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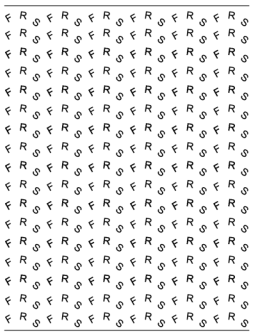
1 February 2021



(FRS) FUTURE RESILIENT SYSTEMS

Using artificial intelligence for financial supervision purposes

#4

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1 Abstract

Artificial intelligence (AI) refers to an arrangement of systems that display intelligent behaviour by 1) analysing their environment and 2) taking actions to achieve specific goals. Technically, AI is essentially the combination of individual machine learning (ML) algorithms to solve complex problems.

This review aims at identifying the quantitative and qualitative importance of AI in public policy de-bates and interventions during the 2019-2020 period. The review is based on Working Papers posted on the Social Sciences Research Network (SSRN) and on annual reports by financial supervisors.

The working papers part covers four topics: defining the AI world; putting AI to use; regulating AI; AI lawmaking and enforcement (see also Table I). The financial supervision part is based on reports originating from international organizations; the European Union; Singapore and Switzerland; China and Japan; the UK and United States (see also Table II).

Overall, it appears that social scientists are increasingly dealing with AI. However, the large majority of contributions focuses on machine learning (ML).

Supervisory authorities are also increasingly relying on AI. However, this is mostly done for internal purposes, the regulatory use being mostly confined to detecting illegal market practices. The exception is the United States, where States are the main players and the regulatory scope is broader than in the rest of the world.

2 Literature Review

2.1 Defining the AI World

1. Generally speaking, the AI world is one where intelligent agents get information from the environment and take related actions (see also Russel & Norvig 2010). Hence, for the European Commission, AI refers to systems that display intelligent behaviour by analysing their environment and taking actions – with some degree of autonomy – to achieve specific goals (COM (2018) 237 final). In other words, whereas 'traditional' algorythms react to changes in parameters set by their user (Mehra 2016), 'deep learning' algorithms make decisions largely independently from pre-set rules and parameters (Picht and Freund 2018). Providing a thighter definition of AI has proven ellusive (Parson et al. 2019), not least due to technological advances making it closer and closer to human intelligence (Lemley & Casey 2020).

2. Early AI research was based on logicist approaches, which have been followed by neurological approaches (Denno and Surujnath 2019). Nowadays, advanced statistical techniques (so-called deep learning) are generally considered the dominant approach (Bogroff and Guégan 2019). Technically, artificial intelligence can be broken down in three essential pieces (Taddy 2018): domain structure, data generation, and machine reading capability. In other words, AI is essentially a combination of individual ML algorithms to solve complex problems. Note, however, that not all algorithms are AI, and not all AI is machine learning (Raj & Seamans, 2019). Most of the recent AI achievements result from advances in machine learning (Agrawal et al. 2017; Fernandez 2019). Fundamentally, ML is a branch of computational statistics. It facilitates predictions by using existing data to fill in missing information (Agrawal et al. 2018; Tiffin 2019) and identify hidden factors or patterns. In other words, computers are not coded, they self-extract the relevant algorithm.

3. This does not mean that computers can acquire wisdom (Broussard 2018) or do not face the causation vs correlation issue (Wall 2018). However, when powered by massive data sets supported by potent computational processing capacities, ML is capable of generating new insights (Yeung and Lodge 2019). For example, using a ML approach, one should be able to predict systemic financial crises twelve quarters ahead and with a very high signal to noise ratio (Fouliard et al. 2019). That being said, transfer learning (saving knowledge gained from solving one problem to apply it to solving another) is still a significant challenge in AI and a major focus of ongoing computer science research (Baum et al. 2019).

