



BANK OF ENGLAND

Speech

Keeping up with fast markets

Speech given by

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I am grateful to Tom Horn, Geir-Are Karvik, Joseph Noss, William Rawstone, Jack Worlidge, Jonathan Rand and to other colleagues for their comments and contributions.

Good morning and welcome to the second day of our conference. Yesterday we heard from Richard Payne's session on the subject of algorithmic trading – a key development in market structure, enabled by the greater prevalence of electronic trading. This morning I want to step back a little further and look at the broader implications of the moves toward more electronic and automated trading.

One phenomenon this has given rise to – and perhaps the element which has most captured the public imagination – is the series of 'flash' events which have occurred over recent years (Chart 1).

The 2010 flash crash in US equities was the first such episode to generate headlines outside the industry. Four years later, in 2014, we saw something similar in the US treasury market, the most liquid bond market in the world.

Closer to home, shortly after midnight in London on 7 October last year, the bid for sterling momentarily evaporated, with the currency falling nearly 10% against the US dollar before quickly reversing (Chart 2). This was a rare example of a flash event involving such a major, liquid, currency pair, and occurred during a G20 meeting in Washington DC, prompting our Governors to swiftly make contact with the Bank's London dealing desk for an explanation. They say markets never sleep; neither did our staff on that particular night!

In these episodes, prices moved sharply, before largely reversing – all within a matter of minutes, and to a degree that far exceeded changes in market participants' perceptions of economic fundamentals.

Of course, sharp movements in asset prices are nothing new in themselves. Just look at the tulip mania ending in 1637, and the equity crashes of 1929, 1987, and the bursting of the dot-com bubble in 2000. What is new is the speed, and the typical near-total reversal. And the Bank's responsibilities for monetary and financial stability make it incumbent on us to keep up.

What has happened?

What is clear is that flash crashes are likely just one symptom of material changes in the structure of certain markets and the nature of their participants. Although these changes are ongoing, we need to understand them and their drivers, if we are to succeed in correctly identifying any implications for financial stability.

One should be wary of over-generalisation, particularly with an audience such as this, given the substantial diversity in markets across both product types and geography. I would nonetheless characterise the broad trends of the past few decades as follows:

Firstly, there has been an increase in electronic trading across most markets. This is particularly the case in markets for inherently liquid instruments – i.e. those which are simple and homogenous, such as equities (Chart 3).

Second, at least initially, the migration from voice to electronic trading has allowed for far greater transparency around the prices at which market participants are both willing, and able, to transact.

This in turn has given rise to a plethora of new data, which combined with advances in technology, has led to the growth of algorithmic trading, including that at high frequency (Chart 4).

And, for the purposes of this speech, by ‘fast markets’ I mean those markets where these trends have gone furthest: most obviously major equity, foreign exchange (FX) and futures markets.

In these markets, there is less need for intermediaries to warehouse risk, due to the inherent liquidity characteristics that attract a wide range of participants, making it easier to find a near-instant match between buyers and sellers. This has allowed the emergence of new technology-focused, smaller, non-bank, market participants that specialise in using algorithms to execute and route orders at high speed. Chief amongst these are principal trading firms (PTFs), who trade on a proprietary basis, using sophisticated technology (Chart 5). Importantly, some PTF firms have been able to make markets at lower marginal cost than other participants, including by closing positions or offsetting risk in correlated instruments in shorter time frames. These competitive pressures have been one factor prompting many banks to warehouse less risk in fast markets, changing their business model to act as agents who sit between end-users and PTFs and the remaining, typically large, bank market-makers.¹

To differing degrees across markets, regulation has also played a role in encouraging such activity. In US equity markets, for example, Regulation National Markets System (2005) required brokers to execute client orders at the best price offered electronically on any venue, leading to fleeting arbitrage opportunities for the fastest moving market participants. In Europe in 2007, MiFID laid the groundwork for more competition, leading to different types of trading venues and more market fragmentation, also contributing to the growth of high-frequency trading.² And this regulatory influence will continue, with MiFID II set to introduce a whole host of new rules which bear on fast markets.

