FSB FINANCIAL STABILITY BOARD

The Use of Supervisory and Regulatory Technology by Authorities and Regulated Institutions

Market developments and financial stability implications

9 October 2020

The Financial Stability Board (FSB) coordinates at the international level the work of national financial authorities and international standard-setting bodies in order to develop and promote the implementation of effective regulatory, supervisory and other financial sector policies. Its mandate is set out in the FSB Charter, which governs the policymaking and related activities of the FSB. These activities, including any decisions reached in their context, shall not be binding or give rise to any legal rights or obligations.

Contact the Financial Stability Board

Sign up for e-mail alerts: www.fsb.org/emailalert
Follow the FSB on Twitter: @FinStbBoard
E-mail the FSB at: fsb@fsb.org

Table of Contents

Executive summary

Technology and innovation are transforming the global financial landscape, presenting opportunities, risks and challenges for regulated institutions and authorities alike. A significant area of innovation is the application of new technologies to help authorities to improve their supervisory capabilities – known as 'SupTech' --- and by institutions to meet their regulatory requirements – known as 'RegTech'.

The opportunities offered by SupTech and RegTech have been created by a combination of factors that have come to the fore in recent years. These include the substantial increase in availability and granularity of data, and new infrastructure such as cloud computing and application programming interfaces (APIs) which allow large data sets to be collected, stored and analysed more efficiently. Authorities and regulated institutions have both turned to these technologies to help them manage the increased regulatory requirements that were put in place after the 2008 financial crisis.

SupTech and RegTech tools could have important benefits for financial stability. For authorities, the use of SupTech could improve oversight, surveillance and analytical capabilities, and generate real time indicators of risk to support forward looking, judgement based, supervision and policymaking. For regulated institutions, the use of RegTech could improve compliance outcomes, enhance risk management capabilities and generate new insights into the business for improved decision-making. For both authorities and regulated institutions, the efficiency and effectiveness gains, and possible improvement in quality arising from automation of previously manual processes, is a significant consideration.

Given these benefits, it is not surprising that SupTech is a strategic priority for an increasing number of authorities. Based on a survey of FSB members, the majority of respondents had a SupTech, innovation or data strategy in place, with the use of such strategies growing significantly since 2016. The most common 'use cases' reported by authorities for SupTech tools were in the areas of regulatory reporting and data management. The use of SupTech for 'misconduct analysis' and microprudential supervision has increased in recent years, whereas use cases for market surveillance were reported as having reduced somewhat. Over half of survey respondents reported having a formal development or testing platform for SupTech tools. Artificial intelligence applications were the most commonly deployed SupTech tool and were expected to remain so into the future.

FSB members reported that the growth in SupTech strategies could be explained by both supply and demand side drivers. The potential for gains in 'efficiency and effectiveness' of regulatory processes, and the possibility for 'improved insights' into risk and compliance developments were, by a large margin, the most commonly cited demand side drivers for SupTech strategies. On the supply side, the most frequently mentioned drivers were the development of data strategies, increased availability of AI techniques, and emergence of machine-readable data.

Despite the opportunities and benefits of SupTech and RegTech, authorities are vigilant to possible risks that could arise from the use of such technologies. Survey responses indicated that the risk reported to be of greatest concern was around resourcing, followed by concerns around cyber risk, reputational risk and data quality issues. Whilst these risks were reported as of most common concern, research indicated a range of possible issues including over reliance

on SupTech tools (particularly a risk that over-reliance on methods built on historic data could lead to incorrect inferences about the future) and the potential for limited transparency or 'explainability' in the design and outputs of tools.

Authorities also reported a range of challenges in designing and implementing a SupTech strategy. These included, unsurprisingly, issues around skills and resourcing, data quality and considerations around integration of SupTech into internal processes. Governance and accountability over the use of SupTech tools also emerged as an area for focus.

Looking to the future, a range of themes emerged as areas which might benefit from further exploration and consideration by authorities as they develop their SupTech and RegTech strategies. These included the importance of senior management buy in, early engagement with users of tools (e.g. supervisors) and collaborations both between authorities, but also with technology vendors and regulated institutions. The potentially catalytic role of data standards and the importance of effective governance frameworks for the use of SupTech and RegTech were also emphasised.

Finally, the report contains a variety of case studies giving practical examples of deployment of SupTech and RegTech tools. These include a number of examples related to the COVID-19 experience, which has served both to increase interest in SupTech and RegTech, but also to illustrate where authorities have been able to deploy these solutions to support remote working, crisis response and enhanced surveillance and supervision.

1. Introduction

Increased adoption of technology is transforming the global financial landscape, raising opportunities and challenges for both authorities and regulated institutions.[1] One important area of innovation is the application of financial technology ('FinTech') for regulatory and compliance requirements and reporting by regulated institutions ('RegTech'), and applications of FinTech used by authorities for regulatory, supervisory and oversight purposes ('SupTech').[2,3]

This report provides a stocktake of recent SupTech and RegTech developments. It describes demand and supply drivers, as well as barriers and enablers, to the development and deployment of SupTech and RegTech by authorities and regulated institutions. It also examines relevant technologies that have enabled the growth of SupTech and RegTech, such as cloud-based services, artificial intelligence (AI), machine learning (ML) and application programming interfaces (APIs). In addition, the report considers the benefits, risks and challenges of SupTech and RegTech to support authorities and regulated institutions in considering the opportunities and implications of these technologies. It examines how certain authorities might develop their SupTech strategies as well as the resources that might be involved. It looks at how certain tools are changing the way in which authorities go about data collection, storage, management and analysis, and discusses applications of these tools by both authorities and regulated institutions. Finally, it concludes with a review of the policy considerations of using such tools and applications, and future areas of consideration for both authorities and regulated institutions.

The report also analyses the potential implications for financial stability of the growing use of SupTech and RegTech tools. On the one hand, these tools could potentially strengthen the resilience of the financial system through new means to facilitate or improve supervision, surveillance, and enforcement by authorities; and reporting and compliance by regulated institutions. Further, the automation of some regulatory and compliance functions through the use of SupTech and RegTech, in areas such as reporting and risk management can reduce the scope for human error, while increasing the potential for real-time monitoring. On the other hand, risks may arise from the overreliance on the use of these new methods. Excessive dependence on SupTech and RegTech could mean sources of risk are overlooked, and there could be a misplaced emphasis on "the risk that can be measured, rather than the risk that matters".[4]

This report, which responds to a request by the Saudi G20 Presidency, was prepared by a workstream of the FSB's Financial Innovation Network (FIN). The work drew on discussions with firms, academic research, and reports by public and private sector institutions to understand the various applications of SupTech and RegTech. The workstream also conducted a survey of FSB Members.

---

1 For the purpose of this report, the term 'regulated institutions' refers to regulated financial institutions.

2 FSB (2017), *Financial Stability Implications from FinTech: Regulatory and Supervisory Issues that Merit Authorities' Attention*, June; FSB (2017), *Artificial Intelligence and Machine Learning in Financial Services: Market Developments and Financial Stability Implications,* November. See Annex 3 for a glossary of definitions.

3 The report draws on examples from specific private firms involved in RegTech, and as vendors in SupTech solutions. These examples are not exhaustive and do not constitute an endorsement by the FSB for any firm, product or service. Similarly, they do not imply any conclusion about the status of any product or service described under applicable law. Rather, such examples are included for purposes of illustration of new and emerging business models in the markets studied.

4 Danielsson et al (2017), *Artificial Intelligence, financial risk management and systemic risk,* Systemic Risk Centre Special Paper No. 13.

Alongside the work on this report, the Saudi G20 Presidency and the BIS Innovation Hub Singapore Centre launched the G20 Global TechSprint to examine the potential for new and innovative technologies to respond to operational challenges in the areas of SupTech and RegTech. The goal is that the work will result in insights into practical supervisory tools and policy and serve as a complement to this report.

2. Drivers of SupTech and RegTech developments

A confluence of drivers has led to the development and application of SupTech and RegTech tools and methods. They arise from the need to support supervisory processes while ensuring compliance with regulatory requirements. From the demand side, since the 2008 global financial crisis, regulatory requirements have been strengthened and authorities and regulated institutions alike are dealing with increased amounts of regulation and data. This encourages the creation and adoption of digitalised compliance and supervisory tools in response. As for the supply side, advances in technology have propelled increased cost efficiency and data capacity as well as greater computing power.[5]

2.1. Demand drivers

- **Enhanced surveillance and compliance:** SupTech and RegTech tools might support enhanced supervision, surveillance, and enforcement by authorities while also improving reporting and compliance by regulated institutions, potentially strengthening the resilience of the financial system. Automation of regulatory and compliance functions such as reporting and risk management may also reduce the potential for human error, while increasing the effectiveness of real-time monitoring and supporting proactive and judgement based supervision.

- **The increased complexity and volume of regulations, and the significant consequences of non-compliance, have led to large increases in spending on compliance and risk management programmes by regulated institutions:** Examples include increased reporting and compliance obligations implemented pursuant to the Dodd-Frank Act in the US and increased reporting obligations under the Markets in Financial Instruments Directive (MiFID II) and Alternative Investment Fund Manager Directive (AIFMD) in the EU.

- **More efficient, effective and value-added regulatory data:** Legacy systems are frequently incompatible with today's digital tools. Digitisation of regulatory data may increase efficiency while strengthening operational resilience and data quality for both authorities and regulated institutions.[6] Indeed, enhancing efficiency was seen as the

---

5 Some of the drivers are more task-oriented while other seem more important for improving the understanding of the underlying technologies.

6 Digitisation is often defined as the process of changing from analogue to digital form. By contrast, digitalisation is defined as the use of digital technologies to change a business model, or the process of moving to a digital business. See Gartner Glossary, online at https://www.gartner.com/en/information-technology/glossary (accessed 25 May 2020).

primary driver of SupTech adoption in the FSB survey by almost half of the authorities that responded (See Graph 1).

- **More insightful policy and forward-looking supervision:** As available data grows and becomes more granular, authorities are working to enhance their supervisory processes.[7] Equipped with the necessary technological tools, the availability of real-time and non-traditional data may allow authorities to be more pro-active in their supervision. Authorities have highlighted enhanced insight as the second most important driver for developing a SupTech strategy (see Graph 1). From a financial stability perspective, such forward-looking, real time surveillance may allow better identification and mitigation of systemic threats.

- **Enhanced focus on cybersecurity and prevention of financial crime:** The increasing digitalisation of financial services necessitates greater awareness of cyber security. SupTech and RegTech tools also support authorities in combating financial crime, including money laundering, terrorist financing, bribery, corruption and insider trading.[8] Some academic research suggests that it is in this area where such applications seem to be at a more advanced stage.[9] Indeed, many providers are designing SupTech and RegTech tools to enhance financial and cyber-crime prevention.[10]

- **Improved risk management capabilities:** SupTech and RegTech tools could increase the accuracy, comprehensiveness and timeliness of risk management. The automation of some areas of previously manual surveillance and compliance functions could enable productivity and effectiveness gains.

- **Larger number of supervised entities due to increased digitalisation:** Industrial and technological developments following the 2008 global financial crisis have increased the opportunities for new entrants to financial services, including 'FinTechs' and regulated institutions from outside the traditional financial sector. This has been particularly noteworthy in the area of payments, investments and lending. These institutions, and the 'ecosystem' of service providers who support them, may be subject to regulatory oversight, and SupTech and RegTech may have a role in helping promote effective standards of compliance and risk management in such sectors.

---

7 Basel Committee on Banking Supervision, *Sound Practices: implications of fintech developments for banks and bank authorities*, February 2018.

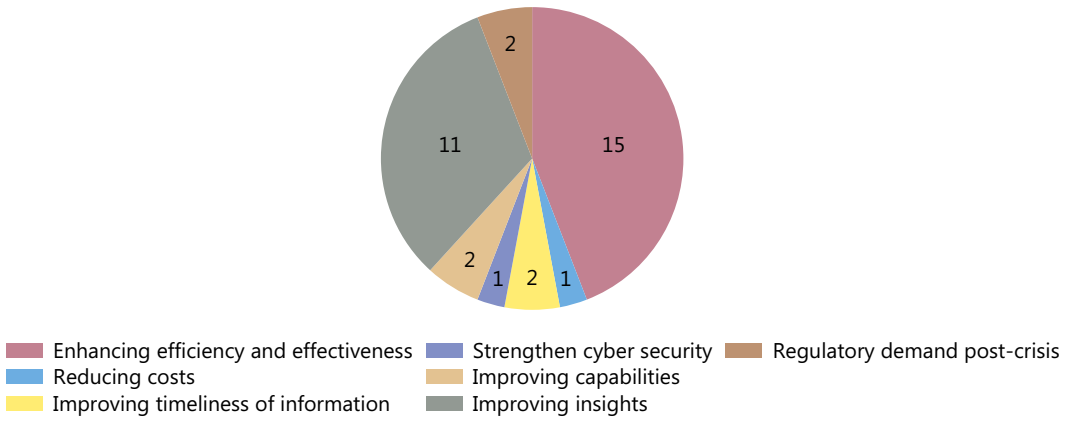
8 *Emerging Trends, Drivers and Challenges in the RegTech Market 2019 – 2023*, *Business Wire*, 26 September 2019..

9 Coelho et al (2019), *SupTech applications for anti-money laundering*, *FSI Papers, No 18*, August.

10 Hanley-Giersch (2019), *RegTech and Financial Crime Prevention*, p.22. 'The RegTech Book'. Janos Barberis, Douglas W. Arner and Ross P. Buckley editors.

Primary demand drivers for developing a SupTech strategy

No. of authorities who rank driver as most important **Graph 1**



Source: FSB survey

2.2. Supply drivers

- **Availability of new analytical methods and tools**: Emerging technologies[11] such as artificial intelligence (AI) and machine learning (ML) allows for greater and more rapid processing of supervisory and regulatory data, as well as improved analysis. They may also assist authorities to identify non-compliance with reduced emphasis on human interaction or intervention.[12] Such tools were viewed by a majority of respondents as the primary supply driver, alongside the importance of having a data strategy in place (See Graph 2). More automated surveillance may give authorities greater ex ante analytical insight serving to reduce stability risks.

- **Availability of data:** The presence of greater quantities of both structured and unstructured data along with the attendant technology to use them may drive increased adoption of SupTech and RegTech tools. Authorities could leverage their analysis of unstructured data (e.g., through social media platforms or search engines), subject to jurisdictions' data privacy laws, to complement authorities' use of regulated institutions' regulatory reporting.

- **Infrastructure developments have allowed for the growth in new regulatory and supervisory tools:** cloud service providers have allowed for increased storage capacity at reduced costs, contributing to the deployment of SupTech and RegTech tools.

- **A more holistic and improved data architecture:** The development of systems that allow for a greater degree of interoperability (e.g. API, micro-services), can enable higher rates of adoption of SupTech and RegTech. In addition, significant advances in

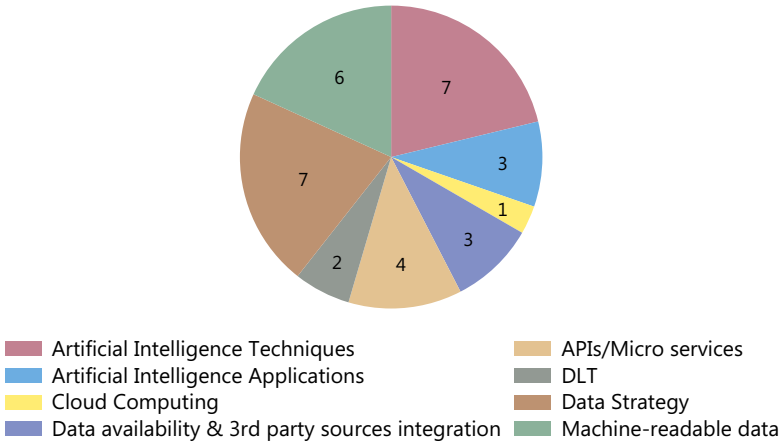
11 Including, prominently, natural language processing, pattern, speech and image recognition tools alongside greater availability of software libraries and more sophisticated algorithms.

12 Arner et al (2016), *FinTech, RegTech and the Reconceptualisation of Financial Regulation*.

database management software and solutions for data exchange allow for greater scalability, versatility, and computational power than has previously been achievable.

Primary supply drivers for developing a SupTech strategy

No. of authorities who rank driver as most important **Graph 2**



Source: FSB survey

3. Benefits, challenges and risks for authorities and regulated entities

Based on the survey results, supervisory authorities and regulated entities utilise innovative SupTech and RegTech technologies to improve surveillance, reduce manual processes and make more effective use of data. These technologies can promote a culture of diligence and vigilance in risk monitoring and management. At the same time, supervisors and regulated institutions should have a good understanding of the associated challenges and risks related to the use of such technologies.

3.1. Benefits

Enhanced capabilities

Based on the survey results, SupTech applications may enhance supervisory capabilities in a number of ways. Securities and markets authorities, for example, need to perform detailed reviews of a high volume of supervised entities' regulatory filings. Leveraging emerging technological tools can help to more efficiently and accurately identify potential issues. At the U.S. Securities and Exchange Commission (SEC), for example, back-testing analysis has shown that algorithms are five times better than random testing at identifying language in investment adviser regulatory filings that could merit further investigation for potential wrongdoing.[13] Certain SupTech tools also allow unstructured data to be integrated into existing data sets for analysis.

[13] Bauguess (2017), *The Role of Big Data, Machine Learning, and AI in Assessing Risks: a Regulatory Perspective*, June.

In addition, the use of some AI/ML applications may identify patterns in data that may not be apparent to human review. The potential benefits of SupTech include:

- Exceptions-based supervision that enables automated collection of regulated institution data to be analysed for the identification of "exceptions" or "outliers" to pre-determined parameters;
- Enhanced decision making of supervisory measures; and
- Use of algorithms in large and complex data sources which might allow for more effective oversight of, for example, high frequency trading.[14]

Data collection and visualisation

SupTech applications can improve the value of data collected by enriching its intelligibility and interoperability.[15] SupTech that enables visualisation (such as risk dashboards and charts) can reduce the density and complexity of data, helping to transform it into accessible indicators. In addition, SupTech can provide the necessary data inputs for ML and deep learning applications for trend and forecasting analysis. RegTech can drive resource efficiencies in collating data for regulatory filings. It can also enable the analysis of large or complex data pools, including customer and risk management data.

Real-time monitoring

SupTech applications that leverage AI/ML models, may improve surveillance and assessment of risks in real time while also providing predictive analysis. Such timely forward-looking monitoring may allow authorities early insights into risk factors that might threaten financial stability. As well, RegTech applications could be used to support real-time risk management by regulated institutions and by supporting enhanced insights into the business for decision-making.

Cost reduction

Cost reduction might be achieved through the digitalisation of data, which could improve the efficiency and effectiveness of operational processes, reducing IT and staffing costs.[16] Supervisory resource requirements might also be reduced by applying common analytical approaches (including scripts and common source codes) across datasets. For regulated institutions, there could be potential cost reductions related to regulatory processes including, regulatory reporting, data collection and risk management.[17]

---

14 *RegTech and SupTech: Implications for supervision*, (2019) Access to Insurance Initiative (*AII*).

15 See Section 6.1 Data collection – for a more detailed discussion of current methods and examples.

16 Broeders and Prenio (2018), *Innovative technology in financial supervision (SupTech) – the experience of early users*, *FSI Insight,* July.

17 Armstrong and Harris (2019) *RegTech and SupTech – change for markets and authorities*, *Trends, Risks and Vulnerabilities*, *ESMA*, 28 February.

3.2. Risks and challenges

Data standardisation and data quality

Based on the survey results, data standardisation, data quality and data completeness are important conditions for effective SupTech and RegTech applications. However, data quality and completeness can pose challenges for authorities and regulated institutions alike, including as they look to leverage non-traditional sources of information such as social media.

Cyber-risk and data security

Cyber risks may grow due to increased use of digital solutions and greater interconnectedness between regulated institutions and external parties, such as technology vendors.[18] [19] Further, novel technologies may introduce or increase cyber-vulnerabilities for authorities and regulated institutions. These issues may serve to magnify financial stability risks, by increasing the attack surface[20] in the event of a cyber incident.

Third-party dependencies

Increased dependencies on third parties, such as cloud service providers, by authorities and regulated institutions may create or amplify risks, including concentration risk.

Resource requirements and costs

The increased use of SupTech and RegTech may require recruitment of specialists such as data scientists and engineers, and for those recruits to be trained in regulatory and supervisory disciplines. Authorities and regulated institutions may also need to consider developing training programs for existing staff to improve their technical and digital skillsets. These measures may allow for safer maintenance and management of applications, potentially reducing operational risks and increasing transparency of inputs and outputs. Recruiting appropriately skilled resources can be challenging – particularly when authorities are competing with the private sector for talent.[21]

Data localisation

Based on the survey results, data localisation measures, (i.e. storing data within the borders of a specific country or territory), can create barriers to effective risk-management practices and

---

18 FSB (2019), *FinTech and market structure in financial services: Market developments and potential financial stability implications*, February.

19 In 2016, the central bank of Bangladesh was attacked, resulting in theft of more than SR 81 mn. Also, in 2017, the Wannacry ransomware attack on more than 200,000 victims across 150 countries. *See North Korea Linked to Digital Attacks on Global Banks New York Time*, 26 May 2016. Also, See *Ransomware Cyber-Attack Threat Escalating - Europol. BBC News*, 14 May 2017.

20 Manadhata, PK. (2008), *An Attack Surface Metric*, November.

21 Similar challenges are faced by banks vs. tech companies as well given the regulatory constraints on compensation policies, which have followed the 2008 global financial crisis. See P Kampkötter, *Non-executive compensation in German and Swiss banks before and after the financial crisis*, *The European Journal of Finance*, Volume 21, Issue 15.

may limit the ability to fully leverage SupTech and RegTech. These measures can increase costs to regulated institutions and amplify cyber security risks in certain systems, raising challenges for effective operational risk management and data aggregation on which SupTech and RegTech applications depend. It should be said that this standard does not apply universally, in larger scale jurisdictions, e.g., EU, same jurisdiction localisation may be valid.

