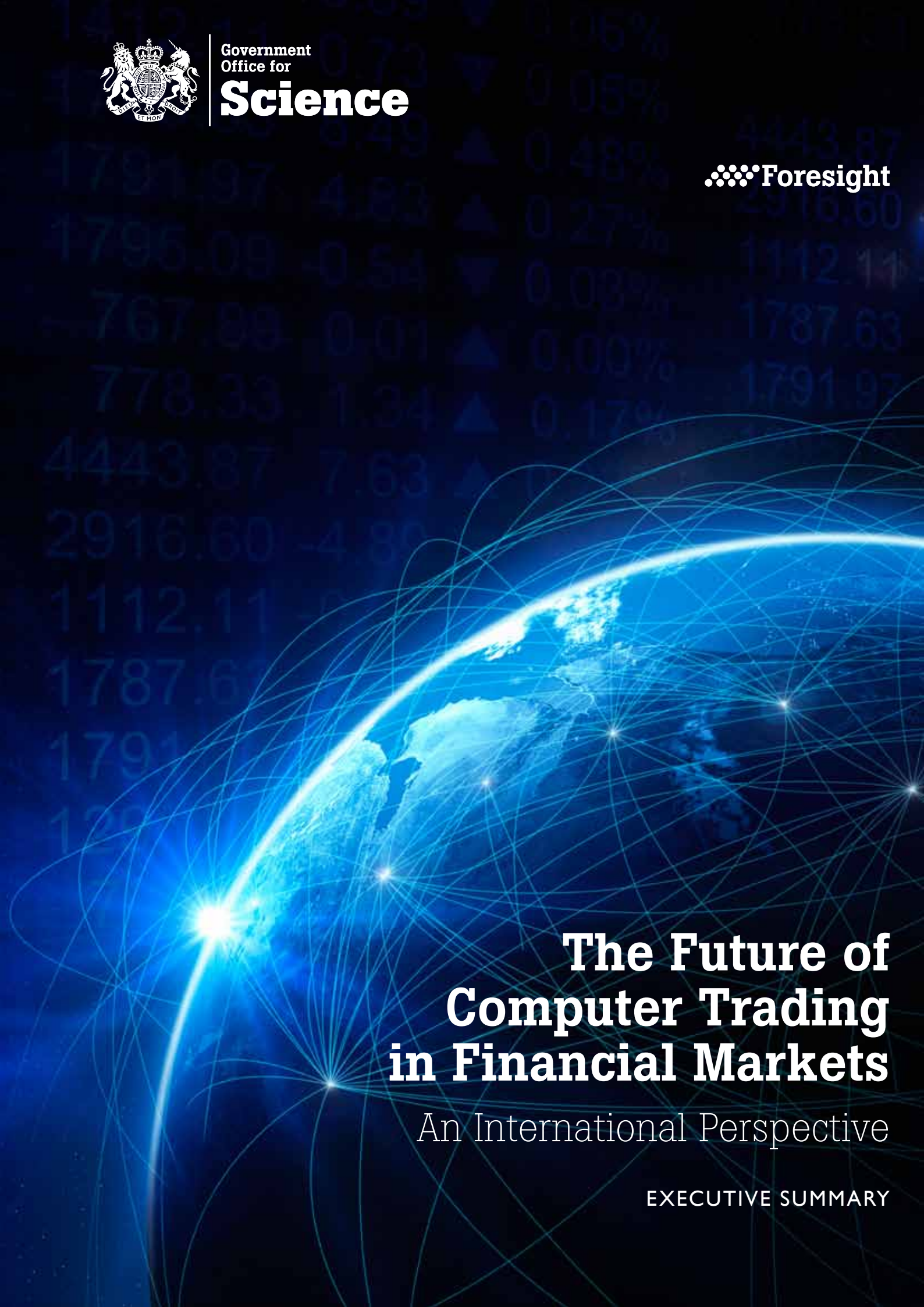

Government Office for Science

Foresight

The Future of Computer Trading in Financial Markets

An International Perspective

EXECUTIVE SUMMARY

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The Future of Computer Trading in Financial Markets

An International Perspective

EXECUTIVE SUMMARY

This Report is intended for:

Policy makers, legislators, regulators and a wide range of professionals and researchers whose interest relate to computer trading within financial markets. This Report focuses on computer trading from an international perspective, and is not limited to one particular market.

Foreword

Well functioning financial markets are vital for everyone. They support businesses and growth across the world. They provide important services for investors, from large pension funds to the smallest investors. And they can even affect the long-term security of entire countries.

