J.P.Morgan

North America Fixed Income Strategy
12 April 2019

Far from the shallow now?

Liquidity provision by high frequency participants in US rates

- Algorithmic activity reacting on a timescale of micro-seconds has come to dominate liquidity provision in the U.S. Treasury interdealer market, representing, by our estimate, 80% of market depth
- These algorithmic participants have fallen as a percentage of total market depth in times of elevated implied volatility, particularly in the most extreme scenarios such as the financial crisis and the taper tantrum…
- …and we find evidence these players dial down a disproportionate share of their provided liquidity into routine data releases and market events, such as payrolls, auctions and post-FOMC meetings
- Taken together this suggests HFT activity has introduced another pro-cyclical (amplifying) mechanism for volatility in times of market stress…
- …though in recent years there's evidence this pro-cyclical behavior has mitigated to an extent

US Fixed Income Strategy

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Liquidity provision by high frequency participants in US rates

The interdealer market for hot-run U.S. Treasuries has changed dramatically in the past few decades. Since 2003, when traditional broker-dealers had exclusive access to the electronic trading venues (e.g., BrokerTec, eSpeed), newer principal trading firms (PTFs) have gained access across various platforms, launching faster, automated trading strategies that have come to dominate liquidity provision, and, more recently, aggressor activity (see *Fast and furious*, M. Salem et al., 11/20/18). Since then, more traditional players have likewise built out automated order placement strategies. In the past decade, non-public venues have also proliferated as both newer entrants and traditional dealers have launched streaming platforms that as of 2018 accounted for roughly 15% of total activity. In this note we take a moment to highlight just one of these developments: the rise of liquidity provision among the fastest, high frequency (HFT) participants. **Using their speed signature to tag their resting limit orders, we can reconstruct the HFT portion of market depth. From this we find their activity has come to dominate liquidity provision in the interdealer market, which suggests important implications for market resiliency and volatility.** This work follows on from previous work looking at HFT aggressor activity, from which we've found evidence that their behavior can serve to amplify bouts of higher volatility (see *Fast and furious* and *The flight of the furious: HFT activity into year-end likely exacerbated volatility*, M. Salem et al., 1/11/19).

Our work **concentrated on data from the BrokerTec interdealer venue, and their public, central limit order book (CLOB) which accounts for roughly 70% of activity in the interdealer market** by some counts[1], though that number was substantially lower for the earliest years of our dataset. **We began by tagging all orders by the time difference between when they were created or explicitly deleted by the user, and when the last update to the CLOB took place, a sort of "reaction speed."** Whereas human participants can react in perhaps a tenth of a second, and orders randomly arriving throughout the day would likewise follow on in perhaps a fraction of a second, we find a bulk of activity reacts on remarkably faster timescales (e.g. micro-seconds), inconsistent with both human reaction speeds and random noise.

Using this technique to tag each order, **we were able to reconstruct snapshots of the live order book, breaking down the market depth (a measure of how much liquidity is available to aggress without moving the price substantially) into a few different speed classes**. While the distribution of players (manual, "human" activity and activity from algorithmic programs of various speeds) was hardly well separated, we found it useful to adopt three speed regimes. We tagged orders created **more than 0.3 seconds** after the prior order book update as "**human**", with this timescale representing, very roughly, both their fastest reaction speed and also the expected tail of the distribution of orders arriving randomly throughout the session.

[1] A recent survey placed BrokerTec at 70% market share in 2018, with NASDAQ's CLOB hosting another 15% of volume (this platform, formerly eSpeed, once accounted for a much higher fraction). The balance of activity now takes place on private streaming platforms owned by a smattering of companies including several large broker-dealers. See *The rise of bilateral markets and trading places first survey of U.S. Treasury venues*, J. Greco, 7/17/18.