Opportunity for regulatory arbitrage

SupTech and RegTech might provide analytics and insight that increase the possibility that certain regulated institutions may be able to 'game' the system. For SupTech, this might involve regulated institutions obtaining information or learning which signals create warnings or alerts in a SupTech monitoring system. They may then be able to structure their regulatory returns in such a way as to remain undetected. As well, as regulated institutions develop their expertise in RegTech, their systems may become better able to identify potential regulatory gaps.

Competition barriers

In their effort to help ensure that financial markets are safe and stable, authorities may seek to encourage competition. Expensive or complex regulatory systems can become a significant entry barrier for new SupTech and RegTech service providers. New entrants often state they do not have the necessary infrastructure, expertise, and funding to navigate complex regulatory requirements. They may also lack the comparative advantage of regulated institutions to fully leverage the cost and process efficiencies.

Reputational risks

Understanding the limitations of new technologies is key to assessing their value in supervision and financial services. Certain tools may detect spurious, rather than meaningful, signals or alerts.[22] Based on the survey results, supervisory authorities broadly agree that most SupTech output may need some level of manual oversight or intervention, before its outputs could be made actionable.[23] In addition, the lack of transparency of some SupTech applications could have implications for the accountability of an authority. For some time, authorities have discussed good governance standards for using AI/ML and comparable tools.[24]

---

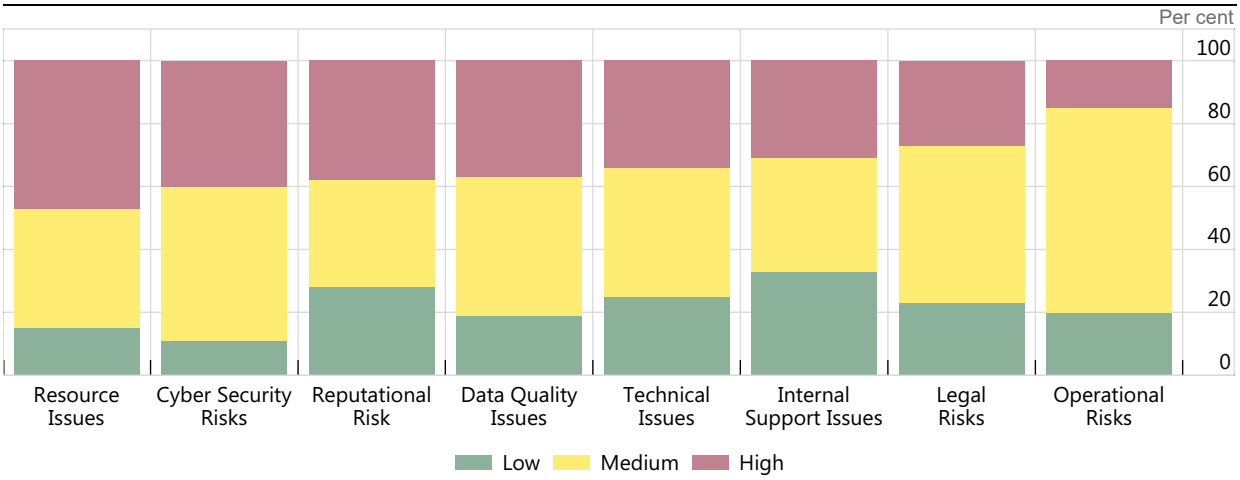
22 Broeders and Prenio, *Innovative technology in financial supervision (SupTech) – the experience of early users*.

23 Ibid.

24 Monetary Authority of Singapore (MAS), *Principles to Promote Fairness, Ethics, Accountability and Transparency (FEAT) in the Use of Artificial Intelligence and Data Analytics in Singapore's Financial Sector* (2018), and Banque de France ACPR discussion document on *Governance of Artificial Intelligence in Finance (2020)*.

Detailed challenges/risks in developing SupTech applications

Percentage risk-severity in each category of risk / challenge **Graph 3**



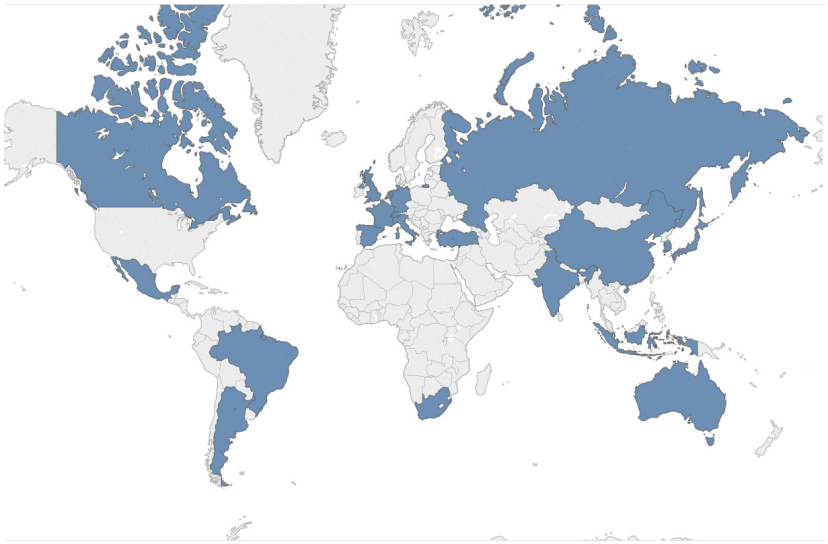
Source: FSB survey

4. SupTech and RegTech strategies, market interaction and monitoring developments

The demand and supply drivers outlined in Section 2 have led to the development of strategies that enable authorities to optimise the potential benefits of SupTech within their organisations. As the survey underlined, most authorities have a SupTech strategy in place or are in the process of developing one. More than half combine the SupTech strategy with a broader innovation or data strategy. Of those authorities surveyed, more than a third reported that their strategies were deployed, while the remainder revealed that they were in the developmental or experimental stages. Of those who said their strategies were deployed, most reported having developed them over the last three years (see Graph 4 below).

Prevalence of data, innovation, RegTech, and SupTech strategies amongst supervisors

Authorities with one or more strategies in place are shaded in blue **Graph 4**



Source: FSB survey

SupTech strategies

SupTech strategies seek to develop tools to support the financial authorities' supervisory responsibilities. Innovation and data strategies, on the other hand, are institution-wide programmes that incorporate the development of SupTech tools. For example, some authorities have dedicated units or teams in place to support the development of SupTech tools. This is the case for the Monetary Authority of Singapore (MAS) and the De Nederlandsche Bank (DNB) where a dedicated office – MAS's Suptech Division and DNB's Supervision Innovation Department – drives the SupTech agenda.[25] The European Central Bank (ECB) has incorporated the use of supervisory technologies as a core element into its strategic vision for banking supervision.[26] The Bank of France's supervisory unit, 'L'Autorité de contrôle prudentiel et de résolution' (ACPR), is exploring SupTech solutions in the context of its Data Transformation Programme, which seeks to change the way it collects, stores, validates and analyses data.[27]

In putting in place a strategy, some authorities have noted specific considerations to ensure its effectiveness. First, senior management's buy-in and support of the benefits of SupTech in the supervisory process is significant, while also realising the limitations and potential risks associated with its use. Second, is the importance of engaging 'front-line' supervisors, who are the end-users of these tools. As such, an early dialogue and ongoing cooperation with supervisory staff can help to ensure successful implementation and adoption. Third, some authorities adopted an approach of 'fast fails' when experimenting with SupTech. This means that authorities could try to set high-level feasibility criteria and short time frames where they can quickly evaluate which applications are a fit for particular use cases and not progress further with those that are not. Fourth, a number of authorities have a strategy for attracting and retaining the appropriate SupTech talent and skills. Having professionals with a strategic understanding of the supervisory goals may better enable the development or acquisition of SupTech tools that can more successfully integrate within authorities' organisational structure. Finally, to keep abreast of technological developments, some authorities actively engage and seek innovative collaboration and dynamic idea sharing with a range of external parties, such as other financial authorities, the academic community, technology vendors and international organisations.[28]

When asked what they considered the main benefits of embracing a successful SupTech strategy, most respondents pointed to heightened capabilities, enhanced supervision, and increased efficiencies (see Graph 5).

---

25 See Annex 1 – Case Study 1 *De Nederlandsche Bank*.

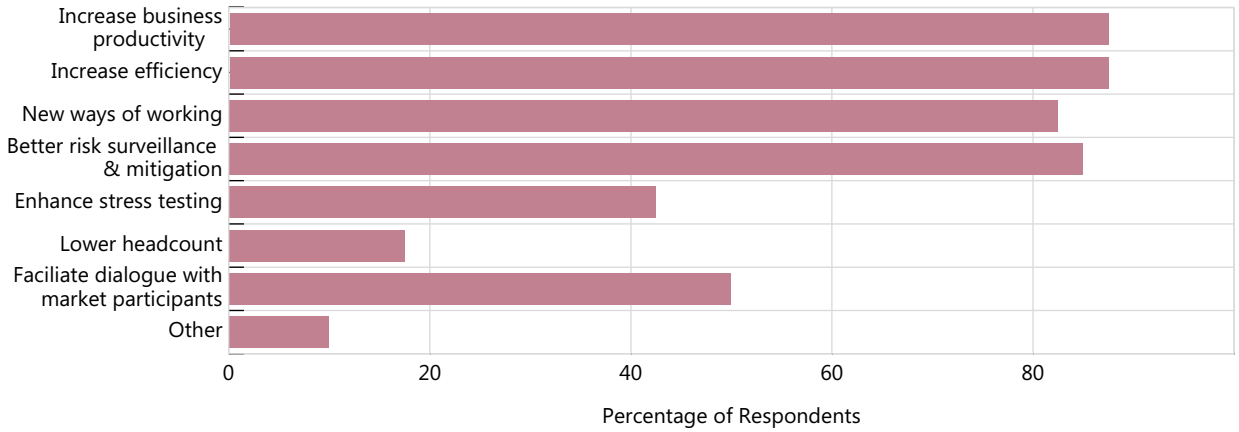
26 See Annex 1 – Case Study 2 *The European Central Bank*.

27 Di Castri et al (2019*), The suptech generations*, *FSI Insights* No 19, October.

28 Ibid.

Envisaged benefits from a digitally-skilled workforce

Percentage of respondents **Graph 5**



Source: FSB survey

RegTech strategies

Responses to the survey showed that around a third of authorities had 'RegTech' strategies in place (i.e. strategies of authorities to promote or encourage the use of new technology by regulated institutions for compliance purposes). Authorities' strategies generally focus on supporting the use of RegTech in the areas of AML/CFT and regulatory reporting. In addition, some authorities have used regulatory sandboxes and other platforms to help test potential RegTech solutions.

Even for those authorities without a formal RegTech strategy in place, the survey shows that the majority of respondents' regulated institutions use RegTech tools and that authorities are supportive of their use. The deployment of these tools has been motivated by anticipated improvements in efficiency, including cost reduction, and enhancements in regulatory compliance effectiveness.

Testing SupTech tools and monitoring developments

The survey shows that authorities' innovation units led the majority of SupTech trials, with approximately half of respondents saying they had a formal innovation unit in place. In a few cases, respondents said they provide a dedicated venue or platform for such testing activities. To illustrate, the ACPR's "intrapreneurship" programme is a dedicated platform for testing novel technologies, and aims to encourage staff members to suggest or lead innovative projects to improve ACPR's tools and processes. Bank of France's 'Le Lab' leads the design of selected projects, and brings on board a dedicated sponsor, an external coach and IT support. Four projects have been selected for the first batch under the theme "use of Big Data and AI". The ECB is developing the "SupTech Virtual Lab" to be in place by end 2020.[29]

In other cases, respondents mentioned using platforms such as Regulatory Sandboxes and Innovation Hubs for testing FinTech tools and promoting innovation while engaging with

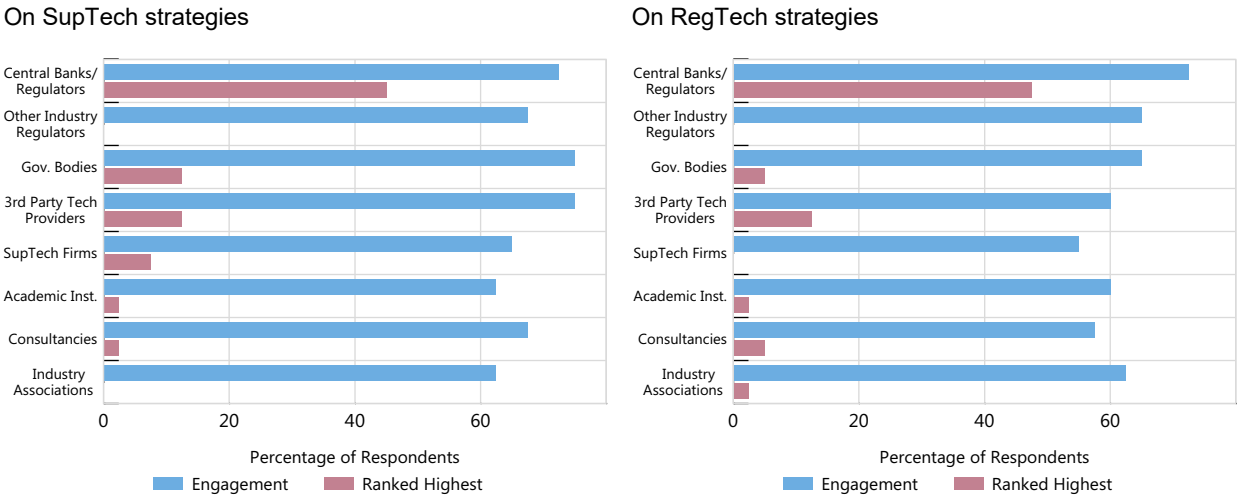
[29] See Annex 1 – Case Study 3 *ECB*.

FinTechs. In some instances, respondents said they might allow for the testing of both SupTech and RegTech tools. For example, The Bank of England (BoE) ran its FinTech Accelerator between 2016-2018 as a venue for technology providers to develop proof of concepts (PoCs), including for SupTech use cases. Since then its Fintech Hub continues to work with technology providers on PoCs whenever this may help fulfil BoE's mission.[30] The UK Financial Conduct Authority (FCA) also holds TechSprints on various themes. In 2017, the BoE and the FCA collaborated in conducting a TechSprint on digital regulatory reporting.

More recently on 30 June 2020, the U.S. Federal Deposit Insurance Corporation (FDIC) announced the start of a rapid prototyping competition to help develop a new and innovative approach to financial reporting. The goal is to improve the ease of financial reporting on the part of regulated institutions while providing more timely and granular data to authorities, and promoting more efficient supervision of individual institutions. Twenty technology providers participated in the competition, and the proposed solutions will be presented to the FDIC for consideration in the subsequent months."[31]

As mentioned above, authorities engage with different types of institutions in monitoring technological developments to enhance their SupTech and RegTech strategies (Graph 5). Most authorities report having collaborated with one another, other governmental institutions, technology companies and academia. As they continue to develop technical and functional knowledge, authorities could look to engage with still more third party providers.[32]

Types of participants that authorities are engaging with **Graph 6**



Source: FSB survey

30 Bank of England, (2020), *Fintech*.

31 FDIC Launches Competition to Modernize Bank Financial Reporting.

32 Di Castri et al (2019), ibid.

Informal SupTech Network

The Financial Stability Institute (FSI) of the Bank for International Settlements (BIS) launched the Informal SupTech Network (ISN) in 2018. The ISN provides a venue for SupTech specialists from financial sector authorities in different jurisdictions to share information on their SupTech work and exchange insights from their experiences.

ISN members can access SupTech related materials contributed by other members through a platform hosted by the BIS. Members meet once a year and engage on a regular basis through a series of webinars designed to inform and update members on specific SupTech work. The support of ISN members has also been instrumental in the publication of SupTech reports by the FSI.

SupTech Hub

The ECB has incorporated the use of supervisory technologies as a core element into its strategic vision for banking supervision. To leverage the full potential of new technologies, the ECB has therefore created a dedicated SupTech Hub and introduced an ambitious Digitalisation Roadmap outlining a set of actions over a 3-year horizon.

The SupTech Hub will facilitate the collaboration on new technologies inside the ECB and with all National Competent Authorities in the Euro area, supported by a new open collaboration platform, the SuperVision Innovators Forum, the use of a SupTech Virtual Lab and the set-up of multidisciplinary innovation teams. See case studies 2 and 3 in Annex 1.

5. SupTech resource considerations

It is important for authorities to continue to stay abreast of technological developments, to be efficient and selective in the allocation of their resources and find creative ways to attract and retain the most appropriate talent. The pace of change in the financial services sector may cause authorities to develop new, or adapt existing, workflows to meet technological developments. In addition, they may work to adjust the organisational culture to enable a SupTech platform that is better suited to additional or new supervisory concerns.[33,34] Having technologically skilled professionals in place better enables the implementation of a flexible SupTech platform.

Specific knowledge of the authorities' unique needs, their regulatory frameworks and technological capacities, are vital to the successful design of a SupTech strategy. Moreover, due to security concerns, it may be difficult to outsource much of the SupTech development and implementation process to external vendors. As such, according to the survey, the majority of authorities continue to rely on internal development of SupTech tools. Survey respondents confirmed that expertise in established technologies such as Excel and SQL appears to be strong and many authorities are rapidly embracing and building skills in ML, AI and a variety of programming languages supporting data science (see Graph 7).

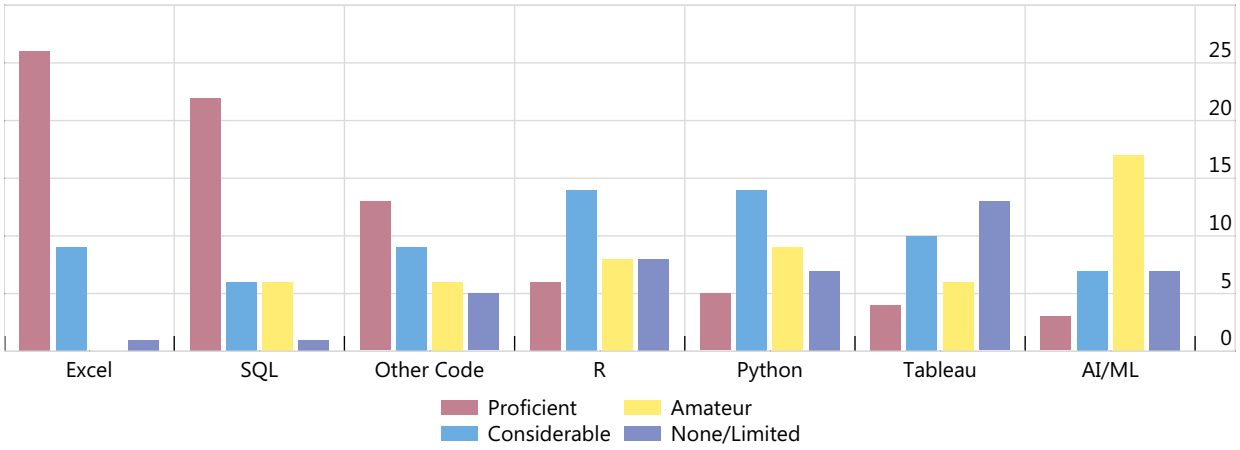
33 Van Steenis, Huw (2019), *The Future of Finance Report, Chapter 9*, Bank of England, June.

34 Financial Conduct Authority (2020), *Data Strategy*, part Y, January.

Data science competency in supervisory authorities

No. of authorities

Graph 7



Source: FSB survey

With the advent of SupTech and RegTech, authorities have become increasingly aware that in the near future a significant focus will have to be placed on recruiting information technology engineering talent.[35] Like economists and lawyers (the two dominant professions in the ranks of authorities),[36] attracting engineers has challenges. Authorities may struggle to attract top talent in the short term. The recruitment and retention of these digitally skilled professionals remains a challenge, as both authorities and the financial services sector compete for similar talent.

To address this, some authorities have developed employee engagement frameworks to recruit and retain digitally skilled employees. As well, according to the survey results (see Graph 8), the majority of authorities offer online training and in house "train the trainer" courses to increase staff skills. Within their organisations, authorities reported work on developing novel approaches to training. These included knowledge transfers between supervisory departments and delivering different kinds of training based on case studies by a pool of experts from different businesses and functions.

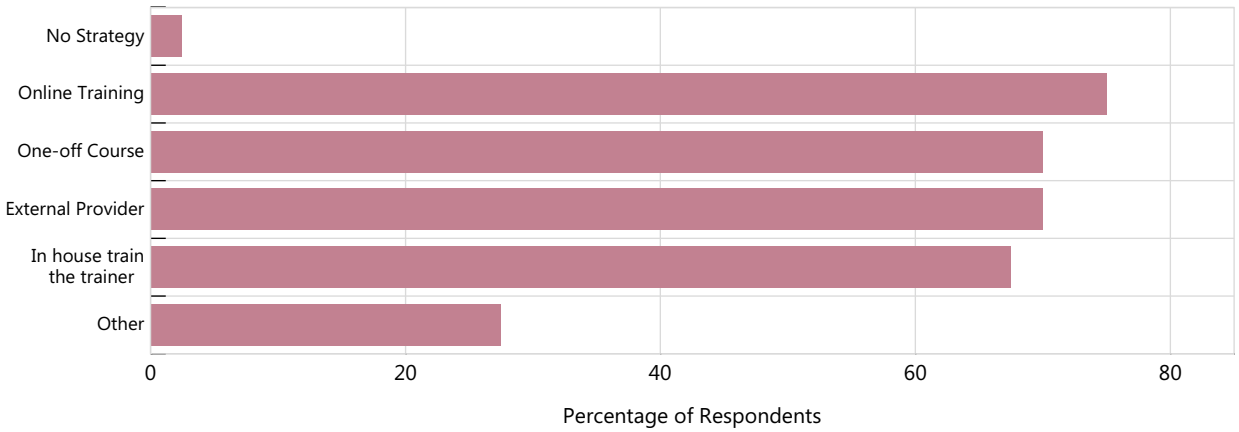
For example, the ECB is building and fostering a digital culture amongst supervisors as a core element of their long-term digital strategy. Various activities are being developed to support this goal including the creation of a comprehensive digital curriculum to offer supervisors the skills required to engage in innovation but also initiatives to raise awareness and facilitate knowledge sharing. The latter include the creation of a mobile app to share relevant content as well as SupTech talks to introduce and exchange ideas on relevant topics.

