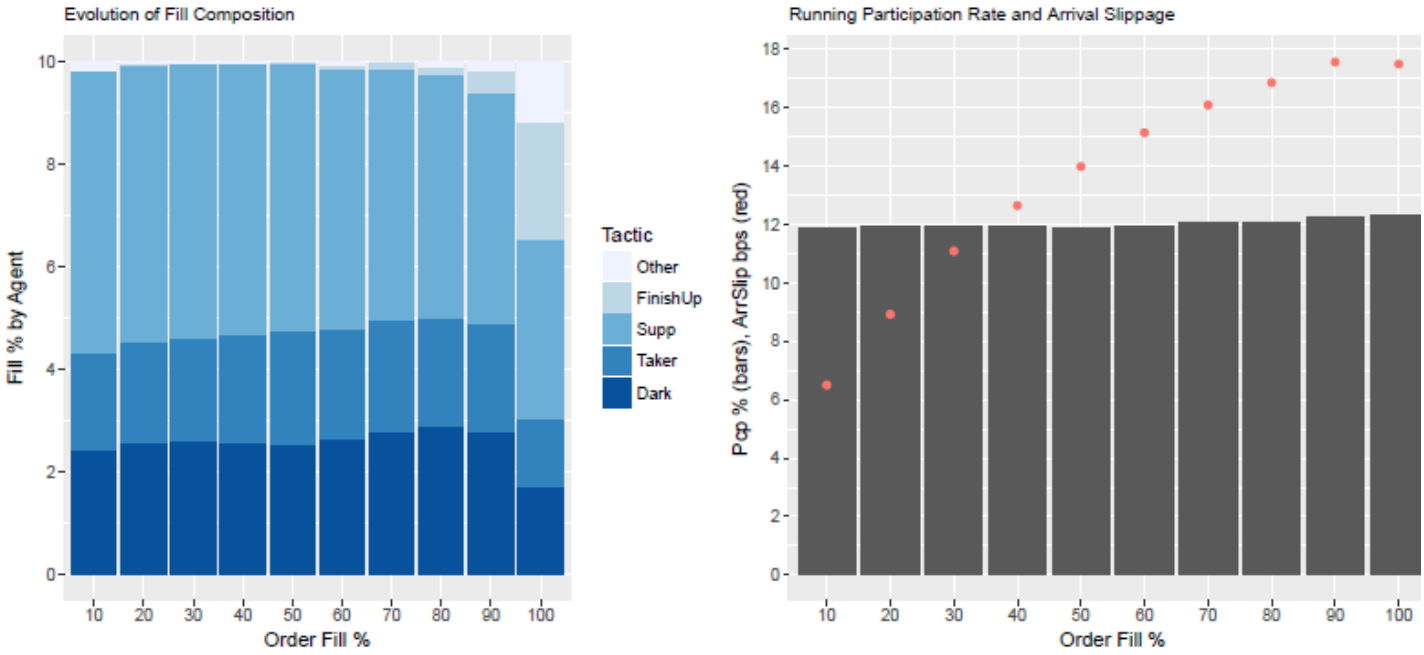
- Dark fills come on average later relative to supplier or taker fills.
- The per-fill cost of the taker tactic is about 0.8 spreads higher than the dark or supplier.

3. Looking inside the order

An order's fill percentile can be used as a "clock" for measuring order life time. Fill percentile is more suitable for subdividing the life of an order into intervals than fixed time duration in minutes or hours. Averaging a quantity over, say, the first five minutes of every order may not be meaningful when both short and long duration orders are present. Averaging over the time it took to fill 5% of every order is preferable.

We divide each order's interval into ten fill deciles. The time duration of the n-th decile is the time it took to fill between $(n-1)\%$ and $n\%$ of the order's total quantity. In each decile we measure the relative contribution of the tactics to the fills. For each fill decile we plot a bar divided into the proportions of each tactic. This is shown on the left-hand side plot in the figure below.

Likewise, to track the running participation rate and arrival slippage during the life of an order, we plot the average cumulative participation rate and average cumulative slippage at the end of each fill decile. This is shown on the right-hand side plot in the figure below.