Financial markets are evolving ever faster through interacting forces such as globalisation, changes in geopolitics, competition, evolving regulation and demographic shifts. However, the development of new technology is arguably driving the fastest changes. Technological developments are undoubtedly fuelling many new products and services, and are contributing to the dynamism of financial markets. In particular, high frequency computer-based trading (HFT) has grown in recent years to represent about 30% of equity trading in the UK and possibly over 60% in the USA.

HFT has many proponents. Its roll-out is contributing to fundamental shifts in market structures being seen across the world and, in turn, these are significantly affecting the fortunes of many market participants. But the relentless rise of HFT and algorithmic trading (AT) has also attracted considerable controversy and opposition. Some question the added value it brings to markets and, indeed, whether it constitutes a drag on market efficiency. Crucially, some also believe that it may be playing an increasing role in driving instabilities in particular markets. This is of concern to all financial markets, irrespective of their use of HFT, since increasing globalisation means that such instabilities could potentially spread through contagion. It has also been suggested that HFT may have significant negative implications relating to market abuse. For these reasons, it is unsurprising that HFT is now attracting the urgent attention of policy makers and regulators across the world.

This international Foresight Project was commissioned to address two critical challenges. First, the pace of technological change, coupled with the ever-increasing complexity of financial trading and markets, makes it difficult to fully understand the present effect of HFT/AT on financial markets, let alone to develop policies and regulatory interventions that are robust to developments over the next decade. Second, there is a relative paucity of evidence and analysis to inform new regulations, not least because of the time lag between rapid technological developments and research into their effects. This latter point is of particular concern, since good regulation clearly needs to be founded on good evidence and sound analysis.

Therefore, the key aim of this Project has been to assemble and analyse the available evidence concerning the effect of HFT on financial markets. Looking back through recent years and out to 2022, it has taken an independent scientific view. The intention has been to provide advice to policy makers. Over 150 leading academics from more than 20 countries have been involved in the work which has been informed by over 50 commissioned papers, which have been subject to independent peer review.

The key message is mixed. The Project has found that some of the commonly held negative perceptions surrounding HFT are not supported by the available evidence and, indeed, that HFT may have modestly improved the functioning of markets in some respects. However, it is believed that policy makers are justified in being concerned about the possible effects of HFT on instability in financial markets. Therefore, the Final Report provides clear advice on what regulatory measures might be most effective in addressing those concerns in the shorter term, while preserving any benefits that HFT/AT may bring. It also advises what further actions should be undertaken to inform policies in the longer term, particularly in view of outstanding uncertainties. In conclusion, it is my pleasure to make the Final Report and all of its supporting evidence and analysis freely available. It is my hope that it will provide valuable insights into this crucial issue.

Professor Sir John Beddington CMG, FRS

Chief Scientific Adviser to HM Government and
Head of the Government Office for Science

Lead expert group overseeing the Project:

Dame Clara Furse (Chair)	Non-executive Director, Legal & General plc, Amadeus IT Holding SA, Nomura Holdings Inc., Chairman, Nomura Bank International, Non-executive Director, Department for Work and Pensions and Senior Adviser, Chatham House.
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Professor Dave Cliff	Professor of Computer Science at the University of Bristol.
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Foresight would like to thank Dr Sylvain Friederich, University of Bristol, Professor Maureen O'Hara, Cornell University and Professor Richard Payne, Cass Business School, City University, London for their involvement in drafting parts of this Report.

Foresight would also like to thank Andy Haldane, Executive Director for Financial Stability at the Bank of England, for his contribution in the early stages of the Project.

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For further information about the Project please visit:

http://www.bis.gov.uk/foresight

Executive summary

A key message: despite commonly held negative perceptions, the available evidence indicates that high frequency trading (HFT) and algorithmic trading (AT) may have several beneficial effects on markets. However, HFT/AT may cause instabilities in financial markets in specific circumstances. This Project has shown that carefully chosen regulatory measures can help to address concerns in the shorter term. However, further work is needed to inform policies in the longer term, particularly in view of likely uncertainties and lack of data. This will be vital to support evidence-based regulation in this controversial and rapidly evolving field.

1 The aims and ambitions of the Project

The Project's two aims are:

- to determine how computer-based trading (CBT) in financial markets across the world could evolve over the next ten years, identifying potential risks and opportunities that this could present, notably in terms of financial stability[1] but also in terms of other market outcomes, such as volatility, liquidity, price efficiency and price discovery;
- to draw upon the available science and other evidence to provide advice to policy makers, regulators and legislators on the options for addressing present and future risks while realising potential benefits.

An independent analysis and an international academic perspective:

The analysis provides an independent view and is based upon the latest science and evidence. As such, it does not constitute the views or policy of the UK or any other government.