As Governor Carney has often stressed, central banks care deeply about the operation of financial markets.³ For the purposes of this speech, I will examine the implications of these developments through two prisms: market efficiency and market resilience.

¹ See BIS (2016), ‘Downsized FX markets: Causes and Implications’.

² The Markets in Financial Instruments Directive (MiFID) was introduced in Europe in November 2007. It increased competition between traditional stock exchanges and alternative trading venues. The resulting fragmentation contributed to the growth of high-frequency trading. See CESR (2009), ‘Impact of MiFID on equity secondary markets functioning’, CESR/09-355, and ESMA (2014), ‘High-frequency trading activity in EU equity markets’, Economic Report 1.

³ See Carney, M (2015), ‘Building real markets for the good of the people’.

Fast markets and market efficiency

There is much evidence that these developments have improved the day-to-day **liquidity and efficiency of these markets**; that is, the degree to which participants are able to transact in reasonable size in a timely manner, at or close to prevailing prices – giving rise to prices that accurately reflect market participants' aggregate view of asset values.

Empirical research has found that, on average, the presence of high-frequency traders has been associated with improved headline measures of liquidity, at least for trading in small size. There are two reasons why this might be the case. First, as mentioned above, because automated traders are able to achieve low operating costs per transaction, they are able to charge a narrower bid-ask spread as compensation for providing market making services (Chart 6). Second, their speed allows them to update or cancel their (limit) orders quickly as news arrives, meaning their quotes are less likely to be stale when they are executed (Chart 7).⁴ There is also evidence to suggest the presence of high frequency trading can improve market efficiency.⁵

These are potentially important benefits. The ability to undertake transactions at – or close to – prices that reflect economic fundamentals facilitates the proper allocation of capital, as well as the management and transfer of risk. It also gives borrowers the confidence to plan, and savers to finance, productive investment. Efficient markets also allow for the transmission of monetary policy by allowing changes in policy interest rates to be reflected quickly across financial markets and assets.

The rise in automated high-frequency trading has, however, also increased the incentive for market participants to protect information that could signal their trading intentions. This is to reduce the risk of being disadvantaged by trading with other – faster-moving – market participants, and thus receiving a worse price (a phenomenon sometimes referred to as 'slippage').⁶

This strategic interaction has manifested itself in two observable trends.

First, there has been a partial reversal in the trend toward greater price transparency I highlighted earlier. Market participants have embraced other forms of trading, which differ to traditional exchanges either by offering less price transparency and/or a narrower range of counterparties.

⁴ This effect has been explicitly modelled by Jovanovic, B and Menkveld, A (2011) and empirically documented in a number of instances and trading venues – e.g. by Hendershott, T, Jones, C and Menkveld, A (2011) for the NYSE, Riordan, R and Storkenmaier, A (2011) for the Deutsche Börse, and Hasbrouck, J and Saar, G (2013) for the Nasdaq.

⁵ See Benos, E, Brugler, J and Hjalmarsson, E (2015), 'Interactions among high-frequency traders', Bank of England Working Paper, No. 523.

⁶ See Kervel, V, and Menkveld, A. J (2017), 'High-frequency trading around large institutional orders', Working paper.

In equity markets, for example, there has been a shift away from trading on ‘lit’ exchanges⁷ (Chart 8). The market has moved more towards ‘off-book’ trading, where participants transact bilaterally, seeking not to reveal information on their trading intentions, and to dark venues⁸, such as broker-crossing networks⁹ and some multi-lateral trading facilities.¹⁰ Meanwhile, FX markets have seen a move away from ‘exchange-like’ platforms¹¹ toward trading methods offering a more restricted range of counterparties and/or offering visibility to participants on who they are trading with (Chart 9). The aim is to disclose less information to the broader market, while counterparty awareness allows monitoring of metrics such as fill ratios and market impact over time.