- The fill composition plot confirms the VWAD measurements, i.e. dark fills tend to come later in the life of the order
- The trading trajectory is mostly flat and stays tight within the 12%-12.5% participation rate range
- Arrival slippage builds up sub-linearly as the order progresses, and saturates in the last fill decile.

Given these diagnostics, a possible course of action is to relax the tight volume tracking, by tilting the fill composition towards more passive / dark and less aggressive fills.

Case Study 2: STEALTH "OPTIMAL" at 12%

The Stealth strategy aims to maximize spread and size capture, while seeking liquidity in lit and dark venues. The algorithm uses the following models to adapt to market conditions: 1) Dynamic return model (seeks to identify reversion and momentum relative to a highly correlated ETF). 2) Spread capture model (seeks to adjust short-term trading behavior based on relative spreads).

The primary benchmark used here is Arrival Price, with additional adjustments for expected cost and industry momentum. Nevertheless, the VWAP benchmark is still useful, for measuring efficiency of trading over the actual interval. The PWP benchmark is also relevant for identifying the risk associated with deviation from a prescribed target rate.

1. Orders

Stealth sample statistics by order size. Slippage is in terms of notional weighted averages.

Size (% ADV)	#Ords	Notl (mln)	ADV (%)	Pcp (%)	Arrival (bps)	Arrival (sprd)	VWAP (bps)	VWAP (sprd)	PWP 15% (bps)
< 0.25	778	315.9	0.15	14.6	-7.7	-2.18	-0.7	-0.23	-2.5
< 1	913	852.8	0.58	14.8	-10.4	-2.95	-1.6	-0.41	-2.8
< 4	416	585.7	1.96	14.5	-15.5	-3.75	-1.7	-0.34	-2.2
≥ 4	30	40.2	4.94	14.1	-45.0	-5.01	-3.8	-0.43	-13.3
Total	2137	1794.6	1.05	14.6	-12.4	-3.12	-1.5	-0.36	-2.8

2. Tactics

Similar to the VWAP sample, we compute the fill contribution and VWAD of each tactic in the table below

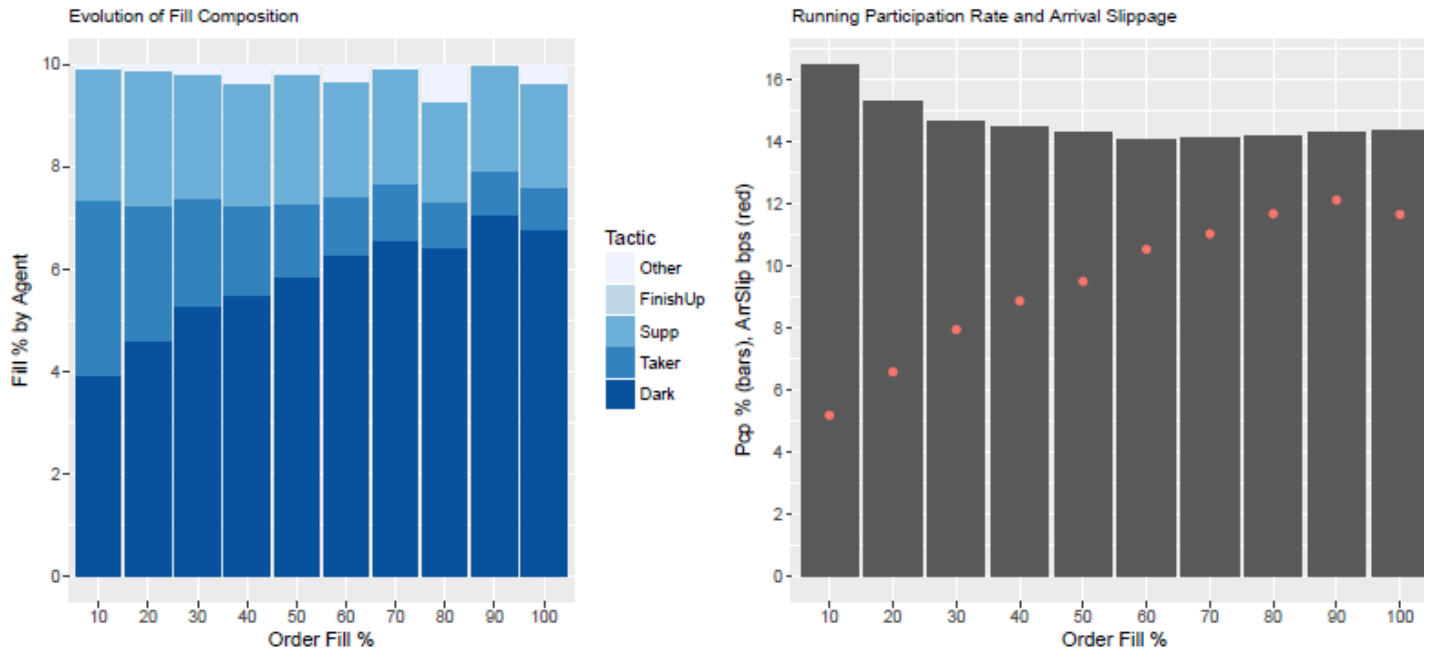
Stealth sample statistics are by order placement tactic. Per-fill slippage is in terms of notional weighted averages.