Over 150 leading academics and experts from more than 20 countries have been involved in the work which has been informed by over 50 commissioned scientific papers, which have been independently peer reviewed. A further 350 stakeholders from across the world also provided advice on the key issues to consider[2].

2 Why the Project was undertaken

Well functioning financial markets are vital for the growth of economies, the prosperity and well-being of individuals, and can even affect the security of entire countries. Markets are evolving rapidly in a difficult environment, characterised by converging and interacting macro- and microeconomic forces, such as globalisation, changes in geopolitics, competition, evolving regulation and demographic shifts. However, the development and application of new technology is arguably causing the most rapid changes in financial markets. In particular, HFT and AT in financial markets have attracted considerable controversy relating to their possible benefits and risks.

While HFT and AT have many proponents, others question the added value they bring to markets, and indeed whether they constitute a drag on market efficiency. Crucially, some believe they may be playing an increasingly significant role in driving instabilities in particular markets. There have been suggestions that HFT and AT may have significant negative implications relating to market abuse. For these reasons, and in view of the vital importance of financial markets, both HFT and AT are now attracting the urgent attention of policy makers and regulators across the world.

1 A list of definitions used in this Executive Summary can be found in Annex C of the Project's Final Report.

2 A list of individuals who have been involved can be found in Annex A of the Project's Final Report.

Two challenges for regulators:

Effective regulation must be founded on robust evidence and sound analysis. However, this Project addresses two particular challenges currently faced by regulators:

- *Rapid developments and applications of new technology, coupled with ever-increasing complexity of financial trading and markets make it difficult to fully understand the present effects of HFT and AT on financial markets and even more difficult to develop policies and regulatory interventions which will be robust to developments over the next decade.*
- *There is a relative lack of evidence and analysis to inform the development of new regulations, not least because of the time lag between rapid technological developments and research into their effects, and the lack of available, comprehensive and consistent data.*

These two challenges raise important concerns about the level of resources available to regulators in addressing present and future issues. Setting the right level of resources is a matter for politicians. However, unlocking the skills and resources of the wider international academic community could also help. Here, a drive towards making better data available for analysis should be a key objective and the experience of this Project suggests that political impetus could be important in achieving that quickly.

It makes sense for the various parties involved in financial markets to be brought together in framing further analytical work, in order to promote wide agreement to the eventual results. Everyone will benefit from further research that addresses areas of controversy, as these can cloud effective and proportionate policy development, and can result in sub-optimal business decisions.

3 Technology as a key driver of innovation and change in financial markets[3]

The relentless development and deployment of new technologies will continue to have profound effects on markets at many levels. They will directly affect developments in HFT/AT and continue to fuel innovation in the development of new market services. And they will also help to drive changes in market structure.

New technologies are creating new capabilities that no human trader could ever offer, such as assimilating and integrating vast quantities of data and making multiple accurate trading decisions on split-second time-scales. Ever more sophisticated techniques for analysing news are also being developed and modern automated trading systems can increasingly learn from monitoring sequences of events in the market. HFT/AT is likely to become more deeply reliant on such technologies.

Future developments with important implications:

- *There will be increasing availability of substantially cheaper computing power, particularly through cloud computing:* those who embrace this technology will benefit from faster and more intelligent trading systems in particular.
- *Special purpose silicon chips will gain ground from conventional computers:* the increased speed will provide an important competitive edge through better and faster simulation and analysis, and within transaction systems.
- *Computer-designed and computer-optimised robot traders could become more prevalent:* in time, they could replace algorithms designed and refined by people, posing new challenges for understanding their effects on financial markets and for their regulation.
- *Opportunities will continue to open up for small and medium-sized firms offering 'middleware' technology components, driving further changes in market structure:* such components can be purchased and plugged together to form trading systems which were previously the preserve of much larger institutions.

3 For a more detailed review of the evidence reported in this section, see Chapter 2 in the Project's Final Report.

Three key challenges arising from future technological developments:

- *The extent to which different markets embrace new technology will critically affect their competitiveness and therefore their position globally:* The new technologies mean that major trading systems can exist almost anywhere. Emerging economies may come to challenge the long-established historical dominance of major European and US cities as global hubs for financial markets if the former capitalise faster on the technologies and the opportunities presented.
- *The new technologies will continue to have profound implications for the workforce required to service markets, both in terms of numbers employed in specific jobs, and the skills required:* Machines can increasingly undertake a range of jobs for less cost, with fewer errors and at much greater speed. As a result, for example, the number of traders engaged in on-the-spot execution of orders has fallen sharply in recent years, and is likely to continue to fall further in the future. However, the mix of human and robot traders is likely to continue for some time, although this will be affected by other important factors, such as future regulation.
- *Markets are already 'socio-technical' systems, combining human and robot participants. Understanding and managing these systems to prevent undesirable behaviour in both humans and robots will be key to ensuring effective regulation:* While the Final Report demonstrates that there has been some progress in developing a better understanding of markets as socio-technical systems, greater effort is needed in the longer term. This would involve an integrated approach combining social sciences, economics, finance and computer science. As such, it has significant implications for future research priorities.