35 Enriques L (2017), *The HR Challenge of FinTech for financial authorities*, July.

36 Ibid.

Prevalence of strategies to up-skill staff with digital skills

Percentage of respondents **Graph 8**



Source: FSB survey

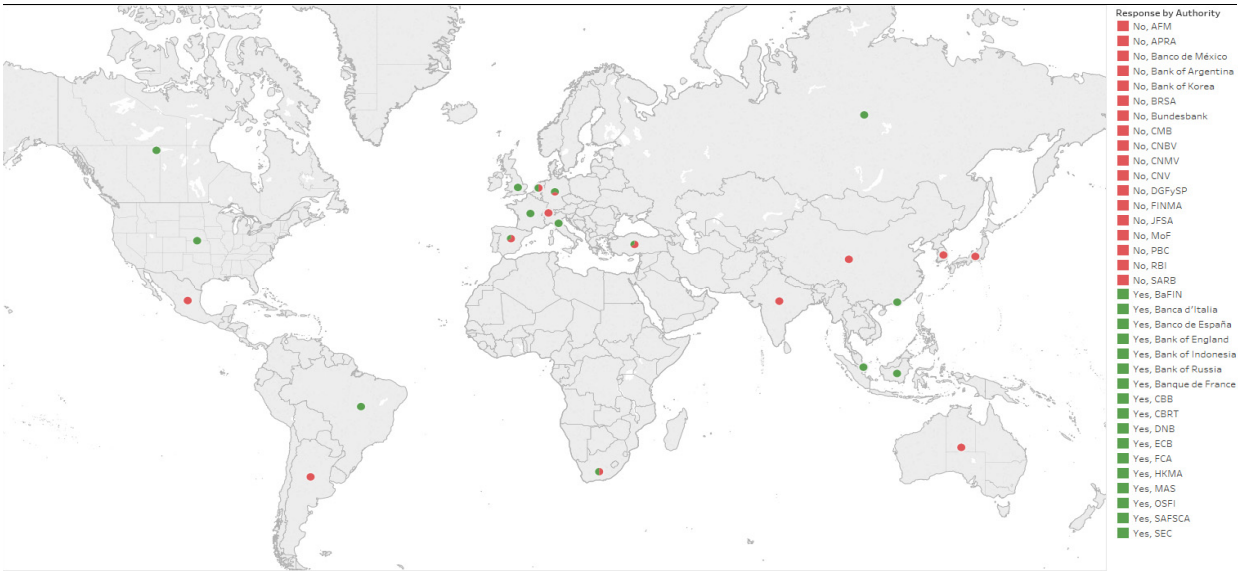
The recruitment efforts for a skilled SupTech workforce may begin with a strategy to attract talent who are motivated to enable financial services to become more effective and efficient. Over the last few years, most financial services authorities have tailored their recruitment strategies to focus on candidates skilled to analyse data (e.g. with skills in cloud-based services, data visualisation, data analytics, and AI). The emergence of new technologies, such as distributed ledger technology (DLT), also triggered an increase in the need for staff with such knowledge, while the need for database management expertise has remained constant.

Some jurisdictions may encounter certain challenges around SupTech implementation. For example, multilingual environments such as that of the ECB, the ESAs and some Asian jurisdictions such as Hong Kong have presented challenges to deploying SupTech tools that rely heavily on the accuracy of their linguistic capabilities. Examples of these tools include news and social media sentiment analysis solutions and natural language processing applications. Language-specific fine-tuning and sometimes complete redevelopment of the tools may be inevitable to achieve good use of SupTech tools in multilingual jurisdictions. Such circumstances could potentially limit the availability of commercial solutions as well as potentially increase the challenge of talent recruitment given the requirement of language proficiencies for certain roles within the SupTech team.

A well-defined SupTech strategy requires effective leadership. Approximately half of the survey respondents use a Chief Data Officer (CDO) model (see Graph 9). For example, the MAS and HKMA have put in place a “hub” and “spoke” CDO model. A dedicated centralised office (“hub”) reporting to the CDO is responsible for data strategy, quality and governance while SupTech initiatives are driven by business units (“spoke”). While many global financial services authorities have a designated CDO, although the SupTech strategy is not the direct report of the CDO for the most part, according to the survey results.

Authorities with a Chief Data Officer (or equivalent position)

Yes/No by authority in each jurisdiction **Graph 9**



Source: FSB survey

6. Data collection, storage, management and analysis

A combination of the increased regulatory requirements, the internet, GPS-enabled portable devices, and growth of the digital economy has led to a strong increase in available data. As such, in recent years, authorities have increased the type of data collected for supervisory purposes. However, this leads to a number of issues relating to the efficiency and effectiveness of how authorities collect data. The Bank of England observed that the process today is often costly, time consuming, relatively inflexible and in some cases involves a degree of duplication.[37] In a 2020 paper, the Bank of England further observed that a series of underlying factors might explain the reasons for this:

- **Heterogeneity of regulated institutions' data** – for any given product or transaction, different entities may hold and describe equivalent data differently. This makes it difficult for authorities to write a set of reporting instructions that are clear and unambiguous to all regulated institutions. In turn, this can lead to differences in how regulated entities interpret instructions and locate data, which may lead to long timelines and quality issues for authorities.

- **Heterogeneity of authorities' own data needs** – most reports are designed to address specific use cases – data may be focused on particular financial product(s) or business line(s) and aggregated in a way that makes it hard to repurpose. This leads to more requests for new reports or a breakdown of existing ones than otherwise would be the case.

- **Duplication of processes across regulated institutions** – many elements of reports' creation are similar across regulated entities. This raises the possibility that further

[37] Bank of England (2020), *Transforming data collection from the UK financial sector*, January.

centralising some processes may further reduce duplication and improve efficiency for the system as a whole.

The BoE also stated that recent developments in SupTech and RegTech technology may help improve how they collect data, making reporting more timely, more effective and less burdensome for regulated institutions.

The rapid growth of data available for regulatory purposes provides opportunities for authorities.[38] Large amounts of unstructured data are becoming increasingly useful for supervisory purposes as innovative AI/ML applications and techniques emerge, however, the use of personal data raises other considerations including the need for adherence to data privacy and data protection standards, and applicable laws and regulations.

To benefit from the opportunities offered by alternative data that may be available for regulatory purposes, both authorities and regulated institutions face challenges. These range from basic data-related activities, such as finding effective and efficient ways to collect data, including, where relevant, from novel sources, storing, processing and managing information, to more advanced activities, such as assessing data quality, and producing analyses and visualisation. A governance framework for alternative data sources assessing the completeness of the data, its validity of the data and the quality of the resulting analysis is of critical importance.

6.1. Data collection

Regulated institutions are now able to leverage new technologies to collect and submit large amounts of both structured and unstructured data (see Graph 10). As discussed in case study 4, unstructured regulatory data, (e.g., social media), often contains useful insights into developments within a regulated institution or sector that structured data, (e.g., regulatory filings) may not reveal. However, unstructured data is often collected in a format that makes it difficult to process (e.g. email),[39] which in turn makes it challenging to analyse efficiently. It is possible that authorities will continue to face these difficulties until SupTech and RegTech technologies are sufficiently advanced to enable more efficient data collection.

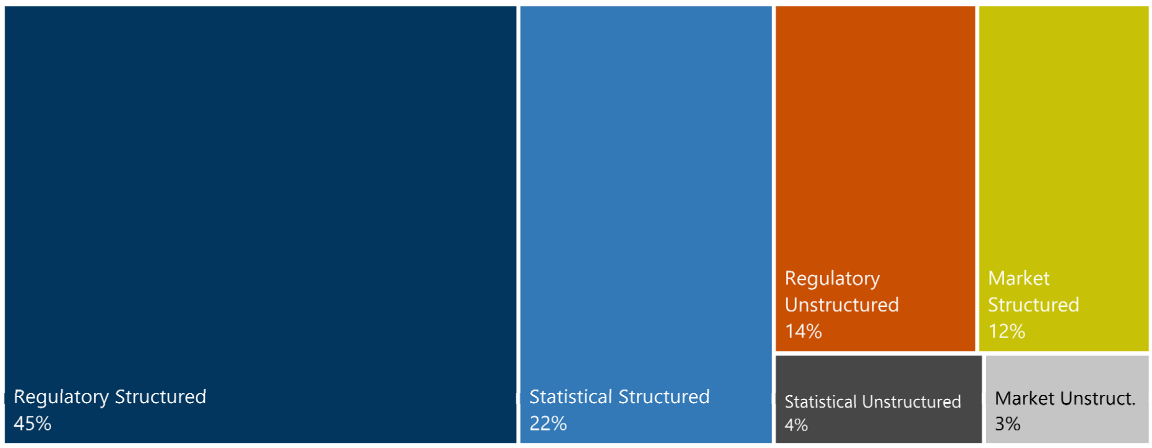
---

38 Ullersma C and van Lelyveld I (2020), *Granular data offer new opportunities for stress testing'*, in Handbook of Financial Stress Testing, Cambridge University Press (forthcoming) March.

39 See Annex 2 – Graph 28.

Data types collected from reporting institutions

Percentage of total data volume **Graph 10**



Source: FSB survey

With increased automation, regulated institutions might reduce compliance costs and generate operational efficiencies in data collection and reporting processes. Close coordination among authorities and regulated institutions is important in the adoption of innovative protocols and technologies to ensure that their systems are compatible.[40] The survey results suggest that there remain significant opportunities in the area of data collection. For instance, over one-third of authorities continue to use legacy systems to collect the majority of reporting data from regulated institutions, while the rest are primarily using web portals.[41]

In addition, the survey results revealed that less than half of the authorities have developed an Application Programming Interface (API) or micro service interface that allows regulated institutions to submit data. Greater use of APIs (with all the underlying processes and support – e.g. DevOps, development methods, standardisation and design, data model) could provide significant benefits for both regulated institutions and authorities. APIs facilitate communication between regulated institutions and authorities by integrating data production process, allowing for greater automation and lower reporting costs. Further, APIs provide the agility to be modified for temporary monitoring purposes in response to unexpected shocks to the economy or more permanently in response to changes in financial system business models.

Another factor that could facilitate the development of SupTech is the establishment of common data standards. This could help promote efficient and harmonised data collection processes. In a 'Confederation of British Industry Financial Services Survey', respondents saw common data standards as the most important digital innovation authorities could adopt to help reduce the costs of regulatory implementation and compliance.[42] Common data standards could also facilitate the implementation of digital reporting instructions, which in turn would make machine executable regulation possible.[43] There are already international initiatives underway particularly

40 Bank of England (2020), *Transforming data collection from the UK financial*, January.

41 Annex 2 – Graph 28.

42 Confederation of British Industry (2018), *Financial Services Survey*, December.

43 FCA (2020), *Digital regulatory reporting, Phase 2 Viability Assessment*.

in the derivatives sector where data elements such as those related to entity, product and trade identifiers[44, 45] are used in reporting. There may be scope for exploring the possibility of extending these international initiatives to other regulatory reporting areas.

Data collection is not only limited to regulatory data submitted by regulated institutions. Several authorities are developing solutions to scrape open source data from search engines[46] companies' annual reports,[47] and analyst research[48] to enhance their supervisory intelligence. The volume of such data is large and frequently comes in an unstructured form that contains natural language text, charts and tables, leading to difficulties in efficient extraction and analysis. To this end, data pre-processing and natural language processing solutions are valuable tools to support efficient data analysis.

Data collection in response to COVID-19

In addition to regulatory returns from regulated institutions, authorities have embraced open source information to augment their supervisory intelligence. This is especially relevant in light of COVID-19 where obtaining timely information is ever more important. To keep track of the COVID-19 policy measures in other jurisdictions, the Prudential Regulation Authority (PRA) at the Bank of England (BoE) deployed web-scraping technology to capture information from various governmental websites (see Case Study 26). Meanwhile the Bank for International Settlements (BIS) uses Google Trends to analyse internet searches for unemployment in order to help assess the regional impact of COVID-19 on labour markets in the United States and Europe (see Case Study 25). The MAS employs a variety of sources such as news, indices, credit ratings, analysts' reports, and risk metrics from commercial databases to enhance its surveillance and credit risk monitoring capabilities. Data in the physical domain such as customer footfall, wait time, peak hours and local population data has also been used by MAS to identify regulated institutions' customer service locations with large crowds, guiding the prioritisation of inspections to enforce compliance with safe distancing rules (see Case Study 28) in response to the COVID-19 pandemic.

6.2. Data storage

The growth in available data for regulatory and supervisory purposes could increase technology expenses, requiring expanded storage infrastructure and more efficient search and indexing protocols. One solution to address the rising cost of data storage is to make more use of cloud technology. Like the application of any technology, the use of cloud storage solutions has both advantages and challenges.[49] By creating geographically dispersed infrastructure and investing heavily in security, cloud service providers may offer significant improvements in resilience for authorities and regulated institutions and allow them to scale more quickly and to operate more flexibly. Economies of scale may also allow cloud service providers to offer services at reduced costs. However, entities that use third-party service providers, like those providing 'public cloud' solutions could encounter operational, governance and oversight considerations, particularly in

44 FSB (2019), *Thematic review on implementation of the Legal Entity Identifier – Peer Review Report*, May.

45 BIS Committee on Payments and Markets Infrastructure (2018) – *Harmonisation of critical OTC derivatives data elements*, April.

46 See Annex 1 - Case Studies 7, 24 and 26 for additional details.

47 See Annex 1 - Case Study 10.

48 See Annex 1 - Case Study 26.

49 FSB (2019), *Third-party dependencies in cloud services: Considerations on financial stability implications*, December.

a cross-border context and linked to potential concentration of those providers. This may reduce the ability of authorities and regulated institutions to assess whether a service is being delivered in line with legal and regulatory obligations. As well, the outsourcing of data storage can also increase cyber vulnerability if authorities and regulated institution do not independently assess potential risks. Accordingly, the use of cloud storage by authorities and regulated institutions is reportedly primarily limited to non-core activities.[50] This is consistent with the survey results, which suggest that the vast majority of authorities store most data on premise for security reasons, with the exception of a handful of members who use the cloud to store all but a small fraction of their data.[51] Nonetheless, cloud services may offer operational risk benefits particularly by reducing reliance on less secure legacy infrastructure, therein potentially supporting financial stability. Most authorities surveyed report that they are considering adopting some cloud solutions for various applications.

6.3. Data management and processing

Efficient and reliable mechanisms for ensuring quality in data management are fundamental to the supervisory process. The survey results (See Graph 11) indicate that around a fifth of the authorities' data are distributed across the organisation, while half of the authorities organise their data to only a limited extent. As for the remaining authorities, they are almost evenly split between those using a data lake model and those using a federated data based system. Two thirds have standardised metadata in place, used to organise data received from reporting institutions. Specifically, the metadata used by authorities include a taxonomy of data reported, a data dictionary and domain sets. In terms of data validation. The survey results indicate that the majority of authorities rely on static automated checks,[52] along with manual checks.

---

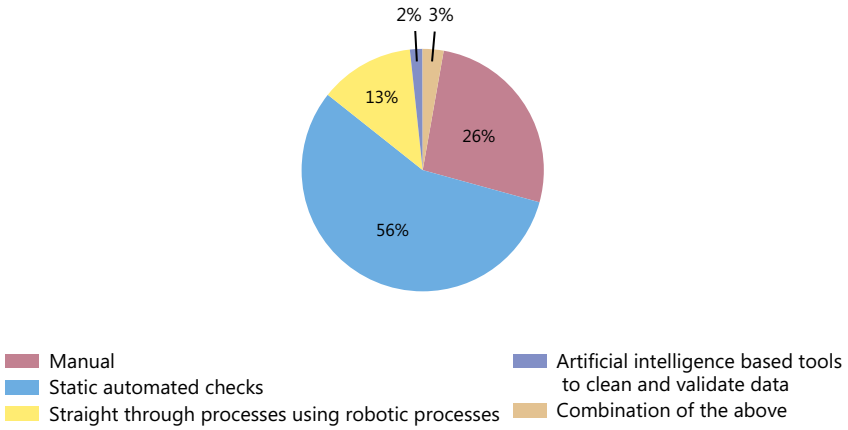
50 FSB (2019), (2019), *FinTech and market Structure in financial services: Market developments and potential financial stability implications*, February.

51 Annex 2 – Graph 28.

52 Static automated checks refer to the process of running a static code when required.

Data validation methods

Percentage of total data validation — **Graph 11**



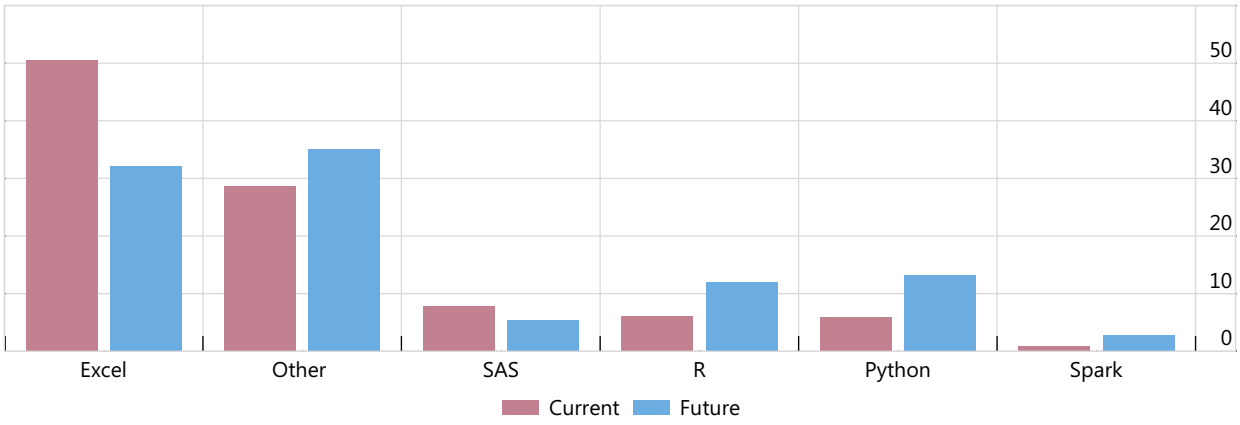
Source: FSB survey

6.4. Data analysis and visualisation tools

Until recently, most authorities have relied predominantly on Excel for most of their data analytical and visualisation needs (see Graph 12). While Excel provides a range of computational, analytical and modelling capabilities, it is limited in its capacity to work with large datasets and different data formats.

Tools used for data analysis – current and future outlook

Average percentage of total analysis — **Graph 12**



Source: FSB survey

Additionally, as noted earlier in the Report, the increase in the use of unstructured data in the supervision of regulated institutions has prompted authorities to explore additional ways to analyse and visualise the data received. While Excel can provide the analytical capability for most structured data, it is rarely capable of processing and visualising less traditional sources and formats such as text and diagrams. To address this difference, authorities have explored ways in which SupTech tools could complement a supervisory view of the regulated institutions by combining different data sources and visualising them. For example, at the ECB, network analytics are being deployed to gain deeper insight into the ownership structures of regulated

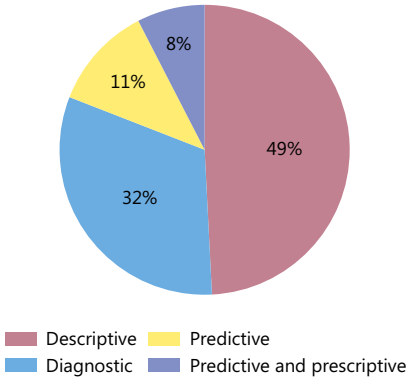
institutions – a task that, in their view, would be almost impossible for the ECB if only Excel was deployed in the analysis.[53]

The rapid growth of data available for supervisory purposes along with authorities' ability to collect increased volumes of information has allowed for the development of more proactive analytical tools. The survey (Graph 12) responses indicate that a few surveyed authorities have already deployed supervisory tools based on Python and R with an aspiration to increase the number of such SupTech tools in the near future.

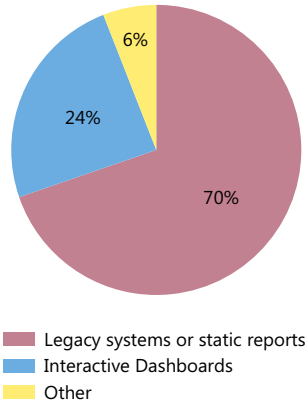
Data analysis functions

Average percentages **Graph 13**

What is the end-result of the analytics output of data?



How is data distributed and presented?



Source: FSB survey

As defined by di Castri et al (2019),[54] the technologies used by financial authorities can be divided into four generations ranging from descriptive, diagnostic, predictive and prescriptive analytics. The majority of technologies used by the surveyed authorities fall into the first or second generation. Less than 10% of surveyed authorities fall into the fourth generation predictive category. In turn, there is scope for improvement in data analytics such as tools providing predictive output in risk surveillance. Such tools may assist authorities in taking actionable and meaningful, forward-looking decisions.

7. Applications by authorities

Collaboration between authorities and regulated institutions has been increasing. Authorities globally have embarked on their own SupTech journeys for a variety of reasons – to enable more forward-looking and judgement-based supervision, generate cost and time savings, and improve data quality. Case Study 6 in Annex 1 provides one such example of the BoE, the FCA and regulated institutions collaborating to enhance regulatory reporting.