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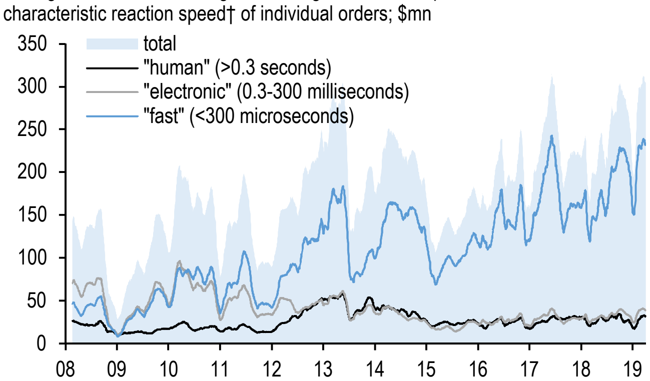
Between 0.3 seconds and 0.3 milliseconds (a bit less than a thousandth of a second), we observed a healthy fraction of activity that, while likely not initiated manually, is also occurring far slower than the fastest "HFT" players. This middle category is dubbed "**electronic**" and today likely represents some of the automated activity among traditional broker dealers, in particular auto-quoting. In outright terms, this portion of depth has fallen since 2013, but has stabilized and moved a bit higher since then. As private streaming platforms like LiquidityEdge and Virtu have proliferated (now accounting for 15% of total activity), we suspect a growing portion of this type of activity has migrated there. And as broker dealers continue to improve the speed/latency of their activities, we *also* suspect some of this activity still on the CLOBs has drifted into the final "fast" category described next.

Exhibit 1: Fast trading flows mostly initiated by principal trading firms (PTFs) have grown to dominate market depth in the central limit order book (CLOB) of the interdealer Treasury market

Rolling 1-month volume-weighted average of market depth* broken into the characteristic reaction speed† of individual orders; $mn

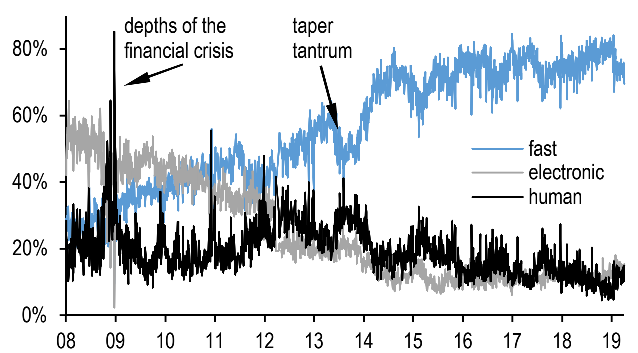


* Market depth defined as the total notional available in the central limit order book (CLOB) at the best three prices, averaged across both the bid and ask stacks, see *Drivers of price impact and the role of hidden liquidity*, J. Younger et al., 1/13/17. We take snapshots of the live order book for every $500mn in traded notional, and average market depth measurements from these snapshots, thus forming a volume-weighted average.

Source: J.P. Morgan, BrokerTec

Exhibit 2: The HFT share of market depth has risen in the past 10 years mostly at the expense of other, higher-latency automated orders, and has in the past been sensitive to spikes in volatility

Rolling 5-day volume-weighted averaged of the percentage of market depth* provided by order book participants of different reaction speeds†; %



† Reaction speed is defined as the minimum time between when an order is created or explicitly deleted by the user and the previous change to the CLOB. Whereas the tail outcome from random updates is perhaps a fraction of a second, we find reaction speeds remarkably faster than this, inconsistent with human reaction speed or random noise. Here we define reaction speeds as follows: **human**: slower than 0.3 seconds (300 milliseconds); **electronic:** between 0.3-300 milliseconds; **fast:** faster than 300 *micro*-seconds.

Source: J.P. Morgan, BrokerTec

Finally, we label flows **faster than 0.3 milliseconds as "fast" flows**. This category covers a broad range of activity from hundreds of micro-seconds to just a handful of microseconds, a distribution that has become increasingly bimodal as the top tier PTFs continue to improve their technology. In this last category, we also include some flows whose reaction times are not even properly resolved by our dataset. While these cutoffs are admittedly arbitrary, we stick to them through most of this piece, to shed light on the market's evolution.