4 The impact of computer-based trading on market quality: liquidity, price efficiency/discovery and transaction costs[4]

While the effect of CBT on market quality is controversial, the evidence available to this Project suggests that CBT has several beneficial effects on markets, notably:

- *liquidity, as measured by bid-ask spreads and other metrics, has improved;*
- *transaction costs have fallen for both retail and institutional traders, mostly due to changes in trading market structure, which are related closely to the development of HFT in particular;*
- *market prices have become more efficient, consistent with the hypothesis that CBT links markets and thereby facilitates price discovery.*

While the above improvements in market quality should not be overstated, they are important, particularly since they counter the belief that HFT provides no useful function in financial markets. Nevertheless, there are concerns relating to market quality which are worthy of mention.

A particular concern:

While overall liquidity has improved, there appears to be greater potential for periodic illiquidity: The nature of market making has changed, with high frequency traders now providing the bulk of such activity in both futures and equities. However, unlike designated specialists, high frequency traders typically operate with little capital, hold small inventory positions and have no obligations to provide liquidity during periods of market stress. These factors, together with the ultra-fast speed of trading, create the potential for periodic illiquidity. The US Flash Crash and other more recent smaller events illustrate this increased potential for illiquidity.

A key message: regulatory changes in practices and policies will be needed to catch up to the new realities of trading in asset markets. However, caution needs to be exercised to avoid undoing the advantages that HFT has brought.

4 For a more detailed review of the evidence reported in this section, see Chapter 3 in the Project's Final Report.

5 Financial stability and computer-based trading[5]

The evidence available to this Project provides no direct evidence that computer-based HFT has increased volatility in financial markets. However, in specific circumstances CBT can lead to significant instability. In particular, self-reinforcing feedback loops, as well as a variety of informational features inherent in computer-based markets, can amplify internal risks and lead to undesired interactions and outcomes. This can happen even in the presence of well-intentioned management and control processes. Regulatory measures for addressing potential instability are considered in Section 7 of this Executive Summary.

Three main mechanisms that may lead to instabilities and which involve CBT are:

- nonlinear sensitivities to change, where small changes can have very large effects, not least through feedback loops;
- incomplete information in CBT environments where some agents in the market have more, or more accurate, knowledge than others and where few events are common knowledge;
- internal 'endogenous' risks based on feedback loops within the system.

The feedback loops can be worsened by incomplete information and a lack of common knowledge.

A further cause of instability is social: a process known as 'normalisation of deviance', where unexpected and risky events (such as. extremely rapid crashes) come to be seen as increasingly normal, until a disastrous failure occurs.

6 Market abuse[6] and computer-based trading[7]

Economic research thus far, including the empirical studies commissioned by this Project, provides no direct evidence that HFT has increased market abuse[8]. However, the evidence in the area remains tentative: academic studies can only approximate market abuse as data of the quality and detail required to identify abuse are simply not available to researchers.

This Project has commissioned three empirical studies that find no direct evidence of a link between HFT and market abuse. The main focus of these studies is not on the measurement of market abuse during the continuous phase of trading, however. The Project has reviewed qualitative evidence on perceived levels of manipulation from various sources including interviews with traders and investors, the financial press, UK and international regulatory reports, submissions to regulatory consultations and large-scale surveys of market participants. A new survey of end users was also carried out by the Project[9].

This qualitative evidence consistently indicates high levels of concern. Claims of market manipulation using HFT techniques are reported by institutional investors such as pension funds and mutual funds in different countries. These claims are, in turn, widely relayed by the financial press. Even if not backed by statistical evidence, these perceptions need to be taken seriously by policy makers because, given that the true extent of abuse is not precisely known, it is perception that is likely to determine the behaviour of liquidity suppliers. High perceived levels of abuse may harm market liquidity and efficiency for all classes of traders.

The qualitative evidence mentioned above is not easy to interpret unambiguously. It is consistent with three different 'scenarios' that are not mutually exclusive:

- High frequency traders exploit their speed advantage to disadvantage other participants in financial terms.
- The growth of HFT has changed order flows in ways that facilitate market abuse by both slow and fast agents (for example, by making 'predatory trading' easier).