53 See Annex 1 - Case study 21.

54 di Castri et al. (2019), *The suptech generations, FSI Insights,* no 19.

The increase in both regular reporting and other data collection needs has meant authorities may look for more efficient ways to process and analyse data. To facilitate the collection of this data, as mentioned in the analysis of the survey results in Section 6, approximately half of authorities have set up an API/micro services interfaces to allow regulated institutions to submit their filings. Nonetheless, many authorities continue to process data either manually or via semi-automated methods. This is often based on security concerns. However, in their responses to the survey, authorities indicated that they are beginning to deploy various SupTech tools and techniques to improve data processing throughout its lifecycle.

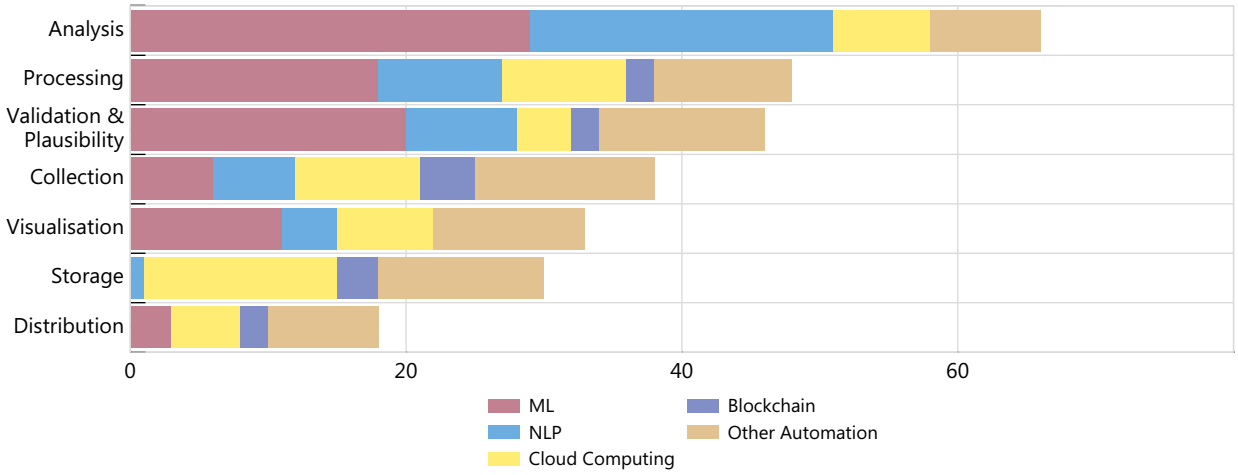
Web scraping, Natural Language Processing (NLP) and analysis of KIDs

Many required disclosures provided to clients come in the form of documents such as Key Information Documents (KIDs), prospectuses, and financial statements. Supervising compliance of this information in terms of required phrases, content (e.g., numerical information), and presentation is challenging when done manually and cannot be performed systematically. Beginning in 2019, European Securities and Markets Authority (ESMA) began exploring the use of NLP to analyse the contents of more than 20,000 KIDs produced according to the Package Retail Investment and Insurance-based Products (PRIIPs) Regulation, from more than 500 issuers, in 21 EU languages. See Annex 1, Case Study 7.

Areas of the data lifecycle where supervisory technologies have been applied

No. of authorities who have applied each technology

Graph 14



Source: FSB survey

As shown in Graph 14, many authorities have introduced ML tools to reduce the pressure on supervisory resources in those areas of the data lifecycle where manual input and judgement have historically been high – such as validation and plausibility, processing and analysis. This has been accomplished through codifying simple checks, processes and calculations on structured data, which previously had taken significant time and manual input. Further, the more automated analysis of structured information may at once improve speed and efficiency while reducing the error rate.

In particular, supervised ML is common among authorities. Case studies[55] highlight the use of indicators from regulated institution's reported data, sectorial and/or macroeconomic information as variables for training models. In turn, these techniques can assist in assessment the risks of individual institutions or credit risks at the sectoral level. ML tools have also been used to detect mis-selling in mortgage loan agreements and consumer credit contracts,[56] identify financial adviser representatives with higher risk of misconduct,[57] as well as identify suspicious trading activity.[58]

NLP tools and techniques have also been introduced to support authorities in extracting greater insight from the available data, compared to manual oversight. SupTech tools based on NLP have the potential to reduce the amount of time needed to obtain key messages found in unstructured data. By parsing and scanning unstructured records which may be public or regulated institution specific information (such as PDFs, e-mails), NLP tools can extract, classify and present authorities with valued insights. For example, authorities such as a Federal Reserve Bank[59] and the BoE[60] are developing NLP solutions to parse large amounts of documents to identify trends. The ECB[61] is exploring the use of market sentiment analysis for enhanced risk monitoring. These tools allow authorities to not only reduce the amount of time spent on certain tasks, but may also pro-actively alert them to emerging developments.

In addition to text documents, authorities process large volumes of transaction data to monitor potentially fraudulent activities for AML/CFT compliance purposes. A combination of NLP and ML technologies have been tested in this sector.[62] In particular, NLP solutions are used to extract data from text fields containing valuable information on the nature of customer behaviour and counterparties in suspicious transaction reports (STRs). Supervised ML methods can then be used to classify the STRs to associated money laundering schemes. Furthermore, network analysis has been used to identify higher risk networks of persons or entities of interest, allowing authorities to prioritise tasks accordingly for risk mitigation purposes.

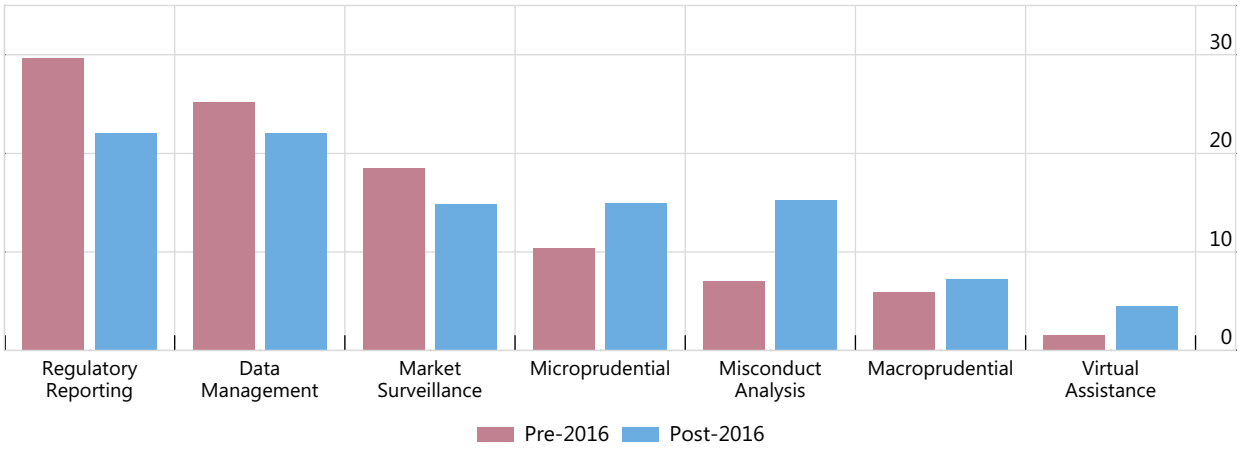
In the survey, authorities were asked to show how their primary use cases for new SupTech tools and data have evolved over the recent years (see Graph 15). According to the survey, authorities had up until 2016, continued to explore and introduce SupTech applications in areas such as regulatory reporting, data management and market surveillance.[63] However, since then, use cases have modestly reduced in these disciplines towards greater use cases in micro prudential and misconduct analysis.

---

55 See Annex 1 - Case Studies 15, 21.
56 See Annex 1 - Case Study 11.
57 See Annex 1 - Case Study 17.
58 See Annex 1 - Case Study 19.
59 See Annex 1 - Case Study 24.
60 See Annex 1 - Case Study 4.
61 See Annex 1 - Case Study 21.
62 See Annex 1 - Case Studies 12 & 13.
63 See Section 6.

Use cases for new tools and data

Average percentage of total use cases **Graph 15**



Source: FSB survey

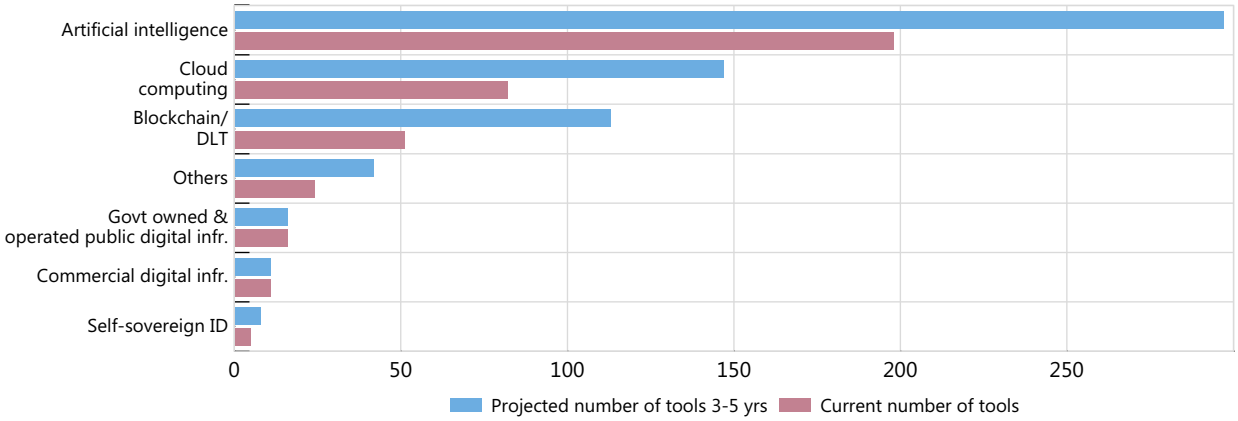
Authorities increased deployment of micro prudential and misconduct analysis tools can in part be explained by the relatively rule-based nature of assessments in these areas. For micro prudential tools, authorities were able to codify some of the simpler checks and validations on structured data returns previously done manually, thus allowing supervisors to focus on higher value tasks. Similarly, misconduct analysis and in particular, the review of some AML/CFT data collection often follows a set of simple rules which could be captured in a programmatic way.

In market surveillance, authorities are seeking to implement SupTech tools; however, the survey indicated future use cases might decrease in some product or market areas. Some respondents reported challenges and difficulties in developing, testing and implementing tools focused on certain aspects of market surveillance. Market surveillance tools are externally focused and often rely on large data volumes and a combination of diverse regulatory, market intelligence and market data. As a result, the design and developments of these tools is more complex and time consuming. However, some authorities have had success developing and deploying models, and as technologies evolve and advance and new approaches are tested and piloted, they may become easier for authorities to develop and implement.

Looking forward, the survey asked members to provide a breakdown of the number of SupTech tools they deploy at present and what they anticipated implementing over the next 3-5 years (see Graph 16). AI, cloud computing and Blockchain/DLT applications were judged the tools most likely to be deployed in the future.

Technologies use in SupTech tools – current and future

Current and projected number of SupTech tools **Graph 16**



Source: FSB survey

Based on the survey results, authorities are most concerned about the operational challenges of introducing SupTech tools, including securing appropriate budget; allocating time to develop applications; evaluating the benefits of the tools; and ensuring that staff have the right skills to make good use of any SupTech applications. Overcoming these operational challenges will be important to help ensure that authorities can realise the benefits of wider SupTech adoption.

COVID-19 Pandemic

With the severe economic stress originating from the COVID-19 pandemic, authorities and regulated institutions have entered a period of heightened uncertainty. Many are working remotely and often accessing tools and information that were not designed to be accessed remotely. In some instances, SupTech and RegTech applications have been deployed to assist frontline supervision and ensure supervisors have the necessary tools to extract and assess regulatory and COVID-19 related financial data. The Case Studies 24-28 in Annex 1, describe tools that have been directly born out of the pandemic. They range from NLP tools to undertake continuous market monitoring, to credit risk forecasting and policy response trackers.

The innovations presented in this report[64] demonstrate the increasing importance of authorities' ability to quickly use the right tools and technology to respond to a fast-changing environment. The use cases clearly demonstrate the quality of the analytics generated as well as timely responsiveness of such tools, which serve to demonstrate the capabilities these technologies may bring.

8. Applications of new technologies by regulated institutions

The demand and supply factors discussed in Section 2 are encouraging regulated institutions to embrace technologies aimed at substituting manual activities with automated processes. The consequence of such a transition is not only the execution of automatable action sequences, but also interaction between human and machine where complex software applications support human operators performing non-automatable tasks. The technical implementation of such

64 For more information, please consult relevant examples on COVID-19 in Annex 1.

methods is frequently based on AI and ML techniques able to recognise patterns and relationships among data.

RegTech can operate at both a micro and macro level, helping individual regulated institutions and potentially reshaping sector-wide regulatory processes. According to the survey, the primary use cases of RegTech tools among regulated institutions are in fraud detection, reporting, risk management and AML/CFT, with an upward trend in the field of KYC and identity verification (See Graph 17).

AML/CFT tools and fraud detection customer on-boarding

Customers increasingly choose to use online platforms to conduct financial transactions.[65] Certain malicious actors are increasingly seeking to exploit these platforms to conduct illicit and fraudulent activities. In response to these rising threats and in order to reduce compliance costs, regulated institutions, in collaboration with RegTech firms, are putting in place AI-based tools to improve their customer due-diligence processes and combat fraud, money laundering and terrorist financing.

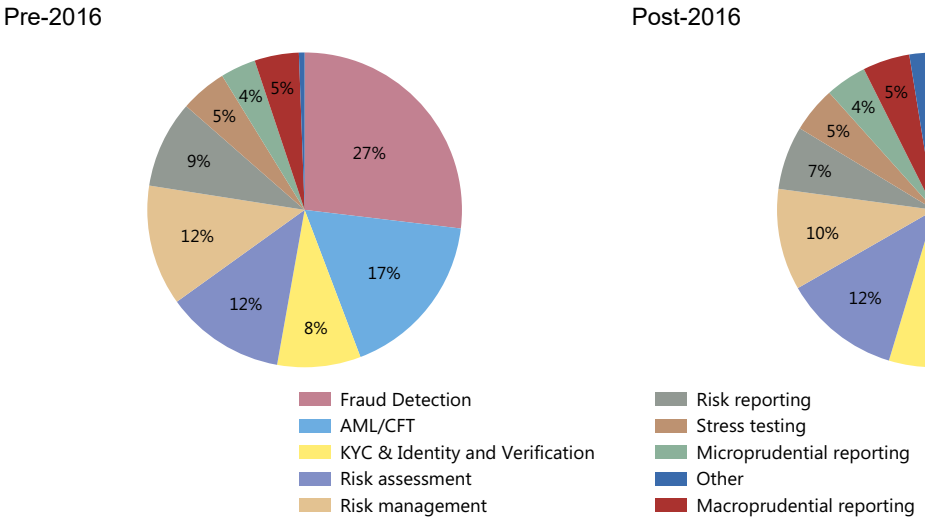
For instance, in its work with a regulated institution, one RegTech provider has developed a name screening optimisation engine to apply ML and NLP techniques to improve name screening. By analysing historical decisions and reducing the number of false alerts, the optimisation engine learns to make assessments similarly to how a human would respond.

Other RegTech providers focus on detecting fraud during remote customer on-boarding. These providers have developed real-time fraud detection software, leveraging advanced AI and biometric technology, to assess whether a user's government-issued photo-based ID is genuine or fraudulent during account on-boarding. The software then compares the results to the user's biometrics using video recording to test live facial movements.

65 Ernst & Young (2019) *Global FinTech Adoption Index 2019*, shows that 75% of global consumers would use a money transfer and payments fintech service, 68% of consumers would consider a non-financial services company for financial services and 93% of SME adopters would prefer to find a technological solution where possible.

Areas where new RegTech tools and uses for data have been developed

Percentage of total tool and data use development **Graph 17**



Source: FSB survey

The survey also shows that the key technologies driving RegTech tools deployed by regulated institutions include ML, NLP and cloud computing (see Graph 18).

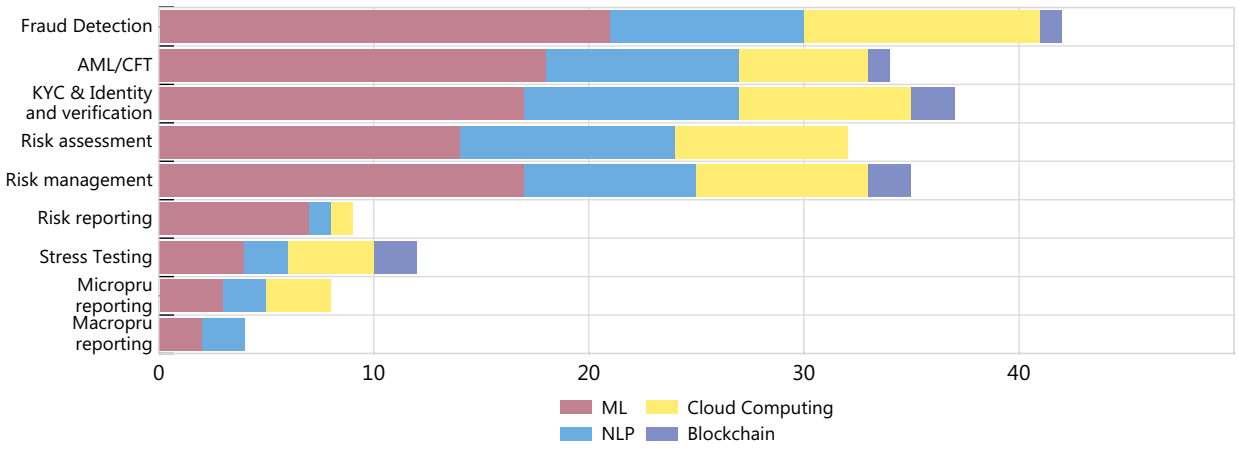
Digital Regulatory Reporting (DRR)

The FCA and BoE TechSprint in November 2016 explored the idea of digitising reporting instructions, with reference to an agreed data model. The TechSprint demonstrated that a small set of reporting instructions could be converted into machine-executable code. Machines could use this code to automatically find and return regulatory reporting directly from a simulated version of a firm's systems.

Work has since progressed to a pilot involving the FCA, Bank of England and a number of regulated banks. See Annex 1, Case Study 6.

Deployment of RegTech tools

No. of authorities who have the tool used in each area **Graph 18**



Source: FSB survey

The growing adoption of RegTech could support financial stability, as these solutions can improve the functioning of regulated financial markets and promote public policy objectives. Certain RegTech tools can assist in building, documenting, and validating quantitative models used to better analyse such areas as credit risk metrics. Some regulated institutions are using advances in RegTech tools to improve their risk management, risk monitoring, and stress testing capabilities. Improved analytic capabilities are enabling some institutions to assess the impact of an increased number of variables across a wider range of scenarios. However, an increasing reliance on RegTech by regulated institutions can also raise challenges for authorities, such as increased operational and cyber risk, the need to ensure the intelligibility of new models, or avoiding the perpetuation of biases present in historical data.[66,67] Certain applications may use "black-box" models, which could raise question of interpretability and explainability of data and results. Dialogue between RegTech providers, regulated institutions and authorities may help to identify and mitigate these challenges.

9. Considerations for future policy

9.1. Financial stability implications

SupTech and RegTech tools discussed thus far have the potential to improve supervision, surveillance, and enforcement by authorities; and reporting and compliance by regulated institutions, thereby potentially strengthening the resilience of the financial system. SupTech and RegTech may also benefit financial stability if automation of regulatory and compliance functions improve quality and reduce errors, whilst also unlocking the potential of real-time monitoring and information processing.

66 Institute of International Finance (2019), *Machine Learning in Credit Risk*, July. In a recent IIF survey financial institutions cite the "difficulty of explaining processes" and "supervisory understanding of or consent to use new processes" as major obstacles to the application of RegTech in stress testing.

67 Doerr S (2019), *Unintended Side Effects: Stress Tests, Entrepreneurship, and Innovatio",* BIS Working Paper no. 823 November.

However, strong governance and skilled human oversight is needed if these tools are to provide enhanced stability. For example, tools that rely upon inferences that are largely based on historical data associated with past instances of instability, which have their own unique characteristics, may not hold for future crises. In addition, insufficient understanding of the technology and interpretation of algorithms, particularly through outsourcing, might exacerbate potential vulnerabilities. SupTech and RegTech applications that use "black box" models may raise questions of interpretability and explainability of data and results. Strong governance around supervisory analytical technology and processes can be important to ensuring the tools act in a manner to best minimise potential risks to stability.

9.2. Future technology use by the regulator

Rapid changes to the financial landscape and evolving market structure could be accompanied by changes in supervisory surveillance techniques. Over 85% of survey respondents expect that the continued evolution of available technologies will result in changes to supervisory processes, with 68% expecting this to be a considerable change. However, authorities expressed concern that undue reliance on SupTech tools could lead to misplaced focus on areas where risks can be easily measured. This may deflect attention from areas of concern that are not as easily given to quantifiable measurement. Thus while authorities may recognise the importance of integrating technology into their supervisory approaches, they could also acknowledge the importance of retaining a forward-looking human based supervisory process.

The modern supervisory philosophy in most jurisdictions surveyed is based on predictive and human judgement-based oversight of regulated institutions. Technology offers the opportunity to automate routine tasks, develop new analytical techniques and provide better information. Using tools such as AI and ML to analyse increasing volumes of regulatory data provides opportunities for authorities to shift their focus to those aspects where humans excel over machines, e.g. judgement-based decision making.