Focusing on 10-year Treasury notes, **Exhibit 1** shows the volume-weighted average of market depth broken out into the above three reaction speed categories. Immediately evident from this exercise is **a concerted rise in order book depth over the past decade**, its rolling 1-month average roughly doubling from ~$100mn notional in the crisis years to roughly $250mn today (depth was notably much higher pre-crisis, though unfortunately our rich dataset does not extend that far). **And the HFT portion of the order book (roughly defined here as orders created within 300 micro-seconds of the previous alteration of the CLOB) is almost entirely responsible for this growth**, **having roughly quadrupled over the same period.** In contrast, the liquidity provisioned by both the human and slower electronic reaction-speed participants has waffled around roughly $60mn by this same metric

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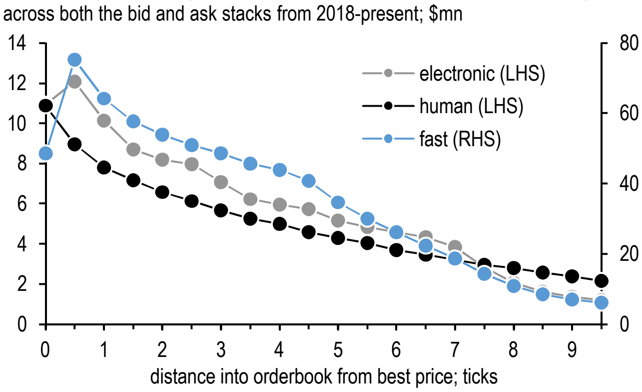
from 2008 to present, this despite BrokerTec having consolidated market share over this period.

Looking on a percentage basis, **we find the HFT fraction of the order book has risen from averaging just 20% of market depth to roughly 80% today** (**Exhibit 2**). While there has been a (comparatively modest) outright decline in slower electronic activity, the share of manually placed orders has declined only modestly over this period, and has risen outright, from roughly \$20mn to an average of \$30mn today. **This steady rise in market depth, driven primarily by HFT activity, has come alongside an equally steady post-crisis march lower in realized volatility in rates markets—a fact that suggests that understanding the behavior of these dominant players in periods of market stress may play a crucial role in understanding the resiliency of US rates markets to rapid flows and repricings**. From Exhibit 2, it's evident that some of **the past decade's most extreme vol events** (the financial crisis and the 2013 taper tantrum in particular) **have seen a medium-term fall in not only overall market depth, but in particular the *share* of depth provided by fast actors.** While admittedly representing a much less sophisticated technological epoch, the financial crisis in particular showed likely human-directed orders came to dominate the book (in excess of 80% of all depth) as market stress reached its apogee. Heading into 2019, amidst a much more modest vol spike, the share of HFT market depth likewise appears to have dipped, albeit by an again modest 5%.

Exhibit 3: These fast actors, along with slower, automated trading activity by broker-dealers tend to concentrate a bit further back in the order book than their human counterparts

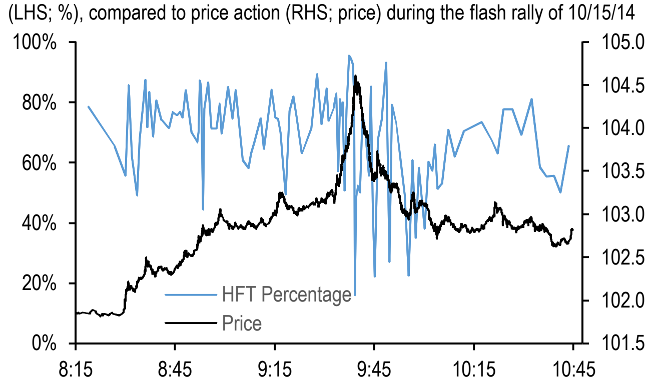
Volume-weighted average of notional available at the best 20 prices, averaged across both the bid and ask stacks from 2018-present; \$mn