Second, market participants’ desire to avoid revealing information on their trading intentions and seek the best price has led them to split up large orders, including via the use of algorithms. This can be seen in a reduction in trade sizes (Chart 10), as well as an increase in the rate at which orders in some markets are updated or cancelled.

Here at the Bank we want end-users to both benefit from and be confident in the effectiveness of financial markets.¹² So whilst these behaviours are presumably rational – and cost-effective – for individual market participants, we are mindful that an aggregate reduction in transparency has the potential to hamper efficient price discovery.¹³ Moreover, the steps some participants are taking to conceal information raises questions about how the aggregate efficiency benefits from faster markets are shared. Finally, the occurrence of flash crashes indicates that, even if fast market prices are more efficient in general, they are not always so.

Collectively, these observations suggest we should at least temper the headline conclusion that fast markets are more efficient: as is often the case, the story here is somewhat nuanced.

Fast markets and market resilience

I want to look now at the implications for **resilience**, both of individual firms and of markets – that is, whether they can function effectively in bad times as well as good.

Again, fast markets may bring some important benefits. For example, because they place less reliance on risk warehousing by intermediaries, they were generally resilient during the 2008-09 financial crisis.

Stresses were concentrated in those markets that had relied on dealer balance sheets: in our case the Bank of England introduced a ‘market maker of last resort’ scheme for corporate bond markets in 2009 to offset

⁷ A regulated multilateral trading system, subject to a range of regulatory requirements relating to: pre and post-trade transparency and non-discriminatory access.

⁸ A trading venue where counterparties can post trading interest without making such information publicly available.

⁹ Where a bank or broker matches clients’ buy and sell orders electronically.

¹⁰ Where buyers’ and sellers’ orders are matched anonymously and executed at an agreed-upon reference price.

¹¹ Electronic platforms operating via a central limit order book but that are not regulated exchanges.

¹² See Bank of England (2015), ‘[Open Forum: Building Real Markets for the Good of the People](#)’, June.

¹³ The available evidence is inconclusive. Some studies have found use of less transparent venues, such as dark pools, beneficial for pricing efficiency, but often only up to a certain share of the market. See Aquilina, A, Diaz-Rainey, I, Ibikunle, G and Sun, Y (2017), ‘Aggregate Markets Quality Implications of Dark Trading’, FCA Occasional Paper, No. 29.

the dysfunction in that market; the question of a similar intervention in equity or FX markets simply never arose.

But fast markets, and associated changes in market structure, affect the nature and distribution of risks in ways we are only beginning to understand. Let me explore three examples: first, the implications of flash crashes; second, the changing distribution of risks across firms; and third the potential vulnerability of critical 'nodes' in fast markets.

Implications of flash crashes

Though flash crashes are headline grabbing, and occasionally sleep-denying, they have so far had limited systemic impact. These episodes have been short-lived, and prices have stabilised quickly. In some sense this is quite natural: a sharp movement in market prices exceeding that justified by fundamentals should present a highly profitable investment opportunity for the timely investor.

While it is reasonable to draw comfort from the resilience of fast markets and the lack of spill-overs so far, it is important we recognise the limits of our understanding.

Having been heavily involved in the analysis of sterling flash episode I am confident that we are able to provide forensic ex-post explanations. The Bank for International Settlements (BIS) Markets Committee study, which the Bank of England helped to author, demonstrates that¹⁴; as does the Joint Staff Report on the 2014 US Treasury flash rally.¹⁵ But I doubt we can fully understand what conditions may trigger similar future events or completely anticipate how they might unfold.¹⁶

Specifically, in my view, we are not yet in a position to rule out that future flash episodes might interact with aspects of financial market infrastructure in a way that gives rise to longer-lasting disruption. Suppose, for example, that a future flash episode happened to coincide with benchmark fixings in foreign exchange markets, or a margin call related to equity or derivative markets. The resulting impact on the recorded values of a range of assets might risk mechanically prompting further sales and price falls.

