HFTs and Dealer Banks: Liquidity and Price Discovery in FX Spot Trading

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Outline

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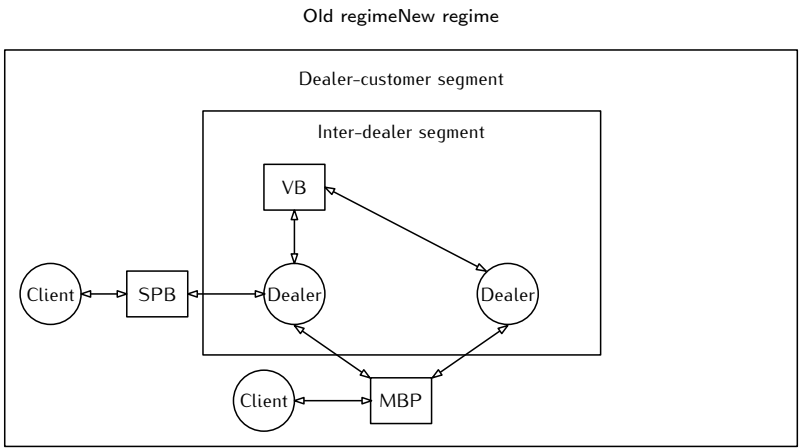
Background

- Financial markets have undergone significant structural changes in the last two decades
  - Trading more electronic, automated, and fast-paced
  - The arrival of "new" market participants: high-frequency traders (HFTs)
- HFTs are particularly prominent in all-to-all markets (e.g., equities) (Menkveld, 2016)
- In OTC markets such as foreign exchange (FX), HFTs also made inroads (Bank for International Settlements, 2011)
- Rich HFT literature in equities but sporadic in FX (Chaboud et al., 2014)

Motivation

- Why study HFTs in FX? A unique two-tiered market: a dealer-to-dealer (D2D) segment and a dealer-to-client (D2C) segment



Dealers vs HFTs in OTC

- D2D predominantly electronic and automated

  → HFTs can have speed and technology advantages...

  ...and thus react quicker to **public** information

- D2C dominated by dealer banks, providing agency execution services, single-dealer platforms, and other client relationship services (Bank for International Settlements, 2018)

  → Dealers could gain **private** information...

  ...through explicit learning such as price discrimination (Collin-Dufresne, Hoffmann, and Vogel, 2019)

  ...or implicit learning via internalised client trades or trade execution for informed clients)

Paper in a nutshell

- Aim: Contrast HFTs and dealers in liquidity provision and price discovery
- Takeaway:
  - HFTs better at processing **public** information; dealers better at **private** information
  - They play **complementary** roles in liquidity provision and price discovery
- Evidence:
  - HFTs withdraw *less* liquidity (than dealers) during market-wide volatility spikes (public information ↑)...
  - ...but *more* ahead of scheduled macroeconomic news announcements (private information ↑)...
  - Dealers' trades more informative than their quotes; HFTs' quotes more informative than their trades
  - HFTs' quote messages contribute most to price discovery, incorporating public information

Outline

Literature

- Link exchange rate dynamics to
  - aggregated order flow (Evans and Lyons, 2002; Evans, 2002; Payne, 2003; Bjønnes and Rime, 2005; Breedon and Vitale, 2010; Evans, 2010)...
  - ...or disaggregated order flows (Evans and Lyons, 2006; Breedon and Vitale, 2010; Cerrato, Sarantis, and Saunders, 2011; Osler, Mende, and Menkhoff, 2011; Breedon and Ranaldo, 2013; Menkhoff et al., 2016).
  - **Our paper**: Leveraging the granularity of our dataset, we are able to...
  - ...contrast the price discovery roles of the traditional (banks) and **new market makers (HFTs)**...
  - ...and to further disaggregate the contribution of trade flows versus **quote updates** to exchange rates for the first time.

Literature (Cont.)