2.2 Putting AI to Use

1. Machine learning is already used in nearly all areas of banking and finance (Bishop 2006 and Murphy 2012). Applications stretch from the detection of mistrades and fraud, to time series model-ling and the optimization of market-making and hedging strategies for financial instruments (Wilkens 2019). For example, ML methods are already used for financial statement analysis (Amel-Zadeh et al. 2020), the detection of accounting misstatements (Bertomeu 2020) and securities litigation (Baker and Gelbach 2020). ML also permits improved descriptions of

expected return behavior relative to traditional forecasting methods (Gu 2018). Moreover, ML is popular in the financial derivatives busi-ness, where real-time updates and information are crucial success components (De Spiegeleer et al. 2018). In other words, while automation used to mainly affect routine or low-skilled tasks, ML and, more generally, AI are likely to increasingly automate non-routine, cognitive tasks performed by high-skilled workers (Aghion et al. 2017) and to reshape the nature of the innovation process (Cockburn et al. 2018). In addition, AI helps market designers to improve the operations of markets (Milgrom and Tadelis 2018). It follows that AI has the potential to affect industrial organization (Varian 2018) and to increase productivity growth. For example, insurance companies have already computerized their consumer contact, insurance solutions, claim processing and fraud detection procedures (Lamberton et al 2017). They increasingly rely on AI to select those claims that require more in depth investigation (Borselli 2018). On the other hand, AI may have mixed effects on labor, particularly in the short run (Furman and Seamans 2018; Gries and Naudé 2020). It may also threaten consumer privacy (Jin 2018) and, more generally, foster discrimination (Packin and Lev-Aretz 2018).

2. Relying on AI requires clearly defined objectives (Coglianese 2020). These may not be easy to identify and achieve. For exemple, activists and policymakers are raising ethical considerations (Puaschunder 2019) that may require the design of algorithms going beyond accurate prediction (Cowgill and Stevenson 2020). In addition, using AI implies having access to large and diverse datasets, which may be of limited use when the past is unlike the future (Snow 2019b) and may ex-plain why larger firms invest and benefit more from AI (Babina et al. 2020). There is also evidence of algorithm aversion in some situations. For example, auditors seem more willing to tolerate contradictory evidence when it comes from a firm's human specialist than from a firm's AI-driven system (Commerford at el. 2019). These limitations could be the reason why only a small fraction of firms are already actively using AI across their operations (Bughin and van Zeebroeck 2018). They may also explain why there still is limited empirical evidence on the current state of AI adoption in finance (Ryll et al. 2020).

3. That being said, AI is widely used by governments (Engstrom 2020). This is especially the case in the US (Engstrom and Ho 2020), where a large number of federal agencies have ML and AI experience (Engstrom et al. 2020); however, it is also occuring in Europe (Finck 2019). Similarly, AI-driven managerial decision-making is increasingly relied upon in the private sector (Adams-Prassl 2019). AI developments should permit to better understand the process by which firm governance structures are chosen (Erel et al 2019), contribute to improve board independence (Kamalnath 2020) and risk tolerance (Hrazdil et al. 2020). On the other hand, these developments raise the question of managerial oversight of AI systems (Hickman and Petrin 2020). This evolution should reduce agency as well as coordination costs, while increasing liability risks at the top of the firm (Armour and Eidenmueller 2019). At the same time, increasing automation may result in algorithms replacing employees as the leading cause of corporate harm – and in corporations becoming immunized from most civil and criminal liability (Diamantis 2020a). These developments have caused a debate about the magnitude of AI-related changes (Watson 2020), humans-AI collaboration (Puranam 2020), AI systems secrecy (Price and Ray 2020) and AI liability regimes (Mannes 2020; Senftleben 2020). From a practice perspective, they generated proposals to bestow corporate personhood to AI systems (Linarelli 2019; Lai 2020) and predictions that AI will increasingly be used for contract drafting and enforcement (Sirena 2020; Scholz 2020) and to hire employees (Sullivan 2018).