5 For a more detailed review of the evidence reported in this section, see Chapter 4 in the Project's Final Report.

6 Here the concern is with market abuse relating to manipulative behaviour, by which a market is temporarily distorted to one party's advantage. Abuse relating to insider trading is not considered here.

7 For a more detailed review of the evidence reported in this section, see Chapter 5 in the Project's Final Report.

8 A list of the studies commissioned by the Project can be found in the Annex.

9 SR1 (Annex refers).

- Other market developments concomitant with the growth in HFT, but not necessarily brought about by HFT growth, may have contributed to an increase in the perception or actual prevalence of abuse. Fragmentation of liquidity across trading venues is an example.

Regulators and policy makers can influence perceptions, even if definitive evidence on the extent of abuse will not be available to settle the debate.

- *Regulators can address the lack of confidence that market participants have in their ability to detect and prosecute abuse in HFT and fragmented markets.* While this may require significant investment in regulatory activity, if progress is made, both the perception and reality of abuse will be reduced; for abusers, even a perceived threat of being caught may be a powerful disincentive.
- *More statistical evidence on the extent of HFT manipulation most often described by institutional investors can be produced*[10]. This will help to correct or confirm perceptions. It will also be important in guiding regulatory action, as the three scenarios outlined above may have very different policy implications.

Detecting evidence of market abuse from vast amounts of data from increasingly diverse trading platforms will present a growing challenge for regulators.

To identify abuse, each national regulator will need access to international market data. Otherwise the market abuser can hide by transacting simultaneously in several separately linked markets. In the USA, the Office of Financial Research (OFR) has been commissioned by the Dodd-Frank Act to fund a financial data centre to collect, standardise and analyse such data. *There may be case for a similar initiative to be introduced in Europe.*

7 Economic impact assessments of policy measures[11]

A number of policies related to CBT are being considered by policy makers with the goals of improving market efficiency and reducing the risks associated with financial instability. This Project has commissioned a variety of studies to evaluate these policies, with a particular focus on their economic costs and benefits[12]*. The key conclusions are set out below.*

Policy measures that could be effective:

- Circuit breakers: *There is general support for these, particularly for those designed to limit periodic illiquidity induced by temporary imbalances in limit order books.* They are especially relevant to markets operating at high speed. Different markets may find different circuit breaker policies optimal, but in times of overall market stress there is a need for coordination of circuit breakers across markets, and this could be a mandate for regulatory involvement. New types of circuit breakers triggered by *ex-ante* rather than *ex-post* trading may be particularly effective in dealing with periodic illiquidity. However, further investigation is needed to establish how coordination could best be achieved in the prevailing market structure.
- Tick size policy: *This can have a large influence on transactions costs, market depth and liquidity provision.* The current approach of allowing each European trading venue to choose its own minimum tick size has merits, but this can result in a race to the bottom between venues. A uniform policy applied across all European trading venues is unlikely to be optimal, but a coherent overall minimum tick size policy applying to subsets of trading venues may be desirable. This coordinated policy could be industry-based, such as the one agreed to recently by the Federation of European Securities Exchanges (FESE) members.

10 'Quote stuffing' or order book 'layering' are obvious examples.

11 For a more detailed review of the evidence reported in this section, see Chapter 6 in the Project's Final Report.

12 A list of the economic impact assessments commissioned by the Project can be found in the Annex .

Policy measures that are likely to be problematic:

- **Notification of algorithms:** The implementation of this, even if feasible, would require excessive costs for both firms and regulators. It is also doubtful that it would substantially reduce the risk of market instability due to errant algorithmic behaviour.
- **Imposing market maker obligations and minimum resting times on orders:** The former issue runs into complications arising from the nature of high frequency market making across markets, which differs from traditional market making within markets. Requirements to post two-sided quotes may restrict, rather than improve, liquidity provision. Similarly, minimum resting times, while conceptually attractive, can impinge upon hedging strategies that operate by placing orders across markets and expose liquidity providers to increased 'pick-off risk' due to the inability to cancel stale orders.
- **Order-to-execution ratios:** This would be a blunt instrument to reduce excessive message traffic and cancellation rates. While it could potentially reduce undesirable manipulative strategies, it may also curtail beneficial strategies. There is not sufficient evidence at this point to ascertain these effects, and so caution is warranted. Explicit fees charged by exchanges on excessive messaging, as well as greater regulatory surveillance geared to detect manipulative trading practices may be more desirable approaches to deal with these problems.
- **Maker-taker pricing:** The issue is complex and is related to other issues like order routing, priority rules and best execution. Regulatory focus on these related areas seems a more promising way of constraining any negative effects of maker-taker pricing than direct involvement in what is generally viewed as an exchange's business decision.
- **The virtual central limit order book (CLOB):** The introduction of competition between trading venues brought about by Markets in Financial Instruments Directive (MiFID) has resulted in more choices for investors and, in many cases, improved market quality, but it has also led to greater complexity and risk. The virtual CLOB it has created is still evolving and improving, but its current structure falls short of a single integrated market. This raises a number of issues for both individual exchange and market behaviour.
- **Constraining internalisation or, more generally, dark trading:** Off-exchange trading can be mutually beneficial for all parties involved, especially where large orders are involved. However, the trend away from pre-trade transparency cannot be continued indefinitely without detrimental effects on the public limit order book and price discovery. Constraining these activities within a range that does not adversely affect price discovery but does allow for beneficial trading is important but difficult. Evidence gathered from European markets is too limited to give satisfactory guidance.
- **Call auctions:** These are an alternative trading mechanism that would eliminate most of the advantage for speed present in modern electronic markets. They are widely used already in equity markets at open and close and following a trading halt, although no major market uses them exclusively. To impose call auctions as the only trading mechanism seems unrealistic and draconian. There are serious coordination issues related to hedging strategies that would make this policy undesirable.