- FX liquidity
  - Overall market liquidity (Mancini, Ranaldo, and Wrampelmeyer, 2013; Karnaukh, Ranaldo, and Söderlind, 2015; Ranaldo and Santucci de Magistris, 2019)
  - Individual liquidity providers (Bjønnes and Rime, 2005; Bjønnes, Rime, and Solheim, 2005)
  - Liquidity during extreme events: the Swiss franc "de-peg" (Breedon et al., 2018); the pound sterling flash crash (Bank for International Settlements, 2017; Noss et al., 2017)
  - **Our paper**: contrast liquidity provision by **HFTs** with dealers for the first time...
  - ...and provide more general evidence of their liquidity provision in response to **adverse market conditions** rather than rare and extreme events

Literature (Cont.)

- High-frequency trading
  - In equities, HFTs play an important role in both liquidity provision (eg Menkveld, 2013; Korajczyk and Murphy, 2019; Van Kervel and Menkveld, 2019) and price discovery (eg Brogaard, Hendershott, and Riordan, 2014)
  - However, it is not clear whether these findings apply to the FX market, given its unique two-tiered market structure
  - **Our paper**: reveal key differences in liquidity provision and price discovery by HFTs and dealer banks in **OTC market (FX)**

Outline

Data

- FCA regulatory dataset from Refinitiv FX Spot Matching: one of the two prominent dealer-to-dealer (D2D) markets
- Limit order book (LOB) event messages
  - New limit order submissions, cancellations, executions
  - Timestamped to the millisecond
  - With participant identifiers
- We use LOB messages to build order books
- GBP/USD and AUD/USD, 2 major currency pairs predominantly traded on Matching
- $\approx$ 2.5 years from 28 October 2012 to 5 June 2015.

Trader classification

- Each message is associated with a four-character Terminal Controller Identifier (Dealing) Code (TCID), which reconciles to the legal entity name of the trading firm
- Based on the TCIDs, we classify market participants into ◂ Data-based cross-check
  - **Dealers**
  - **HFTs**
  - Commercial bank
  - Non-HFT principal trading firms (PTFs) & hedge funds (HF)
  - Other participants

Summary statistics of liquidity and trading

- Both pairs are very liquid
  - High trading volume
  - Tight bid-ask spread
  - Deep top-of-book depth

	# Days	Volume (mil)	# Trade	RQS (bp)	DepthTop (mil)
GBP/USD	638	7721	5329	0.99	6.20
AUD/USD	630	13189	7962	1.36	10.55

Summary statistics of liquidity and trading

- Dealers and HFTs combined contribute to over 70% of the trading volume.
- HFTs more aggressive than dealers and commercial banks.

	Category	# Days	Total Trading Volume (mil)	Total Trading Volume Share (%)	Passive Trading Volume (mil)	Passive Trading Volume Share (%)	Passiveness (%)
GBP/USD	Dealer	638	7030	45.3	4323	56.3	62.2
	HFT	638	5173	33.5	1351	17.0	25.2
	Commercial Bank	638	1737	11.2	1195	15.6	69.7
	Non-HFT PTFs & HF	638	521	3.4	358	4.7	69.8
	Other	638	980	6.5	495	6.4	51.3
AUD/USD	Dealer	630	10972	41.4	5906	44.9	54.3
	HFT	630	8685	33.1	3161	23.5	35.6
	Commercial Bank	630	4962	18.8	3039	23.2	62.0
	Non-HFT PTFs & HF	630	741	2.8	498	3.8	68.3
	Other	630	1016	4.0	585	4.5	58.0

Pause #1

- Questions?

Outline

How to measure liquidity?

- Clear definition in theory: the degree to which a security can be traded at a price close to its consensus value.
- Two major challenges in practice:
- **How** to measure it?
  - Volume, Amihud measure (price change/volume)
  - Bid-ask spread, depth, implementation shortfall
  - Largely depends on data availability...
- **When** to measure it?
  - Market normal times vs stress times

Our approaches to liquidity provision

1. A **traditional** definition: being on the passive side
   - Metrics: bid-ask spread and top-of-book depth
   - Focus on adverse market conditions
     - Market-wide volatility spikes
     - Ahead of macroeconomic news announcements
2. A **more general** definition: "trade against the wind"
   - Can be on the aggressive or passive side (e.g., aggressive buy during a flash crash)
   - Metric: trade against temporary pricing errors identified by a state space model