4. One can thus expect AI to become pervasive across the financial services sector. For example, deep learning methods are deemed superior to standard methods when it comes to financial predic-tions (Heaton et al. 2017). Similarly, models based on machine learning and non-traditional data are considered better at predicting losses and defaults than traditional models in the presence of a nega-tive shock to the aggregate credit supply (Gambacorta et al. 2020). In fact, financial institutions are already using AI to assess credit quality and to price insurance con-tracts (FSB 2017). More specifically, AI can be used for portfolio pricing and risk management (Fer-nandez-Arjona and Filipovi 2020), the construction of risk models (Kakushadze and Yu 2019) and efficient portfolios (Lanza et al. 2020). In addition, AI will contribute to the development of robot fi-nancial advisers (D'Accunto and Rossi 2019). Obviously, financial intermediaries are also using of AI for market-making and automated trading, albeit this is more likely to happen in equities and futures than in fixed income and forex markets (Koshiyama 2020). This is not without impact on labor. For example, there is evidence that analysts with portfolios that are more exposed to AI, are more likely to reallocate efforts to soft skills, shift coverage towards low AI stocks, and even leave the profession (Grennan and Michaely 2020).

5. The increasing use of algorithms for high-stakes decisions has led activists and policymakers to express democracy concerns (Djeffal 2019). One response to these concerns is to engineer new algorithms that go beyond accurate prediction and aim at nudging decision-makers towards socially preferred actions. On the regulatory side, these concerns have generated suggestions to make the use of AI subject to market integrity and consumer protection requirements (Lee 2020). In fact, there is evidence of US lenders engaging in consumer discrimination (Gillis 2020) and over-charging Latino/African-American borrowers for purchase and refinance mortgages (Bartlett et al. 2019). More generally, there is evidence that AI-based creditworthiness assessment may threaten consumer privacy and autonomy (Aggarwal 2020). On the other hand, it is recognized that AI can also protect consumers. There is evidence of algo-rithmic expert recommendations significantly increased consumer health plan cost savings and choice process satisfaction (Bundorf et al. 2019). Similarly, ML-generated "synthetic data" could facilitate compliance with the 'care obligation' US broker-dealers have vis-à-vis retail investors, by enabling them to test investment recommendations (Heaton and Witte 2020).

6. Putting AI to use can prove complex. For example, relying on AI for stock market predictions requires a) extracting events from news text, b) represent them as dense vectors and c) relying on deep convolutional neural networks (Ding et al. 2015), i.e. on computer systems that can classify information like the human brain does. It is important to note that this approach may not be fully tractable by computers and require the use of heuristics to "solve" the problem at hand (Bettismy and Hu 2018). Similarly, using AI for eviden-tiary purposes in criminal proceedings may lead to hard to detect biased results (Palmiotto 2020). In other words, AI is still more about making predictions than establishing causal relationship (Agrawal et al. 2019). In particular, the use of AI increases interdependency (Zetzsche et al. 2020), whereas causal inferences remain hard to identify in the presence of complex data interactions (Feng et al. 2018).

7. Nevertheless, algorithms are progressively supplanting human intervention. For example, AI is more and more used to price goods and services (Calvano et al. 2019). Similarly, self-driving cars, automated conversational agents, AI-supported medical diagnostics, translations

and marketing practices are increasingly part of daily life (Proserpio 2020; Ribers and Ulrich 2020). Likewise, computer programs that mimic human conversations (chatbots) are as effective as capa-ble workers in getting customer purchases, and four times more effective than inexperienced work-ers. However, disclosing chatbot use pre-conversation reduces purchase rates by 80% (Luo 2019). Similarly, AI is increasingly relied upon to recognize sexual harassment (de Haan 2020), to identify criminals and other lawbreakers (Tayebi and Glässer 2016) and to generate evidence for criminal trials (Gless 2020). Conversely, false negatives or positives may result in systematic repression of specific ethnic or social groups (Ünwer 2018). Similarly, using AI to protect business models may infringe competition laws (Dunne 2020). More generally, AI adjudication is likely to foster a turn toward "codified justice," which is likely to favour standardization above discretion (Re and Solow-Niederman 2019).