The changing distribution of risks for individual firms

Moving on to my second example, even in the absence of systemic spill-overs from flash episodes, fast markets alter the pattern of risks that individual market participants are exposed to. And there good grounds for concluding that more needs to be done to ensure market participants take account of this consistently.

¹⁴ See BIS (2017), 'The sterling 'flash event' of 7 October 2016', January.

¹⁵ See Joint Staff Report (2015), '[The US Treasury Market on October 15, 2014](#)'.

¹⁶ In this spirit, the FPC concluded following the sterling flash event that "*such disruptions underscore the concern that liquidity in some markets may have become more fragile in recent years*". See Record of the Financial Policy Committee Meetings held on 23 and 29 November 2016.

Use of algorithms does not change the fundamental risks associated with trading in financial markets (e.g. market, counterparty and operational risks). But use of high-frequency trading algorithms does change their relative intensity and can materially increase the potential to build up significant intraday positions. This latter point is most obviously true for those bank and non-bank intermediaries that specialise in high-frequency trading. And though these firms should be expert in managing such risks, history shows this is not a given. Most famously, in August 2012, Knight Capital – a firm engaged in market making and at the time the largest trader in US equities – lost \$460 million as a result of an undetected manual error in its algorithmic trading software. And in 2013, an error in a trading algorithm at HanMag Securities – a Korean brokerage firm – led it to place erroneous equity option trades, generating losses in excess of its capital.¹⁷

As I noted above, end-users – corporates and asset managers – are increasingly splitting up larger trades into smaller pieces and trading them over a longer period. Doing so exposes them to more execution risk; that is, the risk that prices move against them before they have finished transacting – which traditionally was more the preserve of intermediaries. Some end-users are also now automating this trading process through the use of algorithms. Indeed, a recent Greenwich Associates survey found 21% of institutional asset managers and 10% of corporates do so in foreign exchange markets.¹⁸ In so doing they swap one set of risks for another, and the examples of losses by specialist firms in periods of fast market turbulence cautions against assuming that all end-users will effectively manage the new risks associated with the use of algorithms.

These risks can exist through indirect as well as direct exposure to developments in fast markets. Many exchange-traded instruments (such as government bond futures and Exchange Traded Funds (ETFs)) are intrinsically linked with less liquid underlying (slower market) instruments. ETFs clearly bring many business-as-usual benefits which market participants value – for example, the convenience of being able to transfer risk at high-frequency via standardised, exchange-traded securities in fast markets.

There is a question, however, of how these interlinkages work in stress. During the turbulence of August 2015, for example, equity investors flocked to trade in exchange-traded funds, causing ETFs to appear to be priced at large discounts to the value of their – sometimes less liquid – underlying security (Chart 11).

On this occasion, once again, the dislocation was short-lived.

But if a future stress in fast markets – such as those for ETFs – were to persist for a longer period, it might spill over to cause stress in other linked markets, including for less liquid underlying instruments, including government or corporate bonds as well as equities, leading to wider implications for financial stability.

¹⁷ This also caused the firm to default at the CCP, creating a loss that was mutualised among the rest of the CCP's members.

¹⁸ See Greenwich Associates (2016), 'Long-term investors embrace FX algos'.

There is therefore a need to ensure that market participants' risk management frameworks keep pace with the speed at which these markets are capable of moving, taking into account the speed of possible shocks and the potential for propagation, including to slower markets.

The potential vulnerability of critical nodes in fast markets

Finally, it is unclear whether we yet fully understand how the migration towards fast markets has changed the nature or location of critical nodes within the system, and the risks to which they are exposed.

Any intermediation model relies upon a particular infrastructure and has critical nodes. Traditional over-the-counter (OTC) markets, for example, are critically dependent on the willingness of dealers to warehouse risk in return for the informational advantage that seeing the flow provides.