Order-book liquidity provision measures

- The relative (half) quoted spread (*RQS*) of *trader category i* at time *t*:

$$RQS_{it} = \frac{BO_{it} - BB_{it}}{2 \times Mid_t} \tag{1}$$

- The top-of-book depth (*DepthTop*) contribution by *trader category i*, $DepthTop_{it}$:

$$DepthTop_{it} = Q_{it}^{BO_t} + Q_{it}^{BB_t} \tag{2}$$

- Full sample: HFTs have tighter bid-ask spread and larger top-of-book depth

	Measure	RQS (bp)		DepthTop (mil)		DepthTopShr	
		Mean	SD	Mean	SD	Mean	SD
GBP/USD	Dealer	1.34	0.29	2.30	0.56	0.33	0.06
	HFT	0.88	0.15	3.54	0.84	0.50	0.07
AUD/USD	Dealer	1.97	0.51	2.71	0.62	0.25	0.05
	HFT	1.18	0.23	6.25	1.67	0.55	0.08

Order-book liquidity provision and adverse market conditions

- Do HFTs and dealers have different strengths in market-making? Conjecture:
  - HFT: fast, and better at processing **public** information
  - Dealers: D2C network, and better at processing **private** information
- Examine liquidity provision during adverse market conditions of two distinct types:
  - Market-wide volatility (VIX) spikes: **public** information
  - Ahead of macroeconomic news announcements: **private** information

Order-book liquidity provision and adverse market conditions

- A vector-autoregressive model with exogenous variables (VARX)

$$y_t = \alpha + \Phi_1 y_{t-1} + \cdots + \Phi_p y_{t-p} + \Psi z_t + \varepsilon_t \tag{3}$$

- Endogenous variables:

$$y = \begin{pmatrix} LqtPro_{Dealer} & LqtPro_{HFT} & Vlm & TrdImb & Vol \end{pmatrix}'$$

- Exogenous variables:

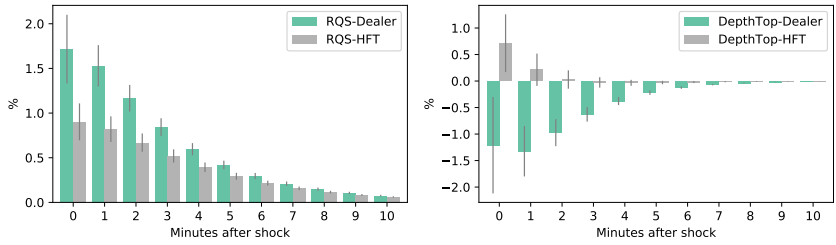
$$z = \begin{pmatrix} \mathbb{1}_{dCompVIX^*_+} & News_{\text{-}5min} & \cdots & News_{5min} \end{pmatrix}'$$

  - $\mathbb{1}_{dCompVIX^*_+}$ is a dummy variable which equals one when $dCompVIX^*_+$, positive VIX innovations, is above its 90% quantile ◂ VIX construction
  - $News_{\text{-}5min}, \ldots, News_{5min}$ is a set of per-minute news time dummies
  - ◂ VARX implementation details

Impulse responses to market-wide volatility spikes

- Dealers provide less liquidity than HFTs when facing a large VIX impulse
  - Dealers' *RQS* widens by about 1.75%, double the magnitudes of HFTs'
  - Dealers' *DepthTop* decreases while HFTs' increases