9.3. Translating rules into machine-readable format and enabling regulatory reporting for regulated institutions

Regulatory reporting has become increasingly complex and expensive for regulated institutions. In addition, poor quality reporting and/or delayed data can create challenges for authorities, in particular, if it affects the authorities' ability to supervise and monitor.[68]

Since 2015, authorities in a wide range of jurisdictions have piloted various ways of turning current 'push-based' solutions into more streamlined 'pull' approaches.[69],[70] Push technology automates the delivery of pre-defined data from the regulated institution to the authority. Pull technology originates with the authority drawing data from the regulated institution as and when needed. The transition involves a move from regulated institutions submitting data using

---

68 FCA (2020), Digital regulatory reporting, Phase 2 Viability Assessment".

69 Such as Australia, Austria, Italy, New Zealand, Philippines, Rwanda, Singapore and the UK.

70 World Bank Group (2018), *From spreadsheets to SupTech: Technology solutions for market conduct supervision*, *Discussion Note*, June.

preformat “push” mechanisms, to authorities requesting data from regulated institution using a ‘pull’ mechanism. For instance, regulated institution could make their data available via an API. Relevant authorities could connect to the API and request data. This data could then potentially be pulled on demand rather than requested at static points.

A “pull” mechanism could have a number of benefits for both regulator and regulated entities. Replacing “push” reports with “pull” data may reduce duplication in regulated institutions data submissions and reduce redundancy in the data submitted to supervisors while also streamlining sign off processes. Regulated institutions could sign off on one set of data rather than a number of reports. Authorities could move to collecting only the relevant data when needed, which could materially improve timeliness and save costs on storing and manipulating large datasets. Storing less data may make it easier to meet data security and privacy rules. However, ongoing oversight of the process is needed to avoid the retrieval of incorrect information, or the premature collection of data prior to validation and consent from the regulated institution.

The regulatory lessons from these pilots to date can be summarised as follows:

- No current automated solution in the market meets all the articulated needs of each key stakeholder. It is possible to satisfy some but not all legal, policy, regulatory, commercial and consumer demands. Ongoing research and collaboration between technology providers, supervisors and regulated institutions is needed.
- Digitising regulatory reporting rules may lead to other benefits, such as regulatory simplification.
- Lack of common data standards is perceived as a significant barrier to improving data collection and using new analytical techniques.
- Open standards that are technology-agnostic may increase competition and reduce the cost of implementing “pull” reporting.

Case studies illustrate ongoing developments in this area that are likely to advance significantly in the coming years. Further details are provided in Case Study 6.

9.4. The ethics of using AI models for supervision

AI may provide opportunities for authorities to analyse more data, and offer more timely insights into financial activities, including possible misconduct risks. It may allow for much greater volumes of data to be analysed more efficiently and effectively than traditional human based analysis. However, regulatory decisions based on AI-derived analysis without appropriate human oversight may introduce a number of additional risks to authorities, e.g., potential legal and reputational challenges arising from lack of transparency and “explainability”, data bias and poor quality data.

The ethics of using predictive AI models in a regulatory context should be understood at the outset, and performance calibrated to the highest of standards of public interest.

Regulated institutions might raise legitimate questions about the fair and transparent use of certain data for regulatory decision making in the absence of transparent and rigorous

frameworks for use by authorities. Such questions could relate to the authenticity or provenance of data used by authorities, the potential inherent bias in some AI models, and concerns around data ownership and consent.[71]

Understanding the potential benefits as well as the challenges to deploying AI based technologies will be crucial for both authorities and regulated institutions. Governance frameworks around transparency, intelligibility, accountability and fairness are critical to the effective deployment of such tools

9.5. The impact of cloud-based services on the future of supervision

Authorities could leverage ongoing developments in data science and processing power, including the use of AI and ML, to derive meaningful insights from increasingly large and complex data sets. To do this at scale would likely necessitate the use of cloud-based services to ensure more efficient and effective supervision.[72] Cloud-based services could help enhance regulatory co-operation as they may enable more efficient and effective information sharing between authorities. However, increasing use of cloud-based services could also mean that authorities may become more dependent on third-party providers for critical strategic and operational functions.

9.6. Collaboration with regulated institutions and other authorities

For authorities exploring SupTech tools, the use of resources such as Innovation Labs may allow them to learn from regulated institutions and technology professionals. In addition, global standard-setting bodies and other international organisations provide platforms for authorities to exchange information on their SupTech initiatives. These platforms could be used to strengthen collaborative efforts on cross-sectoral and cross-border issues (e.g. data localisation). A recent example is the BIS Innovation Hub.

Survey results indicate that there is considerable appetite for increased collaboration, particularly between authorities, on SupTech developments (See Graph 19). Over 70% of respondents envisage significant to considerable levels of supervisory collaboration on development of SupTech tools in the future.

---

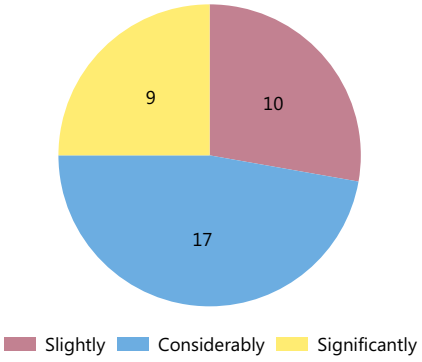
71 European Commission Expert Group on Regulatory Obstacles to Financial Innovation (2019), *30 Recommendations on regulation, innovation and finance*, December.

72 Van Steenis (2019), ibid.

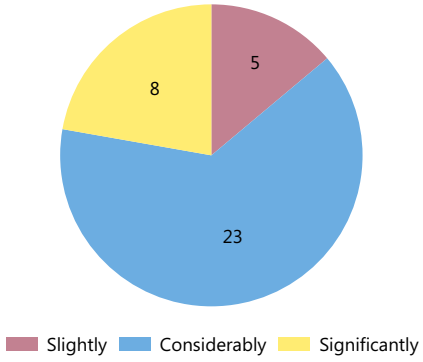
Future supervisory practices and collaboration

Number of authorities **Graph 19**

Anticipated collaboration with other authorities to develop SupTech tools



Anticipated change to supervisory-based practices as a result of new technologies



Source: FSB survey

10. Considerations for future areas of focus

With the rapid pace of change in technology and global financial markets, regulated institutions may look to increase the number of automated activities, to improve operational efficiencies, generate new insights, improve decision-making and reduce costs in data collection and reporting. Going forward, authorities and regulated entities are likely to cooperate more closely as innovative protocols and technologies are increasingly adopted.

The themes that have emerged from the report give rise to some areas for consideration below.

Authorities may need a well-defined and user-centric SupTech strategy that meets their unique objectives. To help successful adoption and implementation, buy-in and support from senior management that acknowledges the benefits of SupTech while also appreciating its limitations and risks is important. In addition, in designing the SupTech strategy, authorities could benefit from strong engagement with their staff, in particular the end-users of these tools, through an early and ongoing dialogue.

Authorities may seek to establish a comprehensive strategy for attracting and retaining the necessary talent base with the necessary digital skillsets. The recruiting process could include hiring of professional expertise with a strategic understanding of the goals for the development or acquisition of SupTech tools to ensure successful integration of the SupTech in the authorities' organisational structure. To keep abreast of technological developments, authorities might consider engaging and seeking innovative collaboration with a range of external parties, such as other financial authorities, the academic community, technology vendors and international organisations. In addition, appropriate staff training programs are important to improving and accelerating knowledge.

Both authorities and regulated institutions may seek to focus on the significant opportunities that exist in the area of data collection. Going forward, based on the survey responses, authorities may increasingly look to develop APIs or micro-service interfaces that allow regulated institutions to programmatically submit data, or authorities to pull data, depending on the context and

specific use cases. Authorities might also choose to migrate away from the use of legacy systems to ensure system compatibility with the latest standards and technologies. Based on the survey responses, tools or solutions that improve data collection could also benefit from common data standards.

Standard setters and authorities may wish to consider evaluating the scope for common data standards and taxonomies for relevant regulatory areas, including the potential for international collaboration, in order for reporting solutions to be made more scalable and interoperable.

With the rapid growth in the amount and richness of data collected, authorities may also benefit from expanding the range of tools they employ for data analysis, leveraging emerging technologies. With the adoption of more tools providing predictive and prescriptive analytical outputs, this could bring about significant improvement in actionable, meaningful and forward-looking risk surveillance and mitigation. At the same time, the use of advanced analytical tools raises the need for adequate data governance frameworks, which authorities may wish to explore further. This would help ensure the explainability of these tools and transparency as to how results of the tools inform decision-making, thereby promoting accountability within authorities.

Both authorities and regulated institutions may wish to adopt an approach and environment that encourages ‘fast fails’ and dynamic idea sharing. Given that SupTech and RegTech are still relatively new fields, not all pilots and proofs of concepts are likely to succeed initially. In turn, authorities and regulated institutions could encourage and foster a spirit of collaboration and innovation, and authorities could encourage open dialogues and debates that will lay the foundation for the future regulatory landscape.

Annex 1 – Case studies and examples

Please note that the following case studies are unique experiences of individual authorities and no generalisations should be necessarily drawn.

Case Study	Title
1	**De Nederlandsche Bank** *Becoming a smart supervisor*
2	**European Central Bank** *Supervisory Technology Hub*
3	**European Central Bank** *ECB's Virtual lab*
4	**Bank of England** *Unstructured data extraction and analysis using ML*
5	**People's Bank of China** *Off-site Payment Transactions Supervision Based on API and AI*
6	**Bank of England, Financial Conduct Authority** *Digital Regulatory Reporting (DRR)*
7	**European Securities and Markets Authority** *Web scraping, NLP and analysis of Key Information Documents*
8	**European Central Bank** *Machine-reading of Fit and Proper Questionnaire*
9	**China Banking and Insurance Regulation Commission** *Multi-party secure computing (credit field)*
10	**Banco de España** *Use of NLP in relation to ESG disclosures in Spain*
11	**Banco de España** *Tools for detection of mis-selling in Spain*
12	**Monetary Authority of Singapore** *Network Analysis for STRs*
13	**Banca d'Italia** *Anomaly measurement in transactions using Big Data*
14	**Commissione Nazionale per le Società e la Borsa (CONSOB)** *Market Surveillance*
15	**European Central Bank** *Early Warning System for Less Significant Institutions*
16	**European Central Bank** *SREP – Truffle Search Analytics for structured text documents*
17	**Monetary Authority of Singapore** *Predictive modelling to identify representatives at higher risk of misconduct*
18	**Monetary Authority of Singapore** *Text analysis of audited financial statements*
19	**Monetary Authority of Singapore** *Data analytics for inspections*
20	**European Central Bank** *Sentiment analysis*

Case Study	Title
21	**European Central Bank** *Network Analytics*
22	**Banque de France/ACPR** *Augmented supervisor*
23	**Banque de France/ACPR** *Advanced network analysis for banking supervision purposes*
24	**Federal Reserve Board of Governors** *NLP for continuous monitoring, web searches and COVID-19 monitoring*
25	**Bank for International Settlements** *BIS Bulletins*
26	**Bank of England** *Policy Response Tracker*
27	**De Nederlandsche Bank** *COVID-19 SAS-VA Dashboard*
28	**Monetary Authority of Singapore** *Monitoring and enforcement of safe distancing measures*

Case study 1: De Nederlandsche Bank (DNB)

Description of innovation

Becoming a smart supervisor

De Nederlandsche Bank (DNB) recently initiated a dedicated Supervision Innovation Department to coordinate and accelerate the implementation of its digital strategy. The strategy's purpose is to adopt a more data-driven approach and deploy technology to support the supervisory process, with the ultimate goal of transforming the DNB into a 'smart supervisor'.

The department has a leading role in the prioritisation of innovation projects in the supervision domain. It reports directly to the Chair of Prudential Supervision, to ensure that there is a strong link between the technological development and the realisation of strategic goals. The department coordinates multiple development teams, that focus on the use of SupTech tools to analyse large sets of (un)structured data, the impact of artificial intelligence on the financial sector, and digitisation of the supervision relationship. The department works closely together with the DNB's Chief Data Officer, as well as the joint DNB and AFM Innovation Hub initiative.[73]

In 2019, the DNB established the Innovation Forum (or iForum) to strengthen cooperation with a wide range of stakeholders, including regulated institutions, academics, service providers and public authorities. The department supports the iForum and serves as a platform to discuss the impact of technology on the financial sector and to work together on digital opportunities to innovate the Dutch financial ecosystem. Potential areas of work that have been identified by iForum participants include improvements in the user-experience of DNB's web portals and the development of a data-tool to monitor the transition to new benchmark rates.[74]

Case study 2: European Central Bank (ECB)

Description of innovation

Supervisory Technology Hub

The ECB has incorporated the use of supervisory technologies as a core element into its strategic vision for banking supervision. To leverage the full potential of new technologies, the ECB has therefore created a dedicated Supervisory Technology (SupTech) Hub and introduced an ambitious Digitalisation Roadmap outlining a set of actions over a three-year horizon. Five building blocks have been identified as key pillars to achieve this vision:

i. **Build a Hub & Spoke innovation model** for banking supervision which is suitable to develop common projects and reap synergies, while allowing for local specialisations;

ii. **Foster a digital culture** to provide supervisors with the skills and mind-set to fully engage in digitalisation;

iii. **Create an innovation ecosystem** that spreads beyond banking supervision, to include start-ups and academia, and benefits from network externalities;

iv. **Harness the power of data and artificial intelligence** to deliver state-of-the-art, data-oriented tools to front-line supervisors;

v. **Automate process and boost current systems** to digitalise processes, enhance core banking supervision IT systems and implement robotic process automation.

---

73 See https://www.dnb.nl/en/supervision/innovationhub/index.jsp.

74 https://www.dnb.nl/toezichtprofessioneel/075_iForum/gezamenlijke-initiatieven/index.jsp.

Insights and outcomes

Various projects using, among others, machine learning, natural language processing and advanced analytics tools, have been launched across diverse functions within banking supervision such as stress testing, authorisation procedures, supervision of Less Significant Institutions and decision-making.

The SupTech Hub will facilitate the collaboration on new technologies inside the ECB and with all National Competent Authorities in the Euro area, supported by a new open collaboration platform (SupTech Virtual Lab as further detailed in Case study 3), the SuperVision Innovators Forum, and the set-up of multidisciplinary innovation teams.

Case study 3: European Central Bank

Description of innovation

ECB's Virtual lab

The ECB is developing a supervisory technology ("SupTech") platform called Virtual Lab, which will provide the digital infrastructure for remote collaboration across the Single Supervisory Mechanism (the ECB and the national competent authorities). It is therefore a key component in achieving the objective of building a hub-and-spoke innovation model.

Virtual Lab is a cloud-based platform that will enable all stakeholders to connect with one another, share content and collaborate on joint projects in a secured environment. Activities carried out via the common platform will include developing, executing and sharing Python and R models, connecting to a centralised data hub, using existing micro services shared by platform participants, taking part in a digital training curriculum and joining virtual project teams of interest.

The SupTech platform will feature notebook hub technology that enables users to combine executable source code with documentation containing, for example, text and images. These interactive notebooks will help to make data analysis more transparent but can also facilitate data visualisation and data exploration by making source code more intuitive. Furthermore, since the platform is cloud-based, it will be scalable, making it ideal for the rapidly growing computing needs in advanced artificial intelligence (AI), ML and deep learning.

The platform will incorporate additional software development best practices, such as version control, model and data management, and model governance, to ensure that only quality-approved codes are deployed in production.

The ECB's SupTech Virtual Lab will provide a solid foundation to instil an inclusive data-driven and innovation-friendly culture, where advanced users can pursue more complex AI, modelling and programming projects, and newcomers are given an intuitive environment to explore experiment and learn about the use of the technology.

Case study 4: Prudential Regulation Authority (PRA), Bank of England

Description of innovation

Unstructured data extraction and analysis using ML

As part of the continuous assessment of regulated institutions (FIs), the PRA receives an enormous amount of unstructured data in the form of text, tables, graphs and images. This data often presents firm's own narrative for internal or external developments, as well as its senior management thinking on current and emerging risks.

It is estimated that each week just the largest FIs submit more than 1.7m words to the PRA. Reviewing all of this firm management information (MI) is an impossible task for any team of authorities. Historically, authorities were focussing their reviews on those themes that were relevant to the current financial condition of the firms. Still, this has resulted in authorities spending a significant chunk of their time locating and reconciling basic information in the unstructured data, instead of analysing it if it was readily available. Additionally, staff and particularly those working on the largest FIs, were unable to easily identify trends and themes across firms and sectors, which could pose potential risks to financial stability.

To address these challenges, the PRA commenced a POC in ML on unstructured firm MI (circa 2m documents). The POC set out to prove that ML, and reinforcement learning could deliver benefits in terms of time savings and supervisory effectiveness. The technologies used were supervised and unsupervised ML, NLP (Optical Character Recognition), connection through APIs to the PRA's file repositories and external market sources for the retrieval of historical and supplementary data.

Objectives

Greater exploitation of firm MI – consume large volumes of unstructured data, quickly creating time savings for staff who spend a significant amount of time sifting and processing firm MI.

Improve efficiency of finding data – use supervised and unsupervised ML to classify firm MI to facilitate more accurate extraction of information and identify key topics more efficiently.

Share relevant trends across peers – interpret past trends against current, conduct peer analysis, and examine sector trends across time series.

Gaining more value from firm MI – rapid analysis prediction and processing based on 'key' areas mentioned by firms as supervisory priorities.

Insights and outcomes

The POC demonstrated that ML and NLP could provide significant time savings to end-users, as well as surface information on previously hard to spot emerging risks. The tool developed as part of the POC provided peer comparison on unstructured data based on supervisory priorities (supervised ML), as well as any other themes of potential interest found in the document body.

Next steps

Following the overwhelmingly positive feedback from end-users, the PRA commenced a full-scale project for the introduction of ML on unstructured firm data, which is expected to deliver an enterprise solution for all of Supervision in Q4 2020.

Case study 5: Peoples Bank of China (PBC)

Description of innovation

Off-site Payment Transactions Supervision Based on API and AI

Recently, the People's Bank of China designed an off-site supervision information system for payment transactions based on API technology (hereinafter referred to as the system). The system introduces technologies such as AI, Big Data, cloud computing and data mining into the supervision of the payment transactions sector.

Using a standardised API, payments transaction and regulatory data are collected and stored efficiently. The system also adopted layered Infrastructure as a Services (IaaS) solution to make full use of available networking and computing resources. Furthermore, and in accordance with the principle of jurisdictional supervision, the data storage arrangements are made flexibly taking into consideration the business volume distribution, computing resource allocation, and data warehousing costs.

The architecture adopted is an improved Unifield and the technologies applied in production are Knowledge Graphs and Artificial Neural Networks. The system also incorporates AI analysis and modelling processes into the data flow process.

Other technologies applied are supervision agent, and, in terms of visualisations - dynamic risk dashboards and graphs. Finally, the system could track payment transactions sector behaviours reducing the density and complexity of raw data by transforming it into panoramic dashboard and data map.

Insights and outcomes

The system achieved substance-over-form supervision, enabled early warning alerts, improved decision-making, thus effectively reducing supervision costs, improving supervision efficiency, and supporting macro-prudential authorisation, by promoting compliance.

Case study 6: Bank of England and the Financial Conduct Authority

Description of innovation

Digital Regulatory Reporting (DRR)

An FCA TechSprint in November 2016 explored the idea of digitising reporting instructions, with reference to an agreed data model. In 2017, a joint FCA-Bank of England TechSprint demonstrated that a small set of reporting instructions could be converted into machine-executable code. Machines could use this code to automatically find and return regulatory reporting directly from a simulated version of a firm's systems.

Work has since progressed to a pilot involving the FCA, Bank of England and a number of regulated banks. This work has looked at three areas of the reporting process:

(i) Standardising data description and identification

Currently some firms use multiple terms or identifiers to describe the same data. Under DRR, firm data would be digitally tagged and identified according to agreed data standards. This means the same data can be identified easily across firms and systems.

(ii) Digitising reporting instructions

Reporting instructions are primarily published in natural language. Firms and reporting software vendors convert those instructions, where possible, into code. This process can be difficult since the instructions may be hard to interpret to the legally untrained.

Under DRR, the regulator would publish a coded version of reporting instructions. The natural language version may also be published or may be replaced by a structured, machine-executable version. This process utilises constrained natural languages to limit the expressivity of regulatory text and requires the building of compilers to convert regulatory rules from machine-readable language into machine-executable language.

(iii) Improving the efficiency of report generation

Firms using their own systems or systems purchased from software vendors currently compile regulatory reports. These reports are then submitted or "pushed" to the regulator. Under DRR reporting systems, they could be designed so that they can consume the digital regulation published by the regulator, identify and collate the data required and provide it to authorities. This may allow authorities to "pull" data from firms.

Next steps

In January 2020, pilot participants published a Viability Assessment resulting from their work, and at the same time the FCA published a refreshed data strategy and the Bank of England published a discussion paper on transforming data collection. The FCA is now examining ways to build prototypes for specific reporting use cases and the Bank of England is collating responses to its discussion paper. Decisions resulting from this work should are expected in Q3 2020.

Case study 7: European Securities and Markets Authority

Description of innovation

Web scraping, NLP and analysis of KIDs

Many regulatory requirements on information to be provided to users in a 'document' format: including Key Information Documents (KIDs), prospectuses, and financial statements. Supervising compliance of this information with the various rules on required phrases, content (e.g. numerical information), and presentation is challenging when done manually and can clearly not be performed systematically. Beginning in 2019, ESMA began exploring the contents of more than 20,000 KIDs produced according to the Package Retail Investment and Insurance-based Products (PRIIPs) Regulation, from more than 500 issuers, in 21 EU languages. This work involves application of the following technologies:

1. The retrieval of documents/items to be assessed using external sources (i.e. web scraping) and/or internal ESMA databases;
2. Development of methodologies to extract information from these documents (natural language processing);
3. Developing tools to share with national supervisory authorities for assessing these documents (software development).