Source: J.P. Morgan, BrokerTec

Exhibit 4: HFT liquidity provision was somewhat erratic through the flash rally of October 2015, but on average remained a majority of market depth through the 9:45 am round trip in yields

The fast fraction of market depth at snapshots for every \$500mn in traded notional (LHS; %), compared to price action (RHS; price) during the flash rally of 10/15/14



Note: Price is from individual aggressor transactions, market depth and fast fraction defined as in the footnotes to Exhibits 1 and 2.

Source: J.P. Morgan, BrokerTec

Automated activity in the interdealer market behaves in a different fashion than human activity, in ways that are arguably impactful for market microstructure. The slowest participants concentrate orders at the best prices, falling off exponentially deeper into the book, though on occasion their limit orders may appear on the bid or offer side quite far from the best bid or offer, lingering throughout the day—activity that may represent client orders placed by a broker dealer at a desired transaction price. **In contrast, the HFT component of the orderbook maintains an impressively rigid profile, concentrating the most orders one or a few prices back from the best bid/offer** (**Exhibit 3**). In the 2-year note, when the price resolution offered on BrokerTec doubled recently, the peak of this distribution went from the second best price to the third or fourth, preserving the distance, in price

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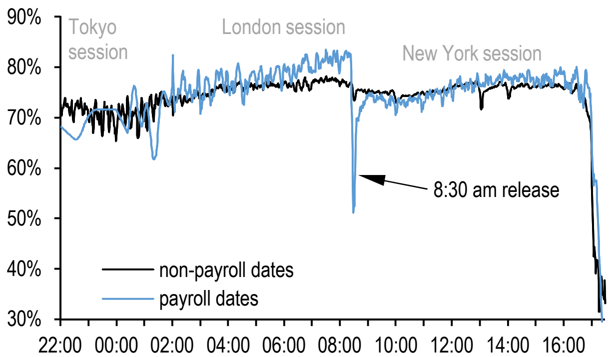
terms, from the best bid/ask (see Interest Rate Derivatives, *US Fixed Income Market Weekly*, J. Younger et al., 3/22/19). From there, HFT orders also fall off somewhat exponentially deeper into the book.

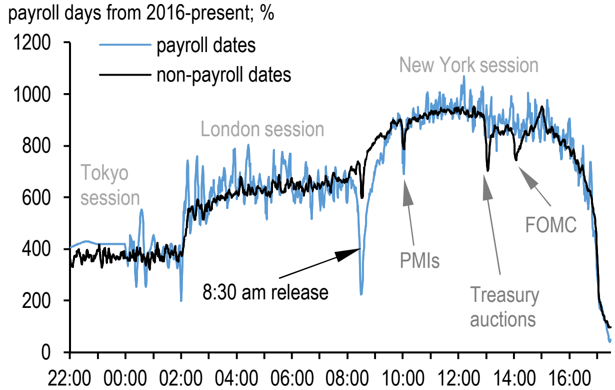
While the financial crisis and the taper tantrum represent prolonged periods of retreat for HFT liquidity provision, **there are numerous examples of acute, intraday episodes where dramatic price action has pressured these automated strategies out of the CLOB, if only for brief moments.** The flash rally of October 15, 2014 represents one such acute price move—one in particular where aggressor activity among HFTs in both the cash and futures markets likely played a key role. On that day, market depth declined sharply into the New York open and into an 8:30 am release of retail sales. The price of the 10 year popped modestly on that print, and drifted higher over the next hour. Then, roughly an hour later, the 10-year yields round-tripped over 20bp lower, then higher, in the span of less than 15 minutes, as HFT aggressor volume surged as a share of total trading[2]. Market depth dropped yet again through this event window, as all market players pulled back liquidity provision. Looking at resting limit orders broken out by the type of participant, **we find HFT players in particular were, through a few acute periods of particularly disorderly price action in the flash rally, a mere 20-30% of the order book, compared to roughly 70-80% earlier in the session (Exhibit 4).**