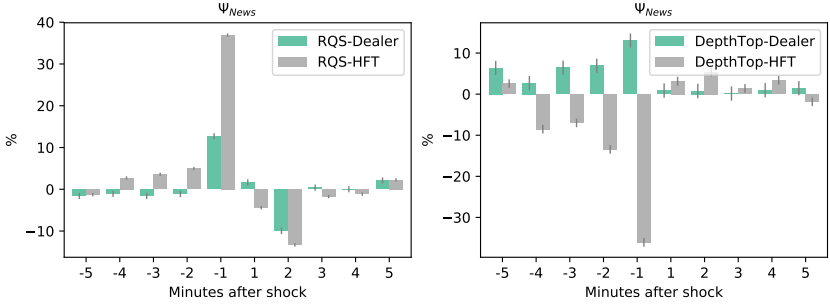
(a) GBP/USD



Liquidity provision around macroeconomic news announcements

- Ahead of announcements, HFTs significantly withdraw their liquidity
  - HFTs' *RQS* increases by over 30% and *DepthTop* decreases by over 30%
  - Dealers much less so

(a) GBP/USD



General liquidity provision: a state space approach

- On the passive side ? = the only way of providing liquidity
- Probably not. For example, traders who aggressively buy during a flash crash
- A more general definition: trade against transitory pricing errors, that is, trade "against the wind"
- How to identify pricing errors? While evident during flash crashes or rallies by definition, they are not trivial to identify during market normal times
- We use a state space model

General liquidity provision: a state space approach

- State space model specification:

$$\begin{aligned} \text{Midquote:} \quad & p_t = m_t + s_t \\ \text{Efficient price:} \quad & m_t = m_{t-1} + w_t \\ \text{Efficient price innovation:} \quad & w_t = \Sigma_i \lambda_i^j \widetilde{x}_{i,t}^j + \mu_t, \quad \mu_t \sim N(0, \sigma_\mu^2) \\ \text{Pricing error:} \quad & s_t = \phi s_{t-1} + \Sigma_i \psi_i^j x_{i,t}^j + v_t, \quad v_t \sim N(0, \sigma_v^2) \end{aligned} \tag{4}$$

- $x_{i,t}^j$ ($\widetilde{x}_{i,t}^j$): trade flow (trade flow innovation) for trader group i and trade type j (aggressive or passive)
- Our parameter of interest: ψ_i, which captures the transitory price impact of trader group i's trade flow
- $\psi_i < 0$: trades against the pricing error, or in a general sense, provides liquidity.

State space results

- Dealers' aggressive trade flows create much larger pricing errors than HFTs'
- HFTs' passive trade flow reduces more pricing errors than dealers'
- HFTs provide market liquidity by **passively** absorbing the pricing errors created by dealers' liquidity-demanding trade flows

Panel A: Aggressive flow			Panel B: Passive flow		
Currency	GBP/USD	AUD/USD	Currency	GBP/USD	AUD/USD
Panel A2: Pricing error equation			Panel B2: Pricing error equation		
ψ^{Aggr}_{Dealer}	0.048	0.049	ψ^{Pass}_{Dealer}	−0.017	−0.021
	(0.003)	(0.002)		(0.002)	(0.002)
ψ^{Aggr}_{HFT}	0.016	0.024	ψ^{Pass}_{HFT}	−0.087	−0.076
	(0.003)	(0.003)		(0.009)	(0.005)
ψ^{Aggr}_{Other}	0.033	0.046	ψ^{Pass}_{Other}	−0.045	−0.036
	(0.005)	(0.004)		(0.003)	(0.003)

Interim conclusions

- So far: dealers and HFTs possess different comparative advantages in market-making in FX market
  - Dealers better at private information events
  - HFTs better at market-wide, public information events
- Next, we turn to their roles in price discovery. Will we see similar patterns?

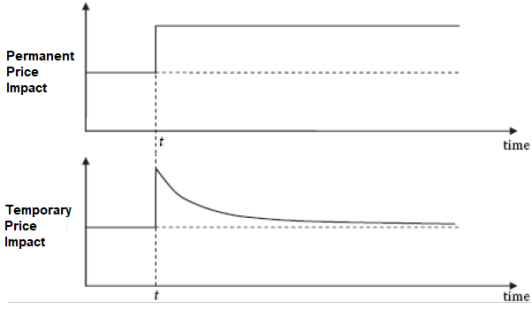
Pause #2

- More questions?