Insights and outcomes

Emerging findings to date have provided a number of insights. This includes the need for further communication with regulated institutions around the KIDs-related provisions of the PRIIPs Regulation. Specifically from analysing the documents, it became clear that certain provisions were being misapplied to such an extent that suggests some confusion on how the provisions are set out. Another insight gained is that the range in percentage compliance with inserting the more than 50 required words and phrases in the KID varies substantially across language groups. This suggests an area where enhanced common supervisory actions across national supervisory authorities in the EU could potentially be of benefit. A third insight gained is that the scenarios used in the investment return simulations required for disclosure in the KID, may need to be adjusted and re-calibrated scenarios to produce meaningfully different outcomes for investors. This insight accords with and lends support to the recent consultation by ESMA and other European Supervisory Authorities to potentially revise the PRIIIPs KIDs Regulation in this direction.

Ultimately, this project has demonstrated that text-based analysis enables a new form of market monitoring: using information in documents that was previously impossible to compare.

At the same time, this project illustrates a number of challenges that need to be borne in mind when developing such tools. This includes finding the right skillset within an organisation to create and disseminate these tools. Another challenge comes from handling the necessary complexity associated with working across so many languages, of which some do not have as well-established language analysis platforms as others. In addition, developing tools with other supervisory authorities needs a common format, but most text-analysis software is specialised (even if it is open-source). Embedding these tools within other authorities, (a possible next step) requires both common IT arrangements and behavioural change—this will inevitably take time.

Case study 8: European Central Bank

Description of innovation

Machine-reading of Fit and Proper Questionnaire

Background

The ECB conducts around 2,500 fit and proper assessments of members of management bodies of significant institutions per year. For each assessment, case handlers have to analyse information on appointees contained in an up to 40-page long fit and proper questionnaire, which is submitted in different formats and languages depending on the country of origin.

Objectives

The objective is to create a tool that partly automates the translation and assessment of fit and proper questionnaires, by using Natural Language Processing (NLP) and ML techniques. The envisaged tool should automatically read and transform all information contained in the questionnaires into a digital format and provide an automated translation. In addition, the tool should be able to immediately identify any "red flags" or concerns about an applicant's credentials that would require further scrutiny. All information contained in the questionnaires should be stored in a database to allow for further analysis.

Insights and outcomes

In early 2020, a proof-of-concept was developed which demonstrated that many of the objectives of the tool could be met successfully. Challenges remained with the correct recognition of scanned documents that included errors or handwritten annotations. Anticipating improvements in the production stage, the tool could potentially save a significant amount of time for case handlers on standard checks. It is envisaged that case handlers will give feedback to the tool about the accuracy of identified issues and thus improve the quality over time. By machine reading all information and data from the questionnaires, the tool also helps to record information which previously could not be stored digitally (thus, replacing time intensive manual data recording).

The tool is one of the first tests within ECB Banking Supervision of a modular, cloud-native architecture with highest security standards. The modular architecture of the tool allows for a flexible use of the different modules for other purposes within banking supervision.

Next steps

Going forward, the ECB is exploring the possibility to deploy the tool in production. Furthermore, it aims to apply the underlying technologies to a larger set of supervisory processes.

Case study 9: China Banking and Insurance Regulation Commission (CBIRC)

Description of innovation

Multi-party secure computing (credit field)

A technology company and a bank cooperate to issue loans to customers. The company has customer behaviour data such as online shopping and payment information, and the bank has traditional financial data such as customer credit, income, and assets. The two combine their information to more accurately judge the credit status of customers based on the overall information they have, to make better credit decisions. At the same time, both expect to better protect customer data privacy and guarantee their own data rights.

The technology company has developed multi-party secure computing technology to guarantee data security. Following the concept of peer-to-peer openness and security first, the premise of multi-party data cooperation is not to expose the user's private data, and the data is "available and invisible" through a variety of security mechanisms. The entire solution provides security guarantees in platform access management, data decentralisation use, data destruction after use, and operational audit at any time.

Insights and outcomes

Model development phase. In the platform development environment, both parties will randomly select a small number of data samples based on the data indicators obtained by the user's authorisation under the premise of statistical significance. The index items are encrypted, desensitised, sampled, segmented, de-identified and ID-identified. At the same time, the access and use of data will also be subject to intelligent risk identification, interception, monitoring and auditing, which effectively guarantees data security and model intellectual property security.

Application deployment phase. Each party uses the model trained based on their own data for local deployment, and uses their own data to make prediction calculations for the applying customers. Both parties share the calculation results of each other and finally obtain a complete evaluation conclusion.

During the entire process, the data and models of all parties are stored in their own network equipment environment, and only the calculation results are transmitted to each other, which truly protects user data privacy and achieves secure computing.

Case study 10: Banco de España

Description of innovation

Use of NLP in relation to ESG disclosures in Spain

Early in 2019, a small pilot was launched to help BdE understand the domestic green economy. To extract and classify relevant pieces of information OCR, text mining and NPL techniques were tested.

As a starting point, a focus was placed on collecting information from the institution's annual financial reports. Yet, the absence of relevant data soon proved to be a challenge and so, the scope was broadened to consider corporate social responsibility reports of both financial and non-financial organisations as well. Given that most of this information is not standardised, that it is recorded in natural language and that it oftentimes hinges on charts, graphs and tables a pre-processing stage was found critical in order to properly streamline the underlying documentation for the exercise's ultimate purposes.

Insights and outcomes

An exhaustive labelling process followed. Due to limited available information for training purposes and the need to maintain flexibility towards the structure of the labels, preference was given to the deployment first of a rule-based model. However, the underlying tool has been designed in a way that it will be capable of supporting pre-trained convolutional neural networks to help tag key areas of the documents.

Case study 11: Banco de España

Description of innovation

Tools for detection of mis-selling in Spain

Market conduct supervision exercises often require the review of a large number of loan agreement samples. In 2019, Banco de España launched two parallel Proof of Concepts on the application of supervised ML to these supervisory processes. The ultimate goal was to be able to cope with larger samples in less time while also maintaining the traceability from the extracted information to their source documents.

For practical purposes, the initial scope was kept narrow. As such, tests focused, on the one hand, on the automatic extraction of specific information from mortgage loan agreements (i.e. non-standardised floor clauses in about 600 sample files). Similarly, a second exercise implied analysing particular aspects of consumer credit contracts (i.e. samples from 5 credit institutions), namely: whether relevant checkboxes had been ticked, whether the handwritten signature had been properly recorded and whether certain type of additional services which had been billed were formally requested by the client. For both these projects a combination of NLP and computer vision techniques, as well as supervised ML tools were used.

Insights and outcomes

Despite being resource-intensive at the outset, the project helped develop a number of technical building blocks that proved reusable for other supervision-related purposes. Training and validating models emerged as a major challenge as well as certain practical aspects regarding the quality of information available on paper. In addition, access to an adequate skillset was also difficult. On the contrary, the search for the appropriate algorithm was less complicated than originally expected. So far, one of the tools has been deployed into production and is used to support certain supervisory exercises on demand.

Case study 12: Monetary Authority of Singapore

Description of innovation

Network Analysis for STRs

MAS supervises regulated institutions (FIs) for their money laundering and terrorism financing (ML/TF) risk management. To enhance supervisory effectiveness, it conducts risk surveillance to detect systemic risks and to target higher risk areas and FIs for closer supervisory scrutiny. Their FIs file Suspicious Transaction Reports (STRs) on potentially illicit flows of funds and financial crime concerns, and these provide useful information for their risk surveillance purposes. Complex typologies often involve multiple accounts at multiple FIs and this may manifest in multiple STRs filed over a period. Therefore, it has developed an STR network analytics tool to help it better analyse FIs.

Insights and outcomes

The use of the STR network analytics tool has helped MAS identify concerning clusters of individuals/entities that exhibited suspicious behaviours, as well as the FIs involved for their supervisory analyses and scrutiny. This helped sharpen their ability to prioritise and target risks in their AML supervision. The insights and emerging risks uncovered from the network analyses were also shared with the financial sector through various platforms, including their AML/CFT Industry Partnership (ACIP), industry workshops, or via advisory notes and supervisory guidance to all FIs. These data driven engagements have raised industry risk awareness, and in turn have prompted FIs to expedite their adoption of innovative data analytics approaches to combat financial crime.

Other than furthering their supervisory objectives, the insights gained from the STR network analytics tool also aided the national effort to combat financial crime. In Singapore, there is an interagency committee that brings together relevant law enforcement and supervisory agencies to investigate and develop risk mitigation plans for priority ML/TF cases. Several concerning networks detected through their STR network analytics have been escalated to that interagency committee for deliberation and coordinated action across agencies.

The data inputs for the network analysis in the initial phase comprise mainly of information from the structured data fields in the STRs. The dataset is being enhanced in order to increase the impact of the network analytics tool. Firstly, NLP models are being developed to extract information from the unstructured, textual data within STRs, e.g. narratives explaining the unusual nature of customer transactions and relationships between counterparties for incorporation into the STR network analysis. Secondly, the analytics tool has also started to process more transaction data and company profile information. These enhancements will strengthen the ability to identify hidden connections, and to detect and prioritise systemic risk concerns for supervisory and inter-agency follow-up.

Case study 13: Banca d'Italia

Description of innovation

Anomaly measurement in transactions using Big Data

The Financial Intelligence Unit (UIF) of the Bank of Italy, on a yearly basis receives i) about 100,000 suspicious transaction reports (STRs) and ii) about 100 million monthly value-based aggregate records (such records are anonymous and aggregate transactions equal to EUR 15,000 or above; SARA database). Moreover, Italy's gold market operators (mainly banks and registered gold traders) report to the UIF gold transactions above EUR 12,500. Furthermore, a system of value-based transactions for cash withdrawals above EUR 10,000 has recently been implemented.

Insights and outcomes

With regard to the SARA database, UIF is using a big data dashboard to monitor wire transfers to and from selected countries. By combining structured and, to a lesser extent, unstructured data (e.g. press articles), the tool is able to calculate indicators that help in measuring the degree of anomaly of each flow. UIF, meanwhile, relies on an external vendor and open source tools to build dashboard and visualisation tools that can analyse a large amount of data in a few seconds and can combine data from different sources.

Concerning the STRs database, UIF is currently developing a tool to classify the reports according to the type of money laundering scheme associated. First, information is extracted from the unstructured part of the STRs using natural language processing (NLP); then a supervised ML technique is used to classify the STRs according to the identified typology.

Finally, UIF is testing a tool that combines network analysis and self-organising maps techniques to search the gold declaration database for fraudulent schemes, by matching the behaviours of operators involved in known fraud to market players that display a similar behaviour.

Case study 14: Commissione Nazionale per le Società e la Borsa (CONSOB)

Description of innovation

CONSOB is developing a data strategy to make a more effective use of relevant information through modern digital technologies. In particular, CONSOB has started a multi-year project to establish a new technology infrastructure, increasing the granularity and frequency of information gathering and sharing, making more efficient its collection, storage and use.

In addition, CONSOB developed, in partnership with academics, a prototype to analyse the PRIIPs Key information Documents in October 2018. During the second half of 2019, CONSOB purchased an artificial intelligence platform from a third-party provider. The platform employs deep learning language interpretation techniques for real-time semantic analysis of unstructured data. It allows understanding of natural language and the identification of relationships across millions of documents from thousands of sources in order to extract relevant data.

A pilot phase is underway to ensure the necessary customisations. Based on the input of the operational divisions, two prototypes are being drawn up, the first one for the analysis of the PRIIPS Key Information Documents and Prospectuses while he second one identifying "facts" and "relationships" across emails and documents gathered during onsite inspections.

Insights and outcomes

Initial challenges were linked to the identification of the right third-party provider, to the prioritisation/selection among the very many possible uses of the artificial intelligence platform and its customisation.

Potential efficiency gains from the overall project are expected in terms of:

- Improved ability to detect cases of mis-selling;
- Pervasiveness and quality of the analysis of financial and non-financial information, market-developments and trends, risks of listed companies;
- Pervasiveness and quality of the analysis on the data and information collected during onsite inspections;
- Identification of pre-contractual information documents with misleading information and ability to intervene more promptly to improve their quality and reliability;
- Prioritisation of risks;
- Capturing relationships and key aspects in the judgement of issuers' auditing companies;
- Identification and prevention of breaches in the area of internal governance, organisational structures, procedures and processes;
- Identification and prevention of fraud, including internet fraud.

Case Study 15: European Central Bank

Description of innovation

Early Warning System (EWS)[75] for LSIs

Background

ECB is responsible for the supervisory oversight of more than 2,400 Less Significant Institutions (LSIs) across the SSM countries. The direct supervisory work for these institutions is conducted by the National Competent Authorities (NCAs).

Objectives

To support both the ECB and NCAs in their work and ensure a level playing field, qualitative supervisory analysis needs to be complemented with a rigorous quantitative tool, which tries to identify cases of financial distress at the level of individual institutions in the European banking sector.

Insights and outcomes

The EWS was developed as a tool that helps the supervisor identify institutions that might need to be followed more closely, and therefore prioritise the efforts towards the banks which might potentially enter into financial distress. The model uses a ML technique of supervised learning and builds on a dataset consisting of bank specific variables coming from quarterly supervisory data (mainly COREP and FINREP), complemented with banking sector specific variables (e.g. whether a bank is a member of an Institution Protecting Scheme) and macro-economic indicators.

The results provide a list of institutions as well as a list of key variables and key risk indicators, which lead to the model outcome. This outcome provides a forward-looking perspective, which aims at making the identification of distress cases timely enough and therefore leave a time window for the supervisor to intervene.

Case study 16: European Central Bank

Description of innovation

SREP – Truffle Search Analytics for structured text documents

Background

Supervisors assess and measure the risks for a bank and summarise all of the findings for a given year in a legally binding supervisory board decision called the Supervisory Review and Evaluation Process (SREP) decision. More than 120 such SREP decisions are issued every year comprising of over 5300 pages of structured text documents.

Objectives

The objective was to create a tool (named Truffle Analytics) which should be able to recognise and search for information in the SREP decisions using NLP and ML techniques. This tool should allow supervisors to search for information across different SREP decisions and facilitate the identification of emerging trends and clusters of risks.

Insights and outcomes

The ECB has started working on the development of SREP Truffle Analytics in 2019 and currently a pilot is being tested with a limited user group on production data. The pilot demonstrates that the main objectives can successfully be met. In particular, apart from searching for key words across different

[75] See Bräuning, M., Malikkidou, D., Scalone, S., and Scricco, G., *"A new approach to Early Warning Systems for small European banks"*, *Working Paper Series*, No 2348, ECB, Frankfurt am Main, December 2019.

SREP decisions the tool allows for the production of relevant graphs and metrics, which can be customised by the end user with a number of filtering functions.

Next steps

After successfully finalising the pilot phase, Truffle Search Analytics will be rolled out to a wider user group. Moreover, in the future, the aim is to add text time series analysis, ontology-based search and text anomaly detection.

Case study 17: Monetary Authority of Singapore

Description of innovation

Predictive modelling to identify representatives at higher risk of misconduct

MAS regulates financial adviser representatives working at insurers, banks, and licensed financial advisory firms in Singapore. When these individuals commit misconduct, such as selling unsuitable life insurance or investment products to consumers, their firms are required to report such cases to MAS. Supervisors review these reports with a view to take regulatory action against the individuals for serious misconduct. Drawing upon supervisors' experience and inputs for predictive factors (e.g. working experience and misconduct history of the representative), MAS tested different factors and developed a simple multi-factor logistic regression model to predict the risk of misconduct for each representative over a period of two years.

Insights and outcomes

The results of the predictive model affirmed supervisors' intuition that factors such as misconduct history and working experience of the representative are statistically significant in predicting future misconduct. Using the model, the MAS is able to identify representatives and transaction samples for scrutiny during onsite inspections.

Case study 18: Monetary Authority of Singapore

Description of innovation

Text analysis of audited financial statements

MAS receives audited financial statements from its regulated FIs annually. While the reports may not always be lengthy, MAS deployed a tool that uses text analysis techniques to look for key words of concern within each report. This has helped supervisors identify and focus on red flags more quickly and systemically.

Insights and outcomes

MAS combined text analysis with quantitative analytics of financial metrics, and visualised the results on a single automated dashboard to give supervisors a bird's eye view of the reports. This relatively simple tool has improved the efficiency in the review of audited financial statements. Having deployed this as a pilot in one department, MAS is looking to widen its use to more supervisory departments.

Case study 19: Monetary Authority of Singapore

Description of innovation

Data analytics for inspections

MAS inspectors have traditionally been relying on human judgement to review firm data and identify potential red flags manually. For instance, in reviewing trade allocations and prices for those trades, typically inspectors select samples and scrutinise the sample trades for anomalies. The process is laborious and resource-intensive. To support this work, inspectors have collaborated with data analysts to develop a tool that automates the process by using algorithms and statistics to guide their analysis. Techniques such as market-basket analysis are used to identify accounts that trade frequently together.

Insights and outcomes

With the automated algorithms, inspectors are able to analyse entire datasets instead of only relying on sampling. Inspectors are also able to focus on trades that are statistical outliers – enhancing their ability to identify specific trades of greater concern. MAS is expanding the use of SupTech to support more inspections.

Case study 20: European Central Bank

Description of innovation

Sentiment analysis

The objective is to create an easily readable and customisable dashboard for ad-hoc analysis of the public sentiment concerning a financial institution. The dashboard should allow supervisors to assess how the supervised institution is perceived by the public and to complement the assessment for the Supervisory Review and Evaluation Process (SREP) with relevant pieces of information.

Insights and outcomes

The ECB is currently in the exploration phase and internal discussions on how to optimise such market sentiment analysis with the help of natural language processing and ML techniques are ongoing. The envisaged tool should be able to provide, in a dashboard format, an overview of market sentiment and allow drilling down into risk trends, a review of market sentiment over time and clustering identified topics into risk categories.

Considering that sentiment may differ across jurisdictions, it is essential that the tool is able to capture and analyse news in different languages and aggregate the results in a single dashboard. Word vectorisation and ML methods can also prove helpful in translating foreign language articles by exploiting the syntactic and semantic relationships between language elements.

Case study 21: European Central Bank

Description of innovation

Improved credit risk forecasting

Advanced analytics has been applied to combine sectoral loan level data (currently used only for monetary policy and financial stability purposes), macroeconomic forecasting and prudential information in order to better understand the severity of shocks to credit risk parameters at the sectoral level.

Insights and outcomes

The ECB is currently in the exploration phase and looking into different development options. Internal discussions with experts across the ECB have shown the huge potential from connecting these two strings of information to offer supervisors the possibility to look through loan level networks. The idea is to create a dashboard showing which SIs are most exposed to those sectors prone to coronavirus-related shocks, as well as comparing their relative provisioning. The tool should allow drilling down into specific exposure types, as well as viewing risk trends and clusters of risk. In turn, this may not only allow an understanding of the comparative position of an SI versus its peers but should also make it possible to gauge the risk development for economies that currently lag those that were first affected by the pandemic-related shock.

In a subsequent step, a credit risk early warning system that relies on sectoral developments is envisaged. Potential extensions also foresee the inclusion of data on security holdings to further enhance the risk position picture of SIs.

Case study 21: European Central Bank

Description of innovation

Network Analytics

Private equity groups are increasingly investing in European banks, with some acquiring multiple holdings in several banks. Supervisors need to have a clear picture of banks' ownership structures and therefore need to know who owns the private equity groups concerned and what cross-party participations these firms hold. This can be challenging, as the structural set-up of these groups tends to be complex and the necessary information is scattered across different data sources.

The objective is to develop a tool that uses network analytics and advanced interactive graph visualisations as a means to gain a more in-depth view of the holdings of private equity groups in supervised entities. This tool would support analysis conducted by supervisors by providing an intuitive visual representation of ownership networks (i.e. the extent of the holdings of these groups and of other shareholder clusters in credit institutions in countries participating in the single supervisory mechanism (SSM), as well as the extent to which shareholders of significant institutions are interconnected).

Insights and outcomes

A multidisciplinary team developed the first iteration of the application providing visualisations and insights related to selected private equity groups in certain countries. The team is back testing the initial results and is aiming to make the tool available soon for broader audiences within the SSM. So far, this work has enabled us to analyse in greater depth the bank holdings of over 300 private equity funds, capturing more than 150,000 interconnecting investments. Depicting this complex situation in an accessible, visual way avoids repetitive manual work and helps supervisors to exercise their expert judgement.

Next steps

The next steps involve focusing on front-end development to improve the experience for end-users. In addition, the development team will enhance the tool's filtering functionality to allow users to focus on the most material interconnections. The possibility of extending the capabilities of the tool to potentially include analysis of the interconnectedness of other financial entities will also be assessed.

Case study 22: Banque de France/ACPR

Description of innovation

Augmented supervisor

'J-VEILLE' , 'ISITEXT', 'DIXIT', 'KARTODOC' and 'SAM' projects are part of a more general ACPR/BdF intrapreneurship project that aims at enhancing the supervisory efficiency by automating time-consuming tasks using data science / data visualization techniques.

J-VEILLE: stems from the observation that the supervisory body receives only 7,000 public claims about institutions' bad practices out of 100,000 court decisions implicating these institutions each year. However, the human resource cost of analysing these court decisions is high. The goal of J-VEILLE is to leverage this large source of data to identify poor banking and insurance practices and release this information to the end user in the form of dashboard. In the J-VEILLE application, the relevant information is extracted from the court decisions using an NLP powered algorithm and auxiliary data sources such as a supervisory list of institutions and legal resources (table of contents, index). The user has direct access to the most relevant information: the date and place of the case, the name of the institution implied, the reason for the decision, the business domain of the case, and the outcome of the case (has the institution been sentenced or not).