Such frictions have started to take new forms in fast markets. In particular at the same time as high-frequency trading activity has increased, a number of banks have stepped back from acting as market makers and have assumed a more infrastructural role. But new market participants still rely on banks to provide market access and extend them credit when engaging in algorithmic trading, through banks' prime brokerage and clearing businesses.

Providing a competitive service to such technologically advanced clients – particularly those trading at very high frequency – requires substantial investment in technology and infrastructure, including that to facilitate the real-time monitoring of exposures and risk management. The costs associated with this are high, and serve as an effective barrier to entry. As few banks provide these services, this leads to a concentration of nodes of market access for short-term liquidity providers.

The changing role of banks/dealers in fast markets prompts the question whether the nature of potentially disruptive risks is also changing. One obvious concern would be if a prime broker or clearing bank was paralysed, including for reasons unconnected to its activity in fast markets – say because of a cyber attack. I think it is fair to say that our understanding of how market functioning would respond in such a scenario – i.e. one in which a number of, in particular high-frequency, liquidity providers were denied market access – remains relatively limited.

If there is a common theme across all three of my examples, it is the limits of our understanding. None of the points I have raised with regard to market resilience are wholly new. We at the Bank are following developments in the structure of these markets and their implications for financial stability closely, including through discussions within the Bank's Financial Policy Committee (FPC).¹⁹ And as regulator both of many participants in electronic markets and some of those markets themselves, the Financial Conduct

¹⁹ See, for example, Shafik, M (2015), 'Dealing with change: liquidity in evolving market structures' and the analysis of the sterling flash crash in box 3 of the Financial Stability Review, November 2016 (pages 39-41).

Authority (FCA) too has remained deeply engaged and responsive to those developments which fall under its purview.²⁰

Likewise, in none of these cases have I argued that there is a risk flashing red that requires an immediate response. Rather in the best traditions of central banking, my conclusion is that the authorities as a whole need to remain vigilant and deepen our understanding, so that we can take appropriate action in the future if required – be that from a macro-prudential or supervisory perspective.

Looking to the future

Financial markets are ever in a state of flux.

In particular, the trend toward greater automation of trading – my focus today – looks certain to continue, both in already fast markets as well as those currently more reliant on traditional intermediation methods.

Market participants have a clear interest here in understanding how risks to their businesses are evolving and in managing them prudently.

For the authorities, we need to dig deep to understand what this means for the financial system as a whole: both to appreciate the benefits and to remain vigilant as to the risks. This remains very much in focus for the Bank and the FCA. It is important for us to ensure that regulation – both of individual participants, market infrastructure and the financial system as a whole – keeps pace with the changes in the type and distribution of risk. Only then can it provide an adequate guard against risks to prudentially regulated institutions and their counterparties.

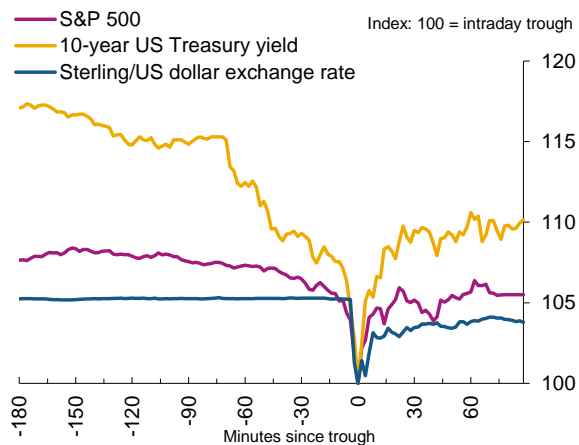
Regulation is most effective when informed by a rich and diverse set of research – and here we need help from the academic community. There is enormous potential for varied and interesting research in the area of fast markets. I have covered just some of the questions which seem to us to be particularly relevant at present – and as markets evolve no doubt new topics and questions will present themselves. I encourage those of you with an interest in this area to keep running with it – your input is of great value to us.