Outline

Price discovery

- Price discovery: the process of incorporating new information into prices
- New information leads to **permanent** price changes



Trade informativeness: Simple price impact measure

- Relative price impact (RPI) by trader-pair:

$$\text{RPI}_t = \frac{d_i \left(\text{Mid}_{t+\Delta_t} - \text{Mid}_t\right)}{\text{Mid}_t} \tag{5}$$

- Price impact the largest when dealers aggressively take HFTs' quotes (HFT→Dealer).

Currency Pair	Category Pair	RPI-10 Sec (bp) Mean	RPI-10 Sec (bp) SD	RPI-30 Sec (bp) Mean	RPI-30 Sec (bp) SD	RPI-60 Sec (bp) Mean	RPI-60 Sec (bp) SD
GBP/USD	Dealer→Dealer	0.49	0.15	0.52	0.20	0.53	0.27
	Dealer→HFT	0.41	0.08	0.41	0.10	0.41	0.12
	Dealer→CB	0.40	0.20	0.43	0.31	0.44	0.41
	HFT→Dealer	**0.69**	0.22	**0.69**	0.23	**0.66**	0.26
	HFT→HFT	0.51	0.17	0.51	0.21	0.52	0.26
	HFT→CB	0.50	0.26	0.48	0.34	0.47	0.42
	CB→Dealer	0.56	0.24	0.59	0.35	0.59	0.40
	CB→HFT	0.49	0.14	0.51	0.19	0.52	0.24
	CB→CB	0.47	0.36	0.48	0.58	0.47	0.71

Trade and quote informativeness: A structural VAR approach

- The structural VAR model (Fleming, Mizrach, and Nguyen, 2018; Brogaard, Hendershott, and Riordan, 2019):

$$Ay_t = \alpha + \Phi_1 y_{t-1} + \cdots + \Phi_p y_{t-p} + \varepsilon_t \tag{6}$$

where

$$y_t = \begin{pmatrix} r_t & x_t' \end{pmatrix}', \qquad A = \begin{pmatrix} 1 & -a_{0,1} & -a_{0,2} & \cdots & -a_{0,k} \\ 0 & 1 & 0 & \cdots & 0 \\ 0 & 0 & 1 & \cdots & 0 \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ 0 & 0 & 0 & \cdots & 1 \end{pmatrix}. \tag{7}$$

- The endogenous vector y_t consists of r_t, the log midquote return, and x_t, a vector of trade and order variables

Permanent price impact

- Rewrite structural VAR into VMA:

$$y_t = \Theta(L)\varepsilon_t = \Theta_0\varepsilon_t + \Theta_1\varepsilon_{t-1} + \Theta_2\varepsilon_{t-2} + \cdots \tag{8}$$

- Permanent price impact (PPI): cumulative impulse responses of CEX return to trade shocks:

$$\text{PPI}_k = \frac{\sum_{j=0}^{\infty} \partial r_{t+j}^{\text{CEX}}}{\partial \varepsilon_{k,t}} = [\Theta(1)]_{1,k}$$

Information share

- A decomposition of the midquote:

$$q_t = m_t + s_t \tag{9}$$

where $m_t = m_{t-1} + w_t$ and $Ew_t^2 = \sigma_w^2$

- Rewrite the structural VAR:

$$\begin{pmatrix} r_t \\ \boldsymbol{x_t} \end{pmatrix} = \begin{pmatrix} \Theta^a(L) & \Theta^{\boldsymbol{b}}(\boldsymbol{L}) \\ \Theta^{\boldsymbol{c}}(\boldsymbol{L}) & \Theta^{\boldsymbol{d}}(\boldsymbol{L}) \end{pmatrix} \begin{pmatrix} \varepsilon_{r,t} \\ \boldsymbol{\varepsilon_{x,t}} \end{pmatrix} \tag{10}$$

- The efficient price innovation variance:

$$\sigma_w^2 = \Theta^{\boldsymbol{b}}(1)\Sigma_{\varepsilon_x}\Theta^{\boldsymbol{b}}(1)' + [\Theta^a(1)]^2\sigma_{\varepsilon_r}^2. \tag{11}$$