Two words of caution: Whilst the above conclusions are consistent with the currently available evidence, further empirical study is desirable for some of the policy measures in particular. It should also be recognised that some of the above individual policy options interact with each other in important ways. For example, the presence or absence of circuit breakers affects most other measures, as does minimum tick sizes. Decisions on individual policies should not therefore be taken in isolation, but should take account of such important interactions[13].

13 See the Project's Final Report (Chapter 6, Section 6.12) and also the supporting evidence papers which were commissioned (Annex refers).

8 Computers and complexity

Over coming decades, the increasing use of computers and information technology in financial systems is likely to make them more, rather than less complex. Such complexity will reinforce information asymmetries and cause principal/agent problems, which in turn will damage trust and make the financial systems sub-optimal. Constraining and reducing such complexity will be a key challenge for policy makers. Options include requirements for trading platforms to publish information using an accurate, high resolution, synchronised timestamp. Improved standardisation of connectivity to trading platforms could also be considered.

However, there is no 'magic bullet' to address this issue. Policy makers will need an integrated approach based on improved understanding of financial systems. This will need to be achieved through:

- **Improved post-trade transparency:** The challenge of ensuring adequate dissemination and storage of trading data to enable market abuse to be identified provides an important example of where improvements need to be considered.
- **Analysis:** Making sense of disclosed information and developing a better understanding of the financial system will be critical. This implies the need to harness the efforts of researchers[14].

A further proposal that is sometimes made is that (various categories of) agents should only be allowed to hold or issue instruments which have been approved by the authorities in advance. This contrasts with the more common position that innovation should be allowed to flourish, but with the authorities retaining the power to ban the uses of instruments where they consider evidence reveals undesirable effects. The former stance, however, not only restricts innovation, but also such official approval may well have unintended consequences. Furthermore, the effectiveness of such official approval is debatable. Officials have no more, and probably less, skill in foreseeing how financial instruments will subsequently fare than credit rating agencies or market agents. Indeed, many, possibly all, of the instruments now condemned in some quarters as having played a part in the recent global financial crisis would, at an earlier time, have probably been given official approval.

A corrective step that could, and should, be taken is to simplify (electronic) financial systems by the application of greater standardisation, particularly in the form of accurate, high resolution, synchronised timestamps. CBT, operating on many trading platforms, has led to a vast expansion of data, which are often not standardised, nor easily accessible to third parties (for example, regulators and academics) for analysis and research. The relevant authorities should consider following the US example and establish a European Financial Data Centre to collect, standardise and analyse such data.

9 Conclusions – key priorities for action[15]

While the effects CBT on financial markets have been the topic of some controversy in recent years, analysis of the available evidence has shown that CBT has led to benefits to the operation of markets, notably relating to liquidity, transaction costs and the efficiency of market prices[16]. Against the background of ever greater competition between markets, it is highly desirable that any new policies or market regulation preserve these benefits.

However, this Project has also highlighted legitimate concerns that merit the close attention of policy makers, particularly relating to the possibility of instabilities occurring in certain circumstances, and also periodic illiquidity[17]. In view of the critical importance of financial markets for global growth and prosperity, the following suggests priorities for action:

14 See Section 9 of this Executive Summary.

15 For a more detailed review of this section, see Chapter 8 in the Project's Final Report.

16 See Section 4 of this Executive Summary.

17 See Section 5 of this Executive Summary.

A. Limiting possible future market disturbances:

A.1 European authorities[18], working together, and with financial practitioners and academics, should assess (using evidence-based analysis) and introduce mechanisms for managing and modifying the potential adverse side-effects of CBT and HFT. Section 7 of this Executive Summary sets out analysis of ten individual policy options, and provides advice on which are supported most by the available evidence. It is also important that such regulatory measures are considered together, not individually, in view of important interactions which may exist between some of them.