Keeping up with fast markets isn't easy. But with your help I'm sure we can rise to the challenge of ensuring that fast markets are there to serve the real economy, both in good times and bad.

Thank you.

²⁰ For example, see Schooling Letter (2016), 'Electronification of trading'.

Chart 1 Recent episodes of heightened short-term volatility in liquid markets^{(a)(b)}

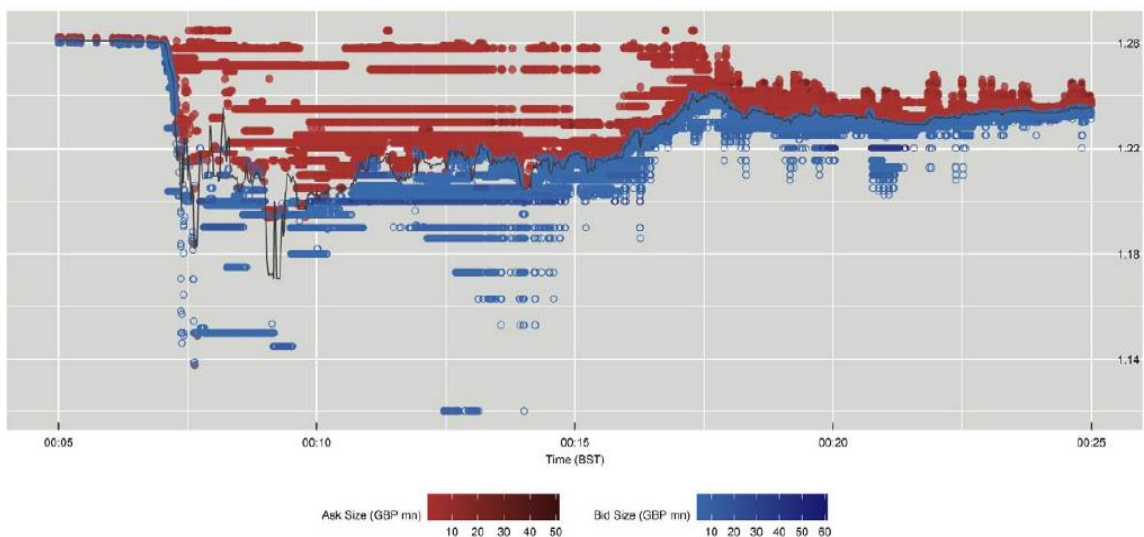


Sources: Bloomberg and Bank calculations

(a) Sterling flash event 7 October 2016 (blue), US equity markets flash-crash 6 May 2010 (magenta), and US Treasury market flash-rally 15 October 2014 (orange).

(b) Data shown in two minutes intervals, and may not fully capture the lowest traded prices during each event

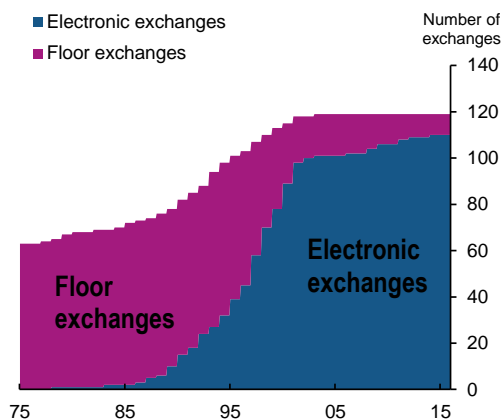
Chart 2 Thomson Reuters Matching GBP/USD price and order book behaviour in the sterling flash event of 7 October 2016^(a)



Source: BIS Markets Committee report: "The sterling flash event of 7 October 2016"

(a) The blue and red circles here represent resting bid and offer limit orders, respectively, in the order book. The black line represents the implied mid-price, and the intensity of the blue and red colours signifies the size of the order.