- Information share (IS): normalized PPI weighted by its innovation variance

$$\mathrm{IS}_k = \frac{[\Theta_k^b(1)]^2\sigma_{\varepsilon_k}^2}{\sigma_w^2} \tag{12}$$

Trade and order variables

- Construct trade and order variables:
  - Trade: Market(able) buy orders (+1) or sell orders (-1) resulting in trades
  - BBO Improve Limit: Limit orders increasing the BB (+1) or decreasing the BO (-1)
  - BBO Worsen Cancel: Cancel orders decreasing the BB (-1) or increasing the BO (+1)
  - BBO-Depth Add Limit: Limit orders adding depth at BB (+1) or BO (-1)
  - BBO-Depth Remove Cancel: Cancel orders removing depth at BB (-1) or BO (+1)
  - Non-BBO-Depth Add Limit: Limit orders adding depth at $<$ BB (+1) or $>$ BO (-1)
  - Non-BBO-Depth Remove Cancel: Cancel orders removing depth at $<$ BB (-1) or $>$ BO (+1)

Message relative frequency

- HFTs account for the largest share of order-book messages
- HFTs more active than dealers at the top of the order book

Curency	Trader Category Order Type	Dealer	HFT	Other	Sum
GBP/USD	Trade	0.62	1.18	0.35	2.15
	BBO Improve Limit	1.14	2.51	0.61	4.26
	BBO Worsen Cancel	0.63	1.95	0.35	2.94
	BBO-Depth Add Limit	3.21	9.73	1.16	14.10
	BBO-Depth Remove Cancel	2.00	9.64	0.74	12.38
	Non-BBO-Depth Add Limit	2.39	13.35	15.65	31.38
	Non-BBO-Depth Remove Cancel	3.03	13.54	16.21	32.79
	Sum	13.02	51.90	35.08	100.00

Results: permanent price impact

- Trade price impact: dealers > HFTs; Quote price impact: dealers < HFTs

		Dealer	HFT	Other	Dealer - HFT
GBP-USD	Trade	0.31	0.25	0.27	0.06*
	BBO Improve Limit	0.23	0.28	0.24	−0.05*
	BBO Worsen Cancel	0.19	0.22	0.21	−0.03*
	BBO-Depth Add Limit	0.07	0.09	0.06	−0.02*
	BBO-Depth Remove Cancel	0.01	0.06	0.02	−0.05*
	Non-BBO-Depth Add Limit	0.02	0.01	0.00	0.01
	Non-BBO-Depth Remove Cancel	0.00	0.05	0.00	−0.05*

Results: information share

- HFTs' limit and cancel orders contribute the majority share to price discovery (>60%)
- If limit orders ≈ public information and trade ≈ private...
- ...→ then HFTs incorporate public while dealers incorporate private information

		Dealer	HFT	Other	Sum
GBP/USD	Trade	9.05	10.98	3.48	23.51
	BBO Improve Limit	8.73	25.85	3.75	38.33
	BBO Worsen Cancel	3.02	11.89	1.26	16.17
	BBO-Depth Add Limit	1.93	9.22	0.55	11.70
	BBO-Depth Remove Cancel	0.05	4.99	0.05	5.09
	Non-BBO-Depth Add Limit	0.09	0.47	0.03	0.59
	Non-BBO-Depth Remove Cancel	0.03	4.54	0.04	4.61
	Sum	22.90	67.94	9.16	100.00

Outline

Conclusion

- We examine dealers and HFTs in spot FX market
- Key takeaways: HFTs (dealers) better at processing public (private) information, playing complementing roles in liquidity provision and price discovery
  - Both HFTs and dealers reduce liquidity in response to volatility spikes and macroeconomic news announcements...
  - ...HFTs withdraw *less* liquidity (than dealers) during market-wide volatility spikes (more public information) but *more* ahead of scheduled macroeconomic news announcements (more private information)
  - Dealers' trades (revealing private information) are more informative than their quotes (incorporating public information); HFTs' quotes more informative than their trades
  - HFTs' quote updates (incorporating public information) contribute the lion's share to price discovery

Q&A

- Thanks for your time!