A.2 Coordination of regulatory measures between markets is important and needs to take place at two levels:

- *Regulatory constraints involving CBT in particular need to be introduced in a coordinated manner across all markets where there are strong linkages.*
- *Regulatory measures for market control must also be undertaken in a systematic global fashion to achieve in full the objectives they are directed at.* A joint initiative from a European Office of Financial Research and the US Office of Financial Research (OFR), with the involvement of other international markets, could be one option for delivering such global coordination.

A.3 Legislators and regulators need to encourage good practice and behaviour in the finance and software engineering industries. This clearly involves the need to discourage behaviour in which increasingly risky situations are regarded as acceptable, particularly when failure does not appear as an immediate result[19]. These recognise that financial markets are essentially complex 'socio-technical' systems, in which both humans and computers interact: the behaviour of computers should not be considered in isolation.

A.4 Standards should play a larger role. Legislators and regulators should consider implementing accurate, high resolution, synchronised timestamps because this could act as a key enabling tool for analysis of financial markets. Clearly it could be useful to determine the extent to which common gateway technology standards could enable regulators and customers to connect to multiple markets more easily, making more effective market surveillance a possibility.

A.5 In the longer term, there is a strong case to learn lessons from other safety-critical industries, and to use these to inform the effective management of systemic risk in financial systems. For example, high-integrity engineering practices developed in the aerospace industry could be adopted to help create safer automated financial systems.

B. Making surveillance of financial markets easier:

B.1 The development of software for automated forensic analysis of adverse/extreme market events would provide valuable assistance for regulators engaged in surveillance of markets. This would help to address the increasing difficulty that people have in investigating events.

C. Improving understanding of the effects of CBT in both the shorter and longer term:

C.1 Unlocking the power of the research community has the potential to play a vital role in addressing the considerable challenge of developing better evidence-based regulation relating to CBT risks and benefits and also market abuse in such a complex and fast-moving field. It will also help to further address the present controversy surrounding CBT. Suggested priorities include:

- *Developing an 'operational process map':* this would detail the processes, systems and interchanges between market participants through the trade life cycle, and so help to identify areas of high systemic risk and broken or failing processes.
- *Making timely and detailed data across financial markets easily available to academics, but recognising the possible confidentiality of such data.*

18 While several of these potential actions for stakeholders are framed within the European context, they will also be relevant to stakeholders in other parts of the world.

19 A term for behaviour which accepts increasingly risky situations in the absence of adverse effects is called 'normalisation of deviance'. See Section 5 of this Executive Summary.

C.2 The above measures need to be undertaken on an integrated and coordinated international basis in order to realise the greatest added value and efficiency. One possible proposal would be to establish a European Financial Data Centre.

In conclusion:

It is hoped that the analysis and arguments contained in the Foresight Final Project Report, together with over 50 commissioned evidence papers which underpin it, will assist policy makers, regulators and market practitioners in their current consideration of CBT. In this context, special thanks are due to the 150 or so leading and independent experts from over 20 countries who have been involved in this undertaking.

This Executive Summary and the underlying Project Report provide an independent view based on the best available science and evidence. They do not constitute the views or policy of the UK or any other government.

Annex
Project reports and papers

Executive Summary

Driver Reviews

DR1: What has happened to UK equity market quality in the last decade?

DR2: Feedback effects and changes in the diversity of trading strategies

DR3: Technology trends in the financial markets

DR4: The global financial markets – an ultra-large-scale systems perspective

DR5: Computer-based trading, liquidity and trading costs

DR6: An ecological perspective on the future of computer trading

DR7: Crashes and high frequency trading

DR8: Automated analysis of news to compute market sentiment

DR9: Leverage, forced asset sales and market stability

DR10: High frequency trading information and profits

DR11: Impersonal efficiency and the dangers of a fully automated securities exchange

DR12: High frequency trading and price efficiency

DR13: Studies of interactions between human traders and algorithmic trading systems

DR14: Prospects for large scale financial systems simulation

DR15: Impact of special relativity on securities regulation

DR16: Electronic trading and market structure

DR17: The evolution of algorithmic classes

DR18: Pricing liquidity in electronic markets

DR19: Market fragmentation in Europe: assessment and prospects for market quality

DR20: Computer-based trading and market abuse

DR21: High frequency trading and the execution cost of institutional investors

DR22: High frequency trading and end of day price manipulation

DR23: Algorithmic trading and changes in firms' equity capital

DR24: The impact of high frequency trading on market integration – an empirical examination