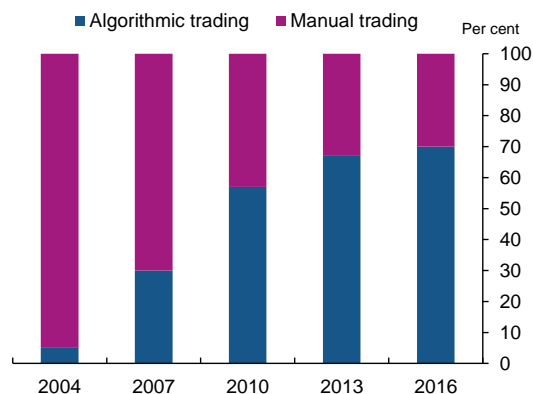
Chart 3 Numbers of electronic and floor equity exchanges^(a)



Sources: Jain (2005), Hendershott & Seasholes (2006), exchange websites and Bank calculations

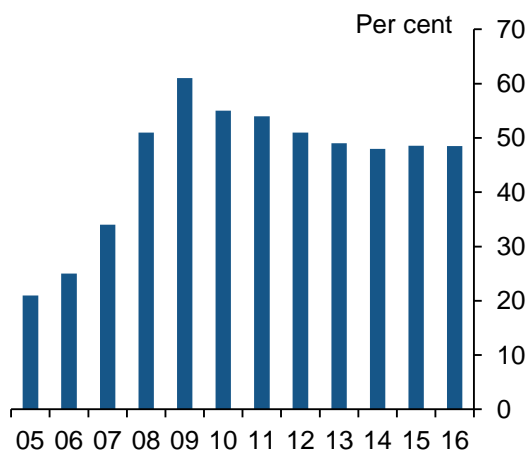
(a) Based on the date of automation of largest international stock exchanges across 119 countries.

Chart 4 Share of algorithmic trading in FX spot markets



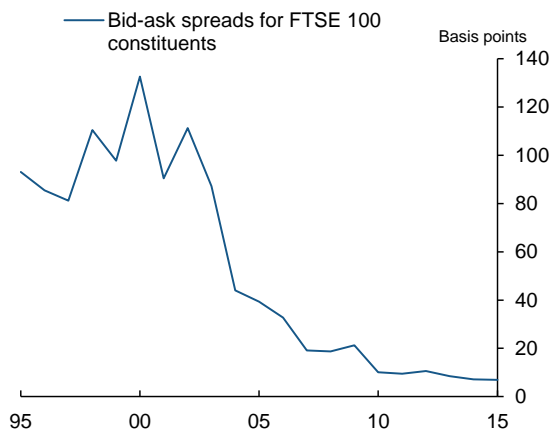
Sources: Bank of International Settlements and Electronic Broking Services (EBS)

Chart 5 Estimated proportion of PTF activity in total US equity trading



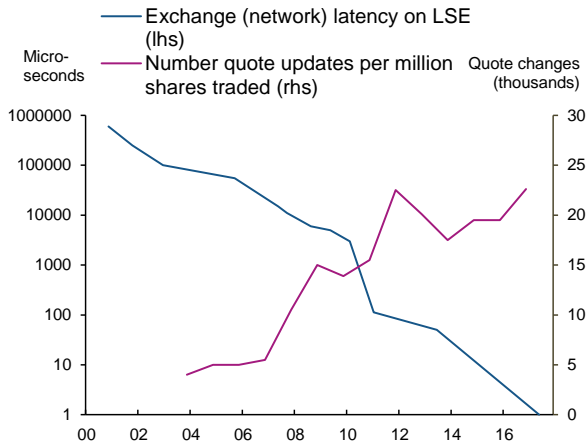
Sources: Tabb Group, reproduced from Credit Suisse – ‘We are all High Frequency Traders Now’