Further HFT screening rules

Back

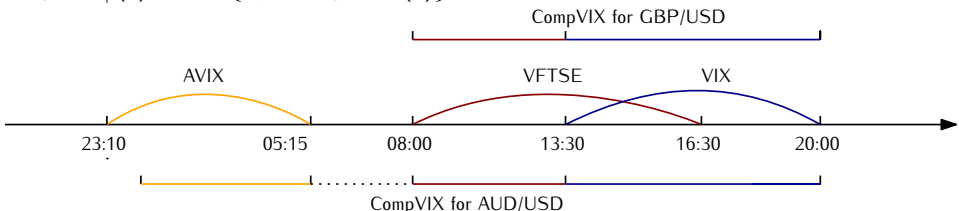
- **Speed rule: HFTs are fast.** Measure the speed of a TCID by its reaction time in:
  - "Add-Take" event: submitting an aggressive market(able) order after a new limit order is submitted by a different TCID which improves the best bid or ask price or adds depth to an existing best bid or ask price
  - "Take-Cancel" event: submitting a cancel order after a partial or full execution of a resting limit order at the same price
- **Inventory rule: HFTs carry low inventory.**
- Combining both the speed and inventory rule, a PTF or hedge fund TCID is classified as an HFT if it satisfies:

$$\begin{gathered}\text{End-of-day position to volume} < 0.2 \\ \underline{\text{and}} \\ \text{Add-Take speed} < 10\text{ms} \quad \underline{\text{or}} \quad \text{Take-Cancel speed} < 10\text{ms}\end{gathered} \tag{13}$$

Construct VIX shocks

Back

1. Fit an autoregressive (AR) model to the first difference of each volatility index and obtain its innovations: $dVIX^*$, $dVFTSE^*$ and $dAVIX^*$
2. Standardise each innovation time series
3. For GBP/USD, $dCompVIX^* = dVFTSE^*$ between 08:00 and 13:30; $dCompVIX^* = dVIX^*$ between 13:30 and 20:00. For AUD/USD, $dCompVIX^* = dAVIX^*$ between 00:00 and 08:00; $dCompVIX^* = dFTSE^*$ between 08:00 and 13:00; $dCompVIX^* = dVIX^*$ between 13:30 and 20:00.
4. Take the non-negative part of the composite VIX innovations: $dCompVIX^*_+(t) = \max\{0, dCompVIX^*(t)\}$.



VARX implementation details

Back

- Estimate VARX model is estimated at a 1-minute frequency
- Remove intraday seasonality by regressing each of the endogenous variables on 10-minute interval dummies and only use their residuals in the VARX estimation.
- Follow Hasbrouck (1991) and insert missing values during the overnight periods.
- To choose the optimal number of lags for the VARX model, we apply the Bayesian Information Criterion (BIC) on each day and obtain the mode lag order across all days.

Summary statistics of VARX variables

Back

- Consistent with the summary statistics before, HFTs quote a narrower bid-ask spread and supply more top-of-book depth at the 1-minute frequency.
- In addition, the standard deviation of HFTs' top-of-book depth is much smaller than dealers', indicating that their top-of-book depth is more stable.

		N	Mean	SD	Min	Q25	Q50	Q75	Max
GBP/USD	RQS_{Dealer}	454801	2.66	1.25	0.00	1.76	2.41	3.41	54.98
	RQS_{HFT}	454801	1.76	0.78	0.58	1.46	1.72	1.95	81.95
	$DepthTop_{Dealer}$	454801	2.32	2.98	0.00	1.04	1.79	2.79	202.60
	$DepthTop_{HFT}$	454801	3.56	1.65	0.00	2.43	3.34	4.46	15.47
	Vlm	454801	9.16	18.70	0.00	1.00	4.00	11.00	1192.00
	$TrdImb$	454801	3.63	6.52	0.00	1.00	2.00	4.00	648.00
	Vol	454801	1.73	1.58	0.00	0.89	1.33	2.24	89.56
	$\mathbb{1}_{dCompVIX^*_+}$	454801	0.10	0.30	0.00	0.00	0.00	0.00	1.00