Exhibit 5: HFT liquidity provision drops dramatically into 8:30 am data releases and other times prone to data-driven price jumps...
Rolling average volume-weighted HFT market depth percentage on payroll and non-payroll days from 2016-present; %



Note: See Exhibit 1 and 2 footnotes for definition of market depth and fast depth
Source: J.P. Morgan, BrokerTec

Exhibit 6: ...contributing an outsized share to the drop in market depth overall into these events
Rolling average total market depth (here to 20 levels deep) on payroll and non-payroll days from 2016-present; %



Source: J.P. Morgan, BrokerTec

HFT liquidity provision also drops—both outright and as a share of total market depth—into routine data releases. For instance, **Exhibit 5** shows intraday market depth averaged over the past three years' worth of payroll days, compared to non-payroll days. While all market participants appear to pare down their offerings into the data release, in the minutes **leading into 8:30 am, HFT depth drops from 80% to roughly 50% of the total, making these players responsible for the bulk (and an outsized share) of the fall in depth (Exhibit 6).** Even averaged across all days of the week, the non-payrolls intraday evolution shows sharp drops in liquidity (and HFT market depth share) into later morning data releases, Treasury auctions and FOMC announcements (Exhibit 6). Looking at payroll dates over time, we find this partial exodus from the market ahead of an anticipated price jump **has remained a**

[2] See *Joint staff report: The U.S. Treasury market on October 15, 2014*

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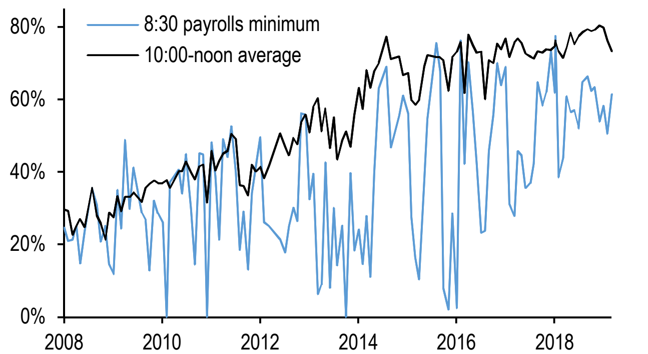
prominent feature of their activity, even as their overall presence has grown through the years (Exhibit 7).

Exhibit 7: This drop in liquidity provision has grown more conspicuous as fast players have grown to represent a larger fraction of the order book

The minimum fraction of market depth provided by fast (HFT) players into the payrolls data release compared to their mid-morning average depth share on the same day; %

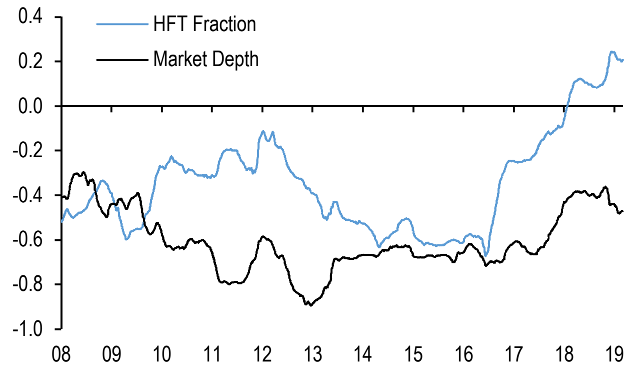


Note: From snapshots of the orderbook at every $500mn in traded notional; minimum snapshot depth fraction from 8:30-8:35am compared to the volume weighted average of snapshots from 10:00am – noon Eastern time. See Exhibit 1 and 2 footnotes for definition of market depth and fast depth