DR25: Exploring the 'robot phase transition' in experimental human-algorithmic market

DR26: Computer trading and systemic risk – a nuclear perspective

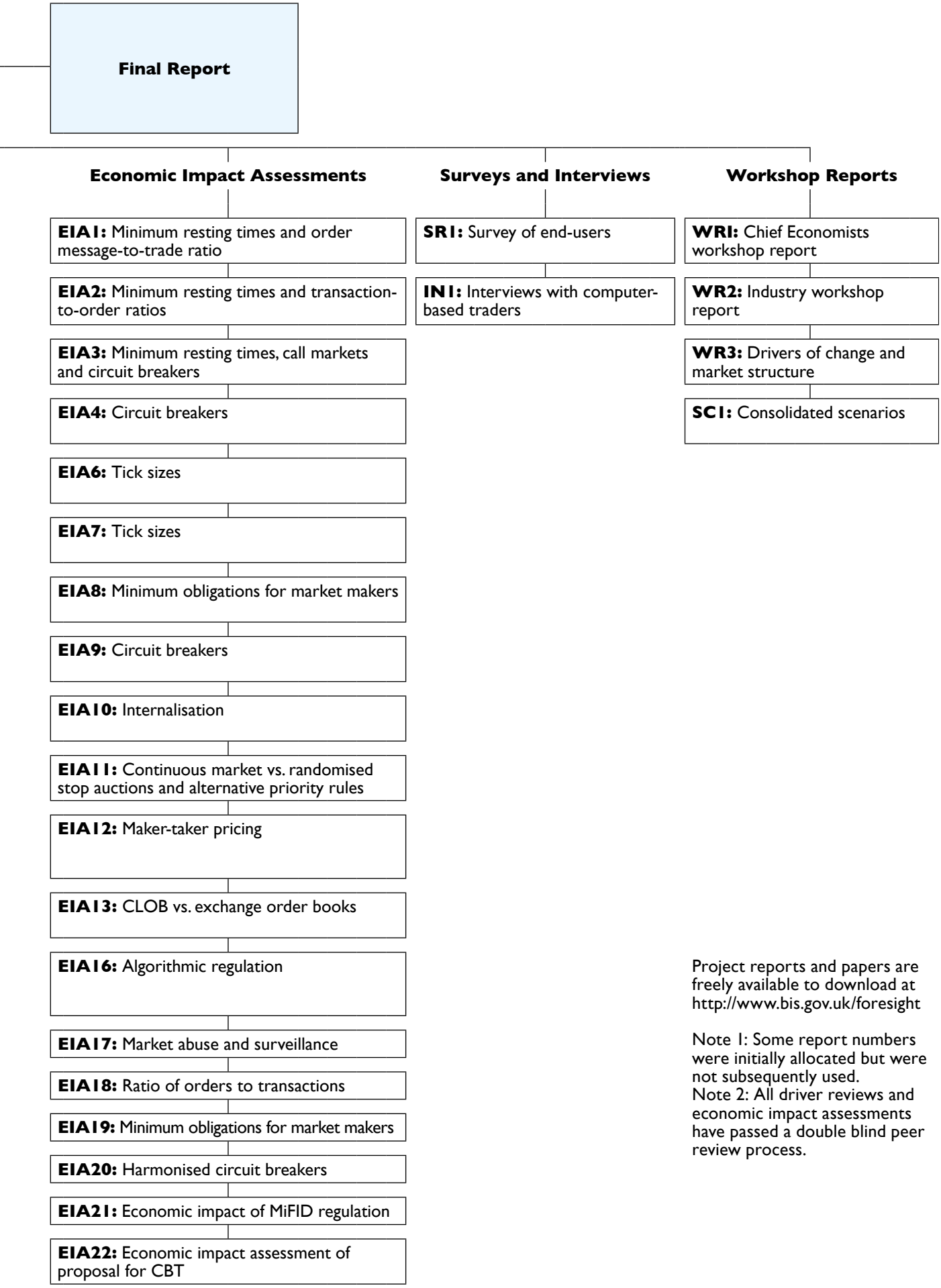
DR27: Brave new world: quantifying the new instabilities and risks arising in sub second algorithmic trading

DR28: High frequency trading – assessing the impact on market efficiency and integrity

DR29: Systemic risk arising from computer-based trading and connections to the empirical literature on systemic risk

DR30: Trust and reputation in financial services

DR31: Standards in financial services



Project reports and papers are freely available to download at http://www.bis.gov.uk/foresight

Note 1: Some report numbers were initially allocated but were not subsequently used.
Note 2: All driver reviews and economic impact assessments have passed a double blind peer review process.

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