Chart 6 Yearly average bid-ask spreads for FTSE 100 constituents



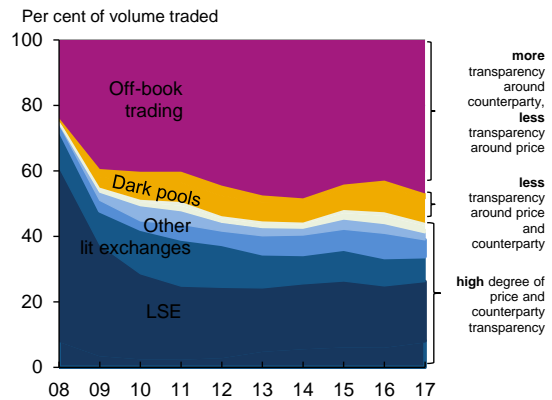
Source: Thomson Reuters

Chart 7 Latency on the LSE and number of US consolidated tape quote updates



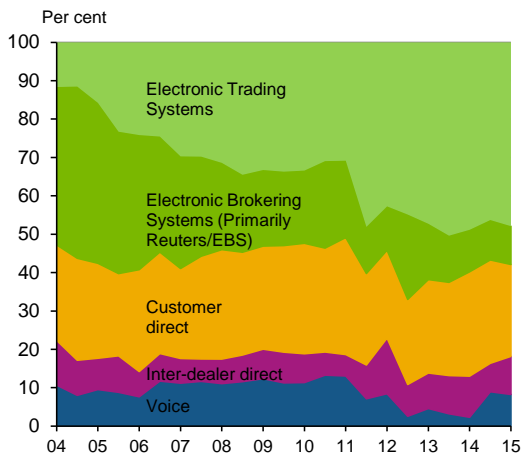
Source: Brogaard (2013), LSE Group, Credit Suisse Research – ‘We’re All High Frequency Traders Now’

Chart 8 Share of trading across venues in UK equity markets



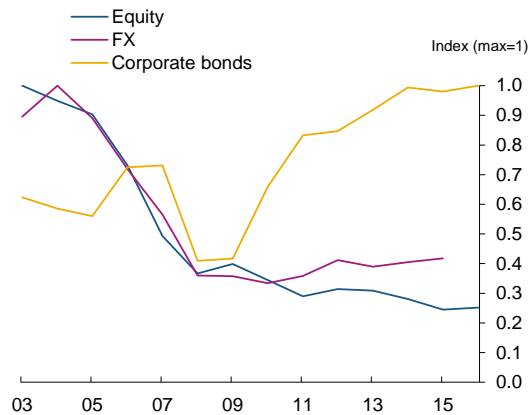
Source: Fidessa

Chart 9 Share of trading across venues in US spot FX markets



Source: US Foreign Exchange Commission

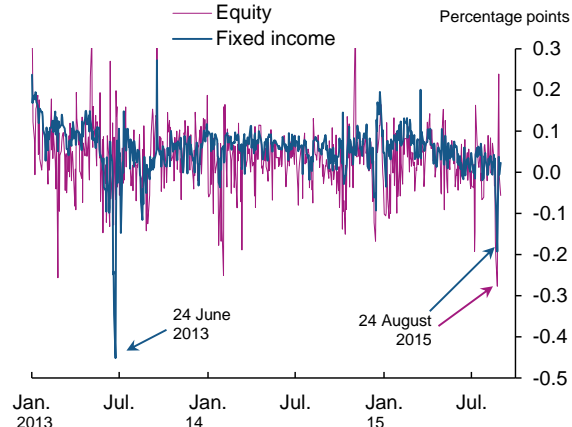
Chart 10 Average trade sizes in selected equity^(a), FX^(b) and corporate bond markets^(c)



Sources: US Foreign Exchange Committee, World Federation of Exchanges, FCA, Mizrach (2017) and Bank calculations

- (a) Trade sizes on London Stock Exchange (LSE)
- (b) Based on US Foreign Exchange Committee survey of US-based participants in FX spot markets
- (c) UK and US corporate bond markets

Chart 11 Deviation from NAV in equity and fixed income ETFs ^(a)



Sources: Bloomberg and Bank calculations.
(a) Average across the 50 largest equity and fixed income ETFs globally by assets.