Source: J.P. Morgan, BrokerTec

Exhibit 8: The HFT's share of market depth has been well anti-correlated with volatility, though this trend has abated in recent years, while overall depth is still well anti-correlated with implied vol

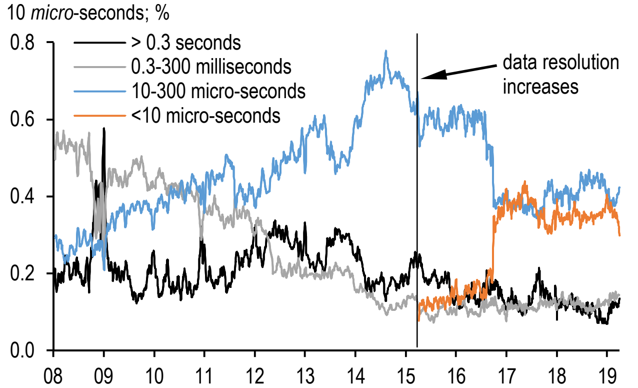
Rolling 3-year partial beta of 1-year z-score of HFT depth percentage and 1-year z-score of overall market depth regressed against 1-year z-score of 3Mx10Y implied volatility and 3M/1Yx3M OIS curve slope; unitless



Source: J.P. Morgan, BrokerTec

Exhibit 9: The latency of order book interactions has continued to shrink over the post-crisis era, with some players reacting to shifts in market microstructure in a handful of micro-seconds

Rolling 5-day volume-weighted average market depth share among participants with various reaction speeds, now including a threshold for reaction speeds below 10 *micro*-seconds; %

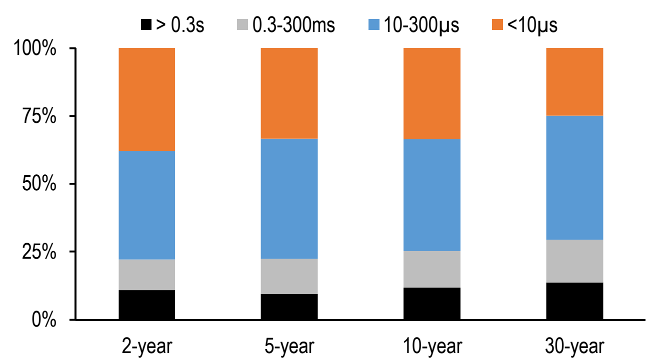


Note: See Exhibit 1 and 2 for definitions of market depth and reaction speeds

Source: J.P. Morgan, BrokerTec

Exhibit 10: This activity exists across the hot-run Treasury curve

Volume-weighted average of the share of market depth provisioned by various reaction speed classes of participants in 2018-19; %



Note: See Exhibit 1 and 2 for definitions of market depth and reaction speeds

Source: J.P. Morgan, BrokerTec

In general, **over the bulk of our dataset, there has been a strong anti-correlation between implied volatility and the percentage of market depth provided by HFT players (Exhibit 8).** As a deep market plays a crucial role in absorbing large flows with relatively orderly price action, **this behavior suggests, now via the passive side of the market, another pro-cyclical amplification mechanism for spurts of rising volatility. That said, HFT depth has managed to remain a more constant share of depth in recent years** which might suggest that these players have grown a

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bit less skittish in their deployment of liquidity in times of elevated vol. Curiously, the sharp shift in the beta between HFT fraction of liquidity and implied vol observed in Exhibit 8 happens to be well correlated with a sharp increase in a class of even *faster* algorithmic flows, with latencies of just a handful of micro-seconds (**Exhibit 9**).

While this piece has focused on the 10-year sector, much of what we've described here generalizes to across the curve in hot-run issues, where HFTs have come to dominate market depth in all benchmark tenors (**Exhibit 10**). **While the resilience of these liquidity providers into the next period of acute market stress remains an open question, there's little doubt that HFT activity has come to play an important role in market microstructure in US rates.**

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