ISITEXT: goal is to automate the analysis of narrative reports filled in by 450 supervised (e.g. insurance) companies each year. The tool checks the consistency of each report (50 to 100 pages long) and identifies key supervisory issues such as green finance, cybersecurity or low interest rate environment. More specifically, ISITEXT uses text mining to industrialize compliance monitoring and produce synthetic dashboards.

DIXIT. The ACPR's supervisors are tasked with controlling banking institutions' compliance with respect to an increasingly large and complex financial regulation, scattered across numerous sources, and under constant evolution. DIXIT aims to enable the ACPR's agents to quickly and easily access the relevant texts to support their control missions, but also to better understand the content and legal scope of those texts. It features NLP powered algorithm and Web-based app technologies; and uses French and European regulatory corpora, as well as internal methodological notes. One of the primary benefits is to facilitate navigation between documents through hyperlinks.

KARTODOC. Regulated bodies are asked to provide their supervisors with an increasing amount of data (quantitative data, narrative reports…). On the other hand, the supervisors are continuously adapting their practices and producing internal documents (guidelines, reports, memos…). The project aims to facilitate navigation through all these documents by providing a unified search engine, which can sort through all file types, ranging from pdfs, and excel spreadsheets to screenshots and document scans. The expected benefit for the agent is to reduce the time necessary to analyse the information, particularly among file types, which are difficult to sift through, and to be able to spend more time analysing the information where it is present.

SAM answers the need for a raped way to assess the regulatory status of regulated financial bodies. The project aims to improve the supervisory function by providing a set of regulatory dashboards to facilitate executive-level decision-making: it distils large and heterogeneous datasets into visual graphics to allow for easy understanding of complex relationships. It uses advanced Visualizations and database management solutions.

Insights and outcomes

All the sub-projects have been tested by a handful of auditors and will be improved based on the feedbacks of the users. Apart from technical relevance, ergonomics appears to be key to the success of any given project: adoption of a new tool can be a tedious process and supervisors' agent need to be able to quickly assess its benefits.

Case study 23: Banque de France/ACPR

Description of innovation

Advanced Network Analytics for banking supervision purposes

The projects aim at developing advanced skills in network analysis for a better understanding of some specific banking supervision issues.

The first project aims to enhance visualization of banking groups' structure using various data sources. As various databases listing the capital links within and between French banks are available at the Banque de France. The study is based on the use and, where appropriate, the comparison of data from the databases: supervisory reporting, Register of Institutions and Assets Database, EuroGroups Register, Legal Entity Identifier level-2 data. The project allows for the hierarchical mapping of French banking groups and the reconstitution of the group composition.

The second project investigates how the Offshore Financial Centres (OFCs) are integrated into the network of international banking positions. A community detection algorithm is performed to uncover the privileged relations between countries' banking systems. Intuitively, the banking systems of countries within a community interact more often and intensely with each other than with those of countries outside the community. Community detection serves to highlight these groups, taking into account all interactions between countries.

Insights and outcomes

Regarding the first project, the multiple sources of information do not make it possible to reconstitute immediately the composition of banking groups in an unequivocal manner. Indeed, the level of granularity, the method of census (nature of the perimeter selected, geographical perimeter), as well as the freshness of the data generate differences, sometimes important, between the databases. An extension of this subject was the development of a web R-Shiny application that allows the extraction of conglomerate structures in the form of hierarchical networks. It was therefore possible to group these conglomerates into different clusters based on the similarity of their structure in order to highlight typologies of conglomerates.

Regarding the second project, the four financial communities (Americas and Oceania, Europe-Africa, South-East Asia, and Scandinavia and the Baltic States) identified by the algorithm indicate a pronounced regional bias for interbank relations. Despite their intangible nature, bank flows appear affected by the distance. As for OFCs, far from being a network on their own, they participate in this system of regionalization. The "America" community includes the Cayman Islands, Panama, Bermuda and the Bahamas; the "Europe" community includes Switzerland, Luxembourg, the Isle of Man, Jersey, Guernsey and Bahrain; and the "South-East Asia" community includes Singapore, Hong Kong and Macao.

COVID-19 Case Studies

Case study 24: Federal Reserve Board of Governors

NLP for continuous monitoring, web searches and COVID-19 monitoring

Description of innovation

There are several use cases of SupTech and RegTech across the Federal Reserve System (FRS) that are currently in use, as well as in the development process. While many of the use cases have originated over the last few years, a number of them have recently been repurposed or adapted to enhance the Federal Reserve's supervisory response to the COVID-19 crisis. The most common application of SupTech is ML techniques, and more specifically natural language processing (NLP) to enhance to create more efficient and effective supervisory processes. Below are three examples of how NLP has been deployed across the Federal Reserve System in response to the crisis.

Insights and outcomes

NLP for Continuous Monitoring

- Starting in 2015, one Reserve Bank began developing an NLP tool for the purpose of reading large amounts of BSA/AML documentation and identifying emerging trends based upon a designed BSA/AML lexicon. Subsequently, the tool was leveraged for voluminous quarterly submissions from regulated institutions under BSA/AML enforcement actions.
- As the COVID-19 crisis emerged, the tool was turned to continuous monitoring of larger banking institutions for the purpose of identify emerging trends in the documentation submitted to the Reserve Bank by the supervised institutions. The lexicon designed for the continuous monitoring of the pandemic could be developed significantly faster (approximately one week) given the lessons learned from the development of the BSA/AML lexicon.
- In conjunction with the NLP tool, a dashboard was developed to allow users to easily and quickly adjust the lexicon by including and excluding detailed rules that generate "hits" within the documentation. Coupled with examiner judgment, the tool is a way to improve the efficiency and effectiveness of an examiner's ability to continuously monitor a financial institution.

NLP for Web Searches

- One Reserve Bank is currently working on a project to develop an NLP tool used to analyse public websites of supervised regulated institutions to identify information on "work with your customer" programs, in response to the COVID-19 crisis.

COVID-19 Monitoring NLP Assistant

- A collection of supervisors for larger regulated institutions is in the processing of developing a web-based search tool designed to efficiently digest and filter the COVID-19 related bank submitted documents, thereby directing supervisors across the Federal Reserve System to documents with the highest occurrence of search terms and expediting the monitoring process.

Case study 25: Bank for International Settlements

Description of innovation

New analytical tools can help to assess the regional impact of COVID-19 on local labour markets in the United States and Europe in real time with Google Trends data.[76]

Background

In light of the COVID-19 outbreak and ensuing economic fallout, the BIS introduced a new series of BIS Bulletins – short pieces that investigate the effects of the pandemic on financial markets and the real economy.[77] These Bulletins complement other work by the BIS, such as Financial Stability Institute (FSI) briefs, which provide information and analysis on COVID-19-related regulatory measures to facilitate understanding of relevant prudential issues in the pandemic.[78]

Objectives

Designing and implementing policy measures that stabilise markets and support economic activity is of the essence during the pandemic. To combat the havoc wrought by COVID-19 effectively, granular information on the impact of COVID-19 across regions is paramount. In two BIS Bulletins, Doerr and Gambacorta (2020a, 2020b) construct employment-based measures of regional exposure to COVID-19, which they verify with real-time data from Google trends, to assess the pandemic's impact on local labour markets in the US and Europe.

Insights and outcomes

For the US, the local COVID-19 exposure measure reflects the share of local employment in sectors that are most affected by COVID-19. The analysis for Europe extends the methodology by taking into account the share of employment among small firms in different regions and constructs regional employment risk indices. In both cases, the analysis shows that regions differ significantly in their risk of COVID-19 affecting local employment. In the US, county-level exposure varies from 2% to 98%, with high exposure in Texas, Florida and Hawaii. In Europe, regions in southern Europe and France are shown to have high-risk indices, while regions in northern Europe have lower risk indices.

To investigate whether these risk indices provide a reasonable measure of local exposure to the COVID-19 shock, the authors use real-time data on internet searches for unemployment from Google Trends. These real-time data show that the employment risk measures are accurate proxies: areas with higher exposure report significantly more Google search queries related to unemployment in March and April 2020. The combination of official statistics and real-time data from non-traditional sources could enhance policymakers' understanding of the heterogeneous impact of the COVID-19 shock and their ability to develop adequate responses. It could also help overcome limitations in official data, such as low-quality, limited coverage, or reporting lags that in some cases could be substantial.

Insights from these analyses could inform supervisory authorities and regulated institutions. In particular, real-time information on regional risks can help regulated institutions manage the risk of their loan portfolio, as well as supervisory authorities identify regulated institutions more exposed to regions at risk.

---

76 S Doerr and L Gambacorta (2020): *Identifying regions at risk with Google Trends: the impact of COVID-19 on US labour markets*, *BIS Bulletin No 8*, 21 April; and Doerr and Gambacorta (2020): *COVID-19 and regional employment in Europe*, *BIS Bulletin No 16*, 15 May.

77 For recent bulletins looking at the pandemic and technological innovation, see R Auer, G Cornelli and J Frost, (2020), *COVID-19, cash and the future of payments*, *BIS Bulletin No 3*, 3 April and C Cantú, G Chong, J Frost and L Gambacorta (2020), *On health and privacy: technology to combat the pandemic*, *BIS Bulletin No 17*, 19 May.

78 See, for instance, JC Crisanto and J Prenio (2020), *Financial crime in times of COVID-19 - AML and cyber resilience measures*, *FSI Brief No 7*, 14 May.

Case study 26: Bank of England

Description of innovation

Policy Response Tracker

Background

With the onset of the COVID-19 pandemic, almost all central banks, governments and international bodies introduced a series of policy measures to contain and reduce the fallout of the economic downturn. For supervisors of UK-based firms with international presence or exposure, this meant a daily check of several jurisdictions authorities' and governmental websites to stay on top of all potential support that a firm group could rely on. This support measures were manually captured and logged by supervisors into local trackers – a time-consuming activity which was also prone to input error. As the number of data requests and communications increased, supervisors had less time to go through all the detail on jurisdictions' websites and often had to consult with firms themselves about the latest monetary or fiscal measures introduced.

To reduce the amount spent on searching and reading through policy measures, as well as reduce the reliance on manually maintained responses trackers, the PRA set up a dedicated dashboard, which automatically captures that information from official websites. The technologies deployed are web scraping (targeted at the English versions of each authority/government website) and NLP – for the extraction of key words, topics and actions taken in each jurisdictions. Once a day the tracker pulls information from the official COVID-19 response pages of each institution as well as a dedicated COVID-19 economic tracker maintained by Yale School of Management and then runs it through several checks and criteria (e.g. user-defined keywords, metrics and risks) to sift and present a summary of the information to supervisors.

To date, the dashboard contains information of policy measures taken by central banks and governments in 50 countries and 5 international bodies. The NLP deployed extracts key information from each measure and presents it on the dashboard along with a hyperlink that can take a user to the original source for further detail (if deemed necessary). Additionally, supervisors can filter on 14 action types (e.g. credit guarantees, emergency liquidity, fiscal stimulus, swap lines) and adjust the timescale to zoom in on a particular period. Finally, users have a centralised view of the latest and most recent historical central bank's policy rates, QE and press releases all in a single view, thus eliminating the need to maintain similar trackers locally.

Insights and outcomes

The use of web scraping along with NLP techniques has significantly reduced the amount of time supervisors of international firms spent looking for and manually tracking policy measures taken in each jurisdiction in response to COVID-19. In a fast-moving external environment, the simple and intuitive user-interface of the policy response tracker allows supervisors to easily filter on a number of categories and choose on which ones to further investigate. While the tool is still considered to be under iterative development, frontline users have praised the timeliness and simplicity of the information presented and have requested that it remain in place after the pandemic is over.

Case study 27: De Nederlandsche Bank

Description of innovation

COVID-19 SAS-VA Dashboard

Currently the DNB are developing an interactive reporting Dashboard to provide insight for supervisors on COVID-19 related risks. The dashboard is still in an early phase, but enables the supervisors to have different data views (e.g. benchmarking, over time, single bank). As the data, templates are manually filled by supervisors and subject to change, the underlying programming needs to have additional flexibility. Future SupTech improvements include incorporating public COVID-19 information and/or analysing comment fields with text analysis (this is not part of the initial Dashboard request).

Case study 28: Monetary Authority of Singapore

Monitoring and enforcement of safe distancing measures

Description of innovation

MAS used data analytics to monitor regulated institutions (FIs') implementation of safe distancing measures and inform inspection and enforcement actions. Data on bank branch locations, customer footfall, wait time and peak hours are collected and visualised on a monitoring dashboard.

Insights and outcomes

The results are used to prompt intervention actions by identifying crowded customer service locations and prioritising inspections on these FIs to enforce compliance with safe distancing rules.

Description of innovation

MAS deployed automation tools using NLP to gather international news and stay abreast of COVID-19 related developments. NLP was also used to analyse consumer feedback on COVID-19 issues, and monitor vulnerabilities in the different customer and product segments. MAS also collected weekly data from regulated institutions to track the take-up of credit relief measures as the COVID-19 pandemic unfolded. The collection process was agile and allowed for quick iterative improvement and adaptation. Data aggregation and transformation were automated and visualised for monitoring.

Insights and outcomes

Highlighted areas identified via these tools were examined in detail by policy analysts in order to construct appropriate measures to address relevant pain-points and issues.

Description of innovation

To strengthen monitoring of FIs' financial risk under the current deteriorating economic conditions, MAS is exploring the development of an integrated surveillance platform to (i) collate and aggregate data and information from various sources (e.g. news, financials, macroeconomic indicators), (ii) enable sense making by applying NLP/sentiment analysis, and (iii) facilitate in-depth analysis and risk identification using machine-learning techniques.

Insights and outcomes

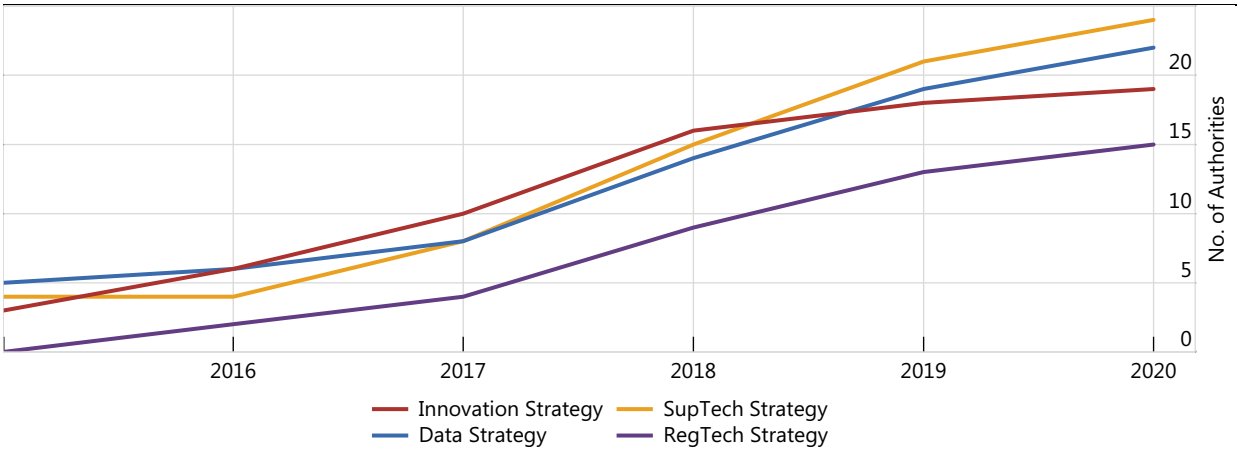
Specific to credit risk, MAS is exploring the use of rule based and AI/ML techniques to estimate a loan's credit grading based on factors such as financials, adverse news, account conduct and covenant breaches that could be indicative of credit weaknesses. This enhances surveillance and credit risk monitoring capabilities, and allows onsite inspections to be conducted more efficiently.

Annex 2 – List of survey respondents

Jurisdictions	
Argentina	Central Bank of Argentina (BCRA) Securities and Stock Exchange Commission of Argentina (CNV) National Superintendence of Insurance (SSN)
Australia	Australian Prudential Regulation Authority (APRA) Australian Transaction Reports and Analysis Centre (AUSTRAC)
Brazil	Central Bank of Brazil
Canada	Office of the Superintendent of Regulated institutions (OSFI)
China	People's Bank of China
ECB	European Central Bank (ECB)
France	Banque de France
Germany	Deutsche Bundesbank BaFin
Hong Kong	Hong Kong Monetary Authority (HKMA)
India	Ministry of Finance Reserve Bank of India (RBI)
Indonesia	Financial Services Authority (OJK) Bank Indonesia (BI)
Italy	Banca d'Italia
Japan	Bank of Japan (BoJ) Japan Financial Services Agency (JFSA)
Korea	Bank of Korea (BoK)
Mexico	Banco de Mexico (Banxico) National Banking and Securities Commission (CNBV)
Netherlands	Authority for Financial Markets (AFM) De Nederlandsche Bank (DNB)
Russia	Bank of Russia
Saudi Arabia	Saudi Arabia Monetary Authority (SAMA)
Singapore	Monetary Authority of Singapore (MAS)
South Africa	South African Reserve Bank (SARB) Financial Sector Conduct Authority (FSCA)
Spain	Banco de España (BdE) Spanish Market Authority (CNMV) Insurance Oversight Body (DGSyFP)
Switzerland	Swiss Financial Market Supervisory Authority FINMA
Turkey	Banking Regulatory and Supervisory Authority (BRSA) Capital Market Board (CMB) Central Bank of the Republic of Turkey (CBRT) Ministry of Finance
United Kingdom	Bank of England (BoE) Financial Conduct Authority (FCA)
United States	Securities Exchange Commission (SEC)

Annex 3 – Detailed survey results

Number of authorities with a strategy over time **Graph 20**

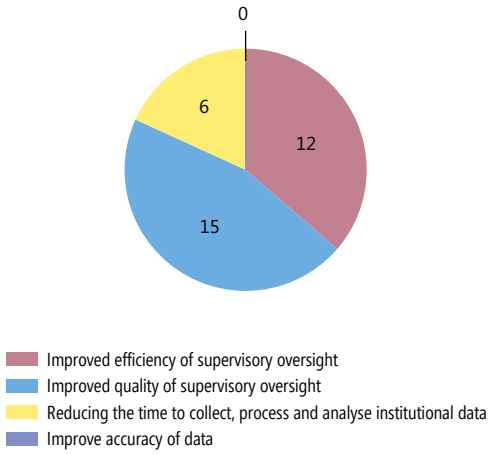


Source: FSB survey

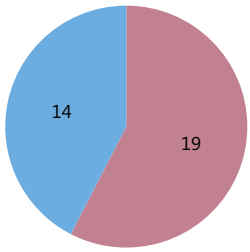
Demand drivers for developing a SupTech strategy by sub-type

No. of authorities who rank each sub-type as most important **Graph 21**

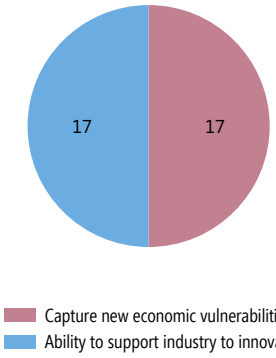
Enhancing efficiency and effectiveness



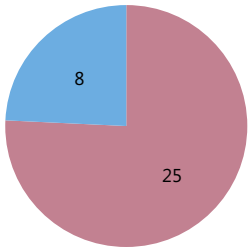
Reducing costs



Improving capabilities



Improving insights

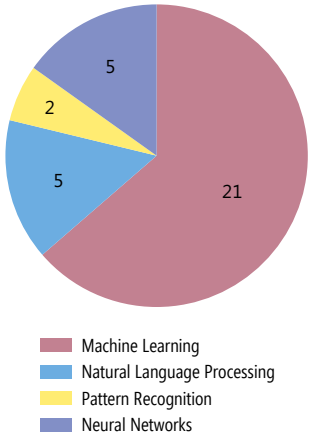


Source: FSB survey

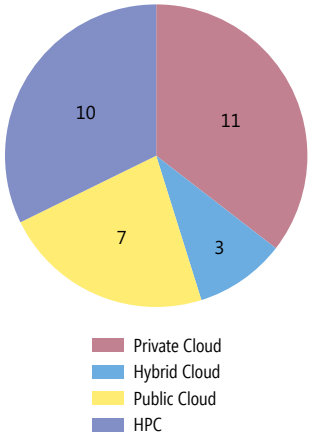
Supply drivers for developing a SupTech strategy by sub-type

No. of authorities who rank each sub-type as most important **Graph 22**

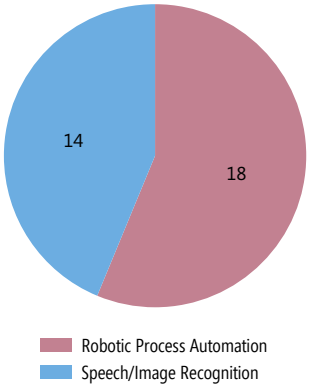
AI Techniques



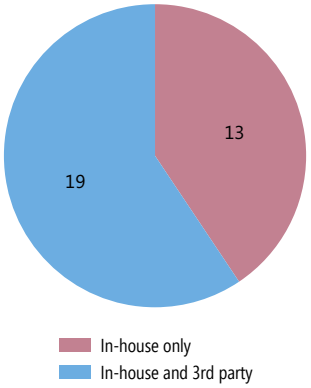
Cloud Computing



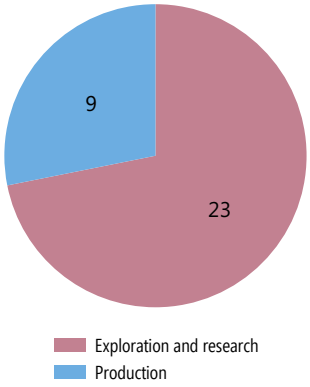
AI Applications



Data availability

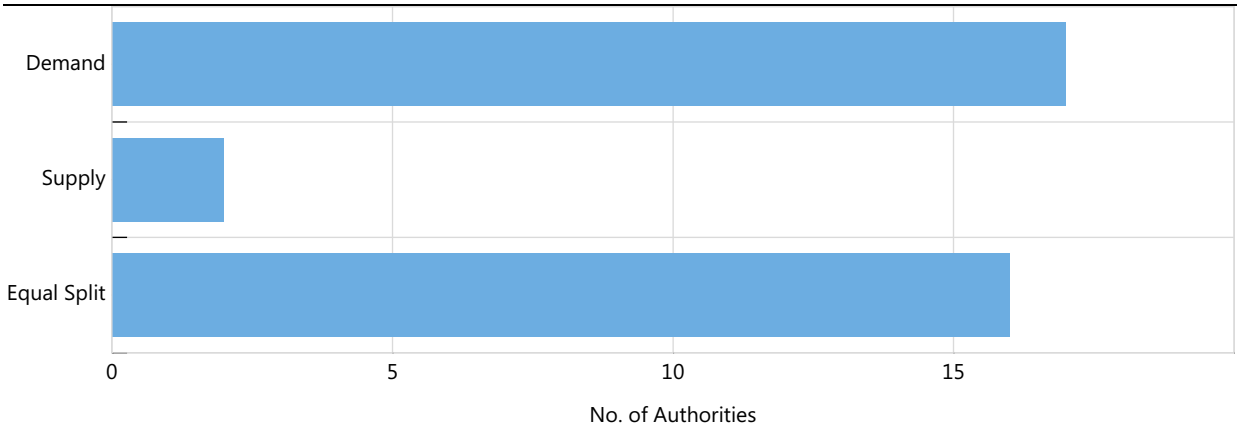


DLT



Source: FSB survey

Most important drivers for developing a SupTech strategy **Graph 23**

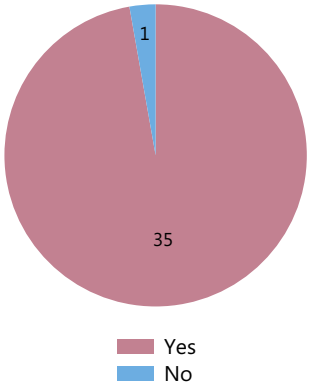


Source: FSB survey

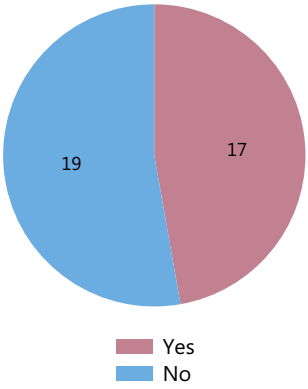
The use of RegTech tools

No. of authorities **Graph 24**

Are regulated institutions using RegTech tools?