Tactic	Fill (%)	VWAD (mins)	Arrival (bps)	Arrival (sprd)
Supp	26.86	17.08	-11.2	-2.83
Taker	22.41	7.67	-13.1	-3.36
Dark	49.26	18.37	-11.7	-2.97
Other	1.47	36.84	-8.5	-2.23
Total	100.00	17.38	-12.4	-3.12

The VWAD measurements show that taker fills (aggressive) occur earlier in the life of the order relative to passive and dark. Moreover, the dark tactic contributes much more to the fills in Stealth relative to VWAP, while the taker has comparable contribution.

3. Looking inside the order

The plots below illustrate the fill composition and the realized participation rate and slippage during the life of the liquidity seeking strategy. Although the strategy has an underlying minimum trading rate at its core, it is given more discretion to deviate as needed relative to the previously mentioned VWAP case study.



- The supplier tactic stays roughly constant, as this strategy is given “leeway” to post ahead of anticipating volume.
- The taker tactic is higher at the beginning of the order, as also seen in the VWAD measurements.
- The trading trajectory is slightly front-loaded, consistent with early taking.
- Arrival slippage builds up sub-linearly as the order progresses, and flattens out after approximately 80% of the order is filled.

Given the additional flexibility available, we may recommend ways in which we can moderate the taker agent and increase the dark tactic in the early part of the order lifecycle to further reduce slippage. And on the opposite end of the order lifecycle, we may also recommend ways to reduce dark exposure in later deciles to capitalize on the price reversion towards the end of the order and post-trade.

Conclusion:

There has been a rising concern and growing criticism of liquidity seeking and more discretionary strategies, which appear to “trade too slowly on unfavorable price moves” and vice versa. On the opposite end of the spectrum, strict scheduled-based strategies have

historically created relatively more impact versus Arrival Price and become suboptimal as liquidity demand increases. We've spent a considerable amount of time evaluating the impact of scheduling and the risk of discretion on performance, as well as the implications associated with each of those given the clients investment goals.

The examples presented above are intended to help illustrate some ways that Deutsche Bank looks to extend post-trade analysis and the evaluation of strategy customizations. They are part of a larger collection of methods used to analyze specific client flows and execution objectives. It is important to acknowledge that when we run these analyses, it's done only for a subset of orders that are affected by a controlled A/B experiment with routine changes, so we can really quantify their impact. There is clearly no "one size fits all" when it comes to post-trade analysis and strategy tuning. However, given a client's investment goals and expectations, we believe there are ways to reduce slippage.

This note is the first of a series of communications on TCA extensions and their applications. We welcome and appreciate any feedback as this research effort evolves.

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