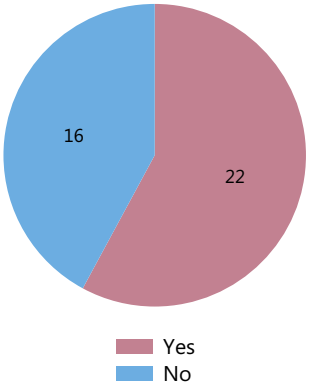


Does your authority encourage the use of RegTech?



Source: FSB survey

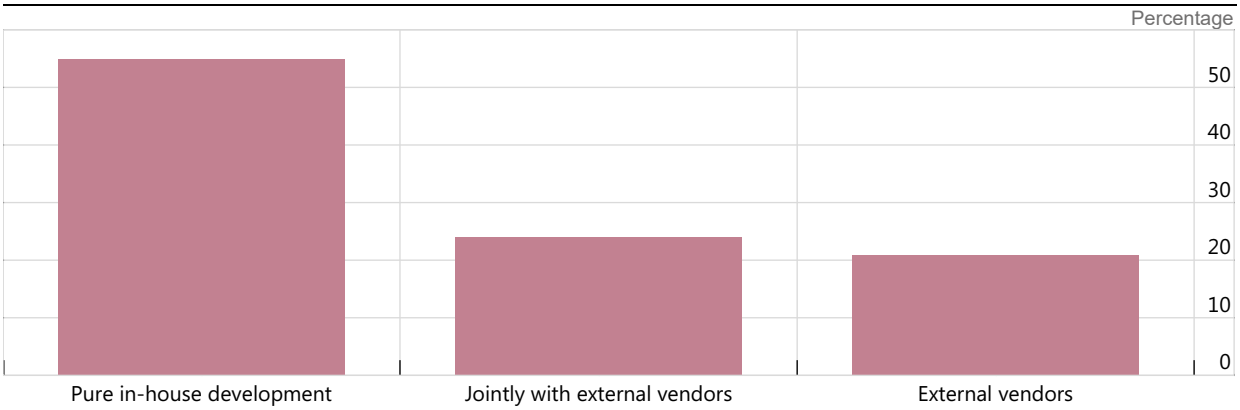
Number of authorities with a formal testing platform for SupTech tools **Graph 25**



Source: FSB survey

Use of external vendors or in-house skills in the development of SupTech tools

Average percentage of authorities' tool development **Graph 26**



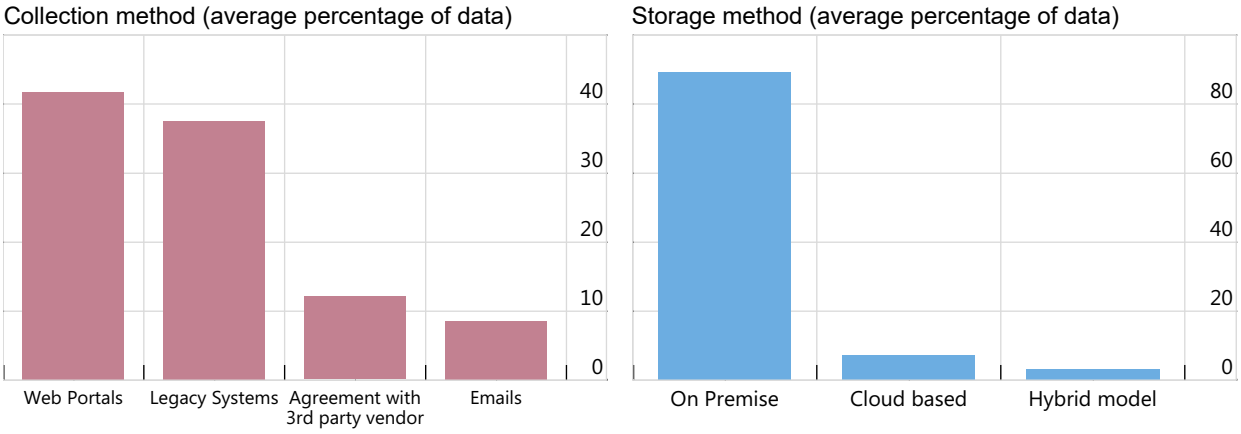
Source: FSB survey

Authorities where the Chief Data Officer oversees a SupTech strategy

No. of authorities with a CDO **Graph 27**

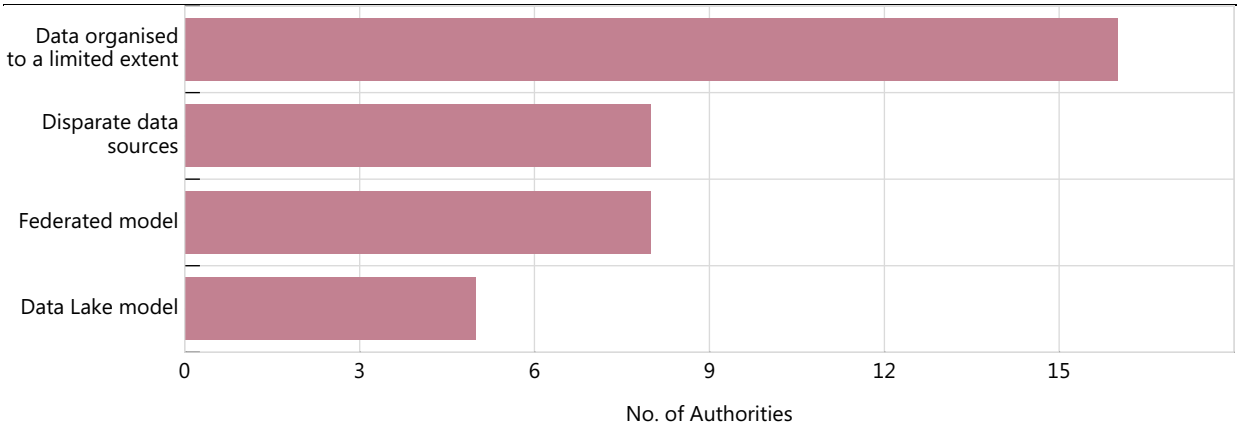
Source: FSB survey

Data collection and storage methods (I) **Graph 28**



Source: FSB survey

Data management models **Graph 29**

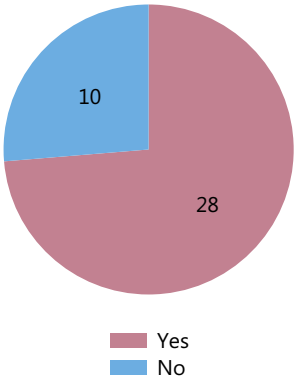


Source: FSB survey

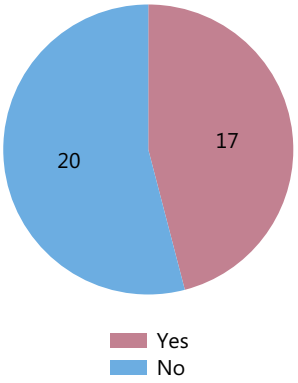
Data collection and storage methods (II)

Graph 30

Authorities with standardised inventory of data received



Authorities with API for data submission

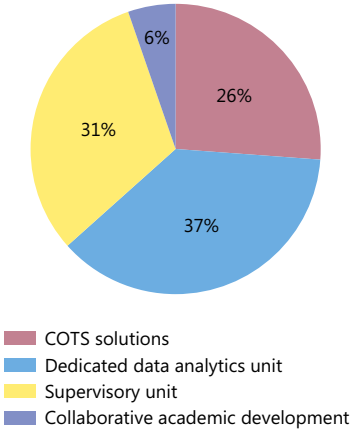


Source: FSB survey

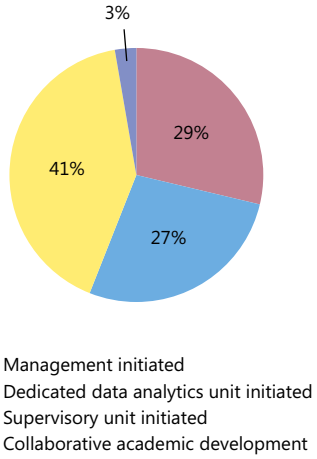
Data analysis functions

Graph 31

Entity responsible for data development



Initiator of data analytics solutions



Source: FSB survey

Annex 4 – Glossary

This glossary defines the terms used in this report. Where available, definitions are aligned with previous reports of the FSB, CPMI, CGFS, MC, BCBS, IOSCO, and FATF, by drawing on the glossary of the ECC ad hoc group on digital innovation. Certain terms are based on definitions by Gartner Information Technology. Some of the terms used are interrelated, as highlighted in the relevant definitions.

- **Algorithm:** a set of computational rules to be followed to solve a mathematical problem. More recently, the term has been adopted to refer to a process to be followed, often by a computer.

- **Artificial intelligence (AI):** the theory and development of computer systems able to perform to perform tasks that traditionally have required human intelligence.

- **Application programming interface (API):** a set of rules and specifications followed by software programmes to communicate with each other, and an interface between different software programmes that facilitates their interaction.

- **Big data:** a generic term that designates the massive volume of data that is generated by the increasing use of digital tools and information systems.

- **Cloud computing:** an innovation in computing that allows for the use of an online network ('cloud') of hosting processors to increase the scale and flexibility of computing capacity.

- **Data lake:** a concept consisting of a collection of storage instances of various data assets.

- **DevOps:** represents a change in IT culture, focusing on rapid IT service delivery through the adoption of agile, lean practices in the context of a system-oriented approach.

- **Digitalisation:** the use of digital technologies to change a business model, or the process of moving to a digital business.

- **Digitisation:** the process of transforming analogue to digital form.

- **Distributed Ledger Technology (DLT):** a means of recording information through a distributed ledger, i.e. a repeated digital copy of data at multiple locations, as in block chain. These technologies enable nodes in a network to securely propose, validate, and record a full history, state changes (or updates) to a synchronised ledger that is distributed across the network's nodes.

- **Fast fail system:** designed to stop normal operation rather than attempt to continue a possibly flawed process.

- **FinTech:** technology-enabled innovation in financial services that could result in new business models, applications, processes or products with an associated material effect on the provision of financial services.

- **Innovation accelerator:** a partnership arrangement between FinTech providers and central banks/supervisory agencies to 'accelerate' growth or develop use cases which may involve

funding support and/or authorities' endorsement/approval for future use in central banking operations or in the conduct of supervisory tasks.

- **Innovation facilitator:** public sector initiatives to engage with the FinTech sector, such as regulatory sandboxes, innovation hubs and innovation accelerators.
- **Innovation hub:** Innovation facilitator set up by supervisory agencies that provide support, advice or guidance to regulated or unregulated institutions in navigating the regulatory framework or identifying supervisory, policy or legal issues and concerns.
- **Machine learning:** a method of designing a sequence of actions to solve a problem that optimise automatically through experience and with limited or no human intervention.
- **Metadata:** is information that describes various facets of an information asset to improve its usability throughout its life cycle.
- **Natural Language Processing (NLP):** an interdisciplinary field of computer science, artificial intelligence, and computation linguistics that focuses on programming computers and algorithms to parse, process, and understand human language. NLP can be regarded as a form of AI.
- **Predictive analytics:** the use of data to predict patterns of activity. As applied to SupTech, predictive analytics may for example identify potential signals such as the unusual use of communications, fraud, likelihood of default, non-routine patterns of leaving the office and non-completion of training. Such signals may predict elevated misconduct risks. Predictive analytics may involve technologies such as machine learning or visualisation tools.
- **Pull technology:** network communication where the initial request for data originates from the client, and then is responded to by the server.
- **Push technology:** software that automates the delivery of information to users.
- **RegTech:** any range of applications of FinTech for regulatory and compliance requirements and reporting by regulated institutions.
- **Regulatory sandboxes:** controlled testing environment, sometimes featuring regulatory forbearance and alleviation through the use of legally provided discretions by the supervisory agency. The testing environment may involve limits or parameters within which the firms must operate e.g., restriction on the time a firm may operate in the sandbox.
- **Structured data:** is information that has a pre-defined data model or is organised in a pre-defined manner.
- **SupTech:** any application of FinTech used by regulatory, supervisory and oversight authorities.
- **Unstructured data:** is information that either does not have a pre-defined data model or is not organized in a pre-defined manner.

Annex 5 – References

Access to Insurance Initiative (2019): "RegTech and SupTech: Implications for supervision".

Armstrong P and Harris A (2019): "RegTech and SupTech – change for markets and authorities" *Trends, Risks and Vulnerabilities*", *ESMA*, 28 February.

Arner D, J Barberis and R. Buckley (2016): "FinTech, RegTech and the Reconceptualisation of Financial Regulation", *Northwestern Journal of International Law & Business*, *University of Hong Kong Faculty of Law Research Paper* no. 2016/035, September.

Auer R, G Cornelli and J Frost (2020): "COVID-19, cash and the future of payments", *BIS Bulletin No 3*, 3 April.

L'Autorité de contrôle prudentiel et de résolution (2020): Governance of Artificial Intelligence in Finance, June.

Bank of England, (2020): "Fintech".

——— (2020), "Transforming data collection from the UK financial", January.

Bank for International Settlements

——— (2017): Blockchain Technology in Financial Services Market - Analysis and Forecast: 2017 To 2026 (Focus on Opportunity and Use Case Analysis), online at https://www.researchandmarkets.com/research/nmqt2b/blockchain.

——— (2018): Committee on Payments and Markets Infrastructure– 'Harmonisation of critical OTC derivatives data elements (other than UTI and UPI) April.

——— (2018): Innovative Technology in Financial Supervision (Suptech) – The Experience of Early Users, online at https://www.bis.org/fsi/publ/insights9.pdf.

Banque De France (2018): A DGSE Model to Assess the Post-Crisis Regulation of Universal Banks, online at https://publications.banque-france.fr/sites/default/files/medias/documents/818279_rdb67_en_v4.pdf.

Basel Committee on Banking Supervision (2018), Sound Practices: Implications of fintech developments for banks and bank supervisors, February.

Bauguess S (2017), "The Role of Big Data, Machine Learning, and AI in Assessing Risks: a Regulatory Perspective", Champagne Keynote Address: OpRisk North America 2017, New York, New York, June.

Bellovin S and P Dutta and N Reitinger**,** Privacy and Synthetic Datasets, Columbia University, Department of Computer Science working paper, available at https://osf.io/bfqh3/download/?format=pdf.

Bloomberg (2017), Big U.S. Banks Could See Profit Jump 20% With Deregulation, online at https://www.bloomberg.com/news/articles/2017-08-23/big-u-s-banks-could-see-profit-jump-20-with-trump-deregulation.

British Broadcasting Corporation (2017), "Ransomware cyber-attack threat escalating – Europol", May.

Broeders D and J Prenio (2018), "Innovative technology in financial supervision (suptech) – the experience of early users", *FSI Insight,* July.

Business Wire (2019) "Emerging Trends, Drivers and Challenges in the RegTech Market 2019 – 2023", 26 September. https://www.businesswire.com/news/home/20190926005598/en/Emerging-Trends-Drivers-Challenges-RegTech-Market-2019.

Cantú C, G Cheng, S Doerr, J Frost and L Gambacorta (2020), "On health and privacy: technology to combat the pandemic", *BIS Bulletin No 17*, 19 May.

Coelho R, M De Simoni and J Prenio (2019), "Suptech applications for anti-money laundering", *FSI Papers,* no 18, August.

Confederation of British Industry (2018), "Financial Services Survey", December.

Crisanto J-C and J Prenio (2020), "Financial crime in times of COVID-19 - AML and cyber resilience measures", *FSI Brief No 7*, 14 May.

Danielsson, R, R Macrae, and A Uthemann (2017), "Artificial Intelligence, financial risk management and systemic risk", *Systemic Risk Centre Special Paper,* no. 13.

Di Castri S, S Hohl, A Kulenkampff and J Prenio (2019), "The suptech generations", *FSI Insights*, no 19, October.

Doerr S (2019), "Unintended Side Effects: Stress Tests, Entrepreneurship, and Innovation", BIS Working Paper no 823, November.

Doerr S and L Gambacorta (2020): "Identifying regions at risk with Google Trends: the impact of COVID-19 on US labour markets", *BIS Bulletin No 8*, 21 April.

——— (2020): "COVID-19 and regional employment in Europe", *BIS Bulletin No 16*, 15 May.

The Economist (2016), 'The Alphabet of Success", September.

Enriques L (2017) 'The HR Challenge of FinTech for financial authorities', *Oxford Business Law Blog*, July.

Ernst & Young (2019) "Global FinTech Adoption Index 2019".

European Commission Expert Group on Regulatory Obstacles to Financial Innovation (2019): *30 Recommendations on regulation, innovation and finance*, December.

Federal Reserve Bank of Dallas (2015**),** Too Small to Succeed? —Community Banks in a New Regulatory Environment, online at https://www.dallasfed.org/~/media/documents/outreach/fi/2015/fi1504.pdf.

Financial Conduct Authority (2020) "Data Strategy", part Y, January.

——— (2020), "Digital regulatory reporting, Phase 2 Viability Assessment".

Financial Stability Board (2017***)***, "Financial stability implications from FinTech: Supervisory and regulatory issues that merit authorities attention"**,** June, https://www.fsb.org/wp-content/uploads/R270617.pdf.

——— (2017), "Review of OTC derivatives market reform**:** Effectiveness and broader effects of the reform", June, https://www.fsb.org/wp-content/uploads/P290617-1.pdf.

——— (2017), "Artificial intelligence and machine learning in financial services: Market developments and financial stability implications", November.

——— (2019), "FinTech and market Structure in financial services: Market developments and potential financial stability implications", February.

——— (2019), "Thematic review on implementation of the Legal Entity Identifier – Peer Review Report", May.

——— (2019), "Third-party dependencies in cloud services: Considerations on financial stability implications", December.

Hanley-Giersch J 'RegTech and Financial Crime Prevention' p.22. 'The RegTech Book'. Janos Barberis, Douglas W. Arner and Ross P. Buckley editors.

International Institute of Finance (2016), "Regtech in Financial Services: Technology Solutions for Compliance and Reporting", March.

——— (2019), "Machine Learning in Credit Risk", August.

Kampkötter P (2014) "Non-executive compensation in German and Swiss banks before and after the financial crisis", *The European Journal of Finance*, vol 21, no 15, May.

Lagarde C (2018) "A Regulatory Approach to Fintech", *IMF Finance & Development*, March, vol 55, no 2, March.

Monetary Authority of Singapore "Principles to promote fairness, ethics, accountability and Transparency (FEAT) in the use of artificial intelligence and data analytics in Singapore's financial sector".

New York Times (2016), "North Korea Linked to Digital Attacks on Global Banks." www.nytimes.com/2016/05/27/business/dealbook/north-korea-linked-to-digital-thefts-from-global-banks.html.

PwC, RegTech: A New Disruption in The Financial Services Space, https://www.pwc.in/consulting/financial-services/fintech/fintech-insights/regtech-a-new-disruption-in-the-financial-services-space.html, accessed 9/4/2019.

Ullersma C and van Lelyveld I (2020), 'Granular data offer new opportunities for stress testing', in Handbook of Financial Stress Testing, Cambridge University Press (forthcoming) March.

Van Steenis, Huw (2019) 'The Future of Finance Report", Bank of England, June.

World Bank Group (2018), "From spreadsheets to SupTech: Technology solutions for market conduct supervision", *Discussion Note*, June.