8. According to some studies, the use of AI may result in permanent GDP decline for countries with significant unskilled labor (Alonso et al. 2020); this evolution has generated calls for an automation tax that would slow the adoption of AI and give workers and social support systems time to adapt (Ooi and Goh 2019). However, other studies conclude that Northern robotization may lead to higher wages in the South (Artuc et al. 2018) while AI applications are much more often about enhancing human capabilities than about reducing labor costs (Bessen et al. 2018). More generally, it is emphasized that AI may significantly affect international trade (Goldfarb and Trefler 2018, Madnick et al. 2020). For example, AI already plays a critical role in in the allocation of scarce medical resources (Price 2019).

9. The increasing role of AI has generated governance and ethics initiatives. They are considered most developed in China and the EU, with the US catching up whereas India as well as Australia had a rockier start (Daly et al. 2019). Some of these initiatives reflect concerns that the use of algorithmic may occur without adequate democratic oversight or control. For example, in its February 13, 2019 Declaration by the Committee of Ministers, the Council of Europe has specifically addressed the manipulative capabilities of algo-rithmic processes. Similarly, the European Commission has emphasized that the regulatory frame-work must create an ecosystem of trust in AI (COM(2020) 65 final). At the same time, countries such as the Netherlands (Zouridis 2020) and Germany (Binder 2020) have introduced fully automated taxation procedures that are presumably based on artificial intelli-gence, e.g. via a default logic approach (see Pertierra et al. 2017; Lawsky 2017). There is also evi-dence of AI developments facilitating the detection of corruption (Ash et al. 2020) and collusion (Abrantes-Metz and Metz 2018), and contributing to swifter and less costly judicial proceedings (Har-low and Rawlings 2020). That being said, the use of machine learning remains less impressive when the past is unlike the future, i.e. when standards are superior to rules (Fagan and Levmore 2019). This could create some mismatch between AI-powered legislation and the real world (Harned and Wallach 2020). It follows that lawmakers are likely to overrule AI in legal domains where the challenges of measurement are present (Levmore and Fagan 2019).

2.3 Regulating AI

1. Fundamentally, the emerging role of AI raises resilience (Tomlinson 2020), accountability (Doshi-Velez and Kortz 2017), legitimacy (Michaels 2020), privacy (Yeung) and fairness issues (Ulenaers 2020). A good lack of resilience example is provided by the EU Settlement Scheme's

new template for automated administration of post-Brexit residence in the UK: it is essentially considered as half-baked and raising foundational questions about the nature of administrative justice (Tomlinson 2020). When it comes to discrimination, it remains unclear whether AI facilitates (Hacker 2018) or hampers (Kleinberg 2019) it; in any event, algorithmic equal treatment concerns could be addressed via adequate disclosure regimes (Rambachan et al. 2020). Finally, regarding accountability, entrepreneurs may face liability either because they are using AI (von Ungern-Sternberg 2018 and Diamantis 2020b) or because they failed to do so (Hacker et al. 2020). Algorithmic fairness concerns could be minimized by insuring that algorithm scores are either equally accurate for members of legally protected groups or reflect the same percentage of false positives or false negatives for each of group. While it may often not be possible to achieve parity in both these dimensions, parity in the ratio of false positives to false negatives seems a tractable requirement (Hellman 2019).

2. In addition, the use of AI could also facilitate anti-competitive (Cave 2019) and criminal practices (Dupont et al. 2018). For some, the availability of AI is unlikely to generate collusive practices (Chassang et al 2019; Veljanovski 2020). However, simulations have shown that self-learning pricing algorithms may collude on supra-competitive fixed-price equilibria (Klein 2019). In addition, the implications of AI developments for data dispersion and ownership may result in (potentially inefficient) State intervention (Yeung 2019).

3. Almost two decades ago, legal theorists have emphasized that in the AI world, like in the regulated world, outcomes must be explained, justified, compared to and contrasted with alternatives (Rissland et al. 2003). However, as for many innovations, the rise of AI first occurred in a regulatory vacuum (Scherer 2016). In recent years, policy-makers have become aware of the importance of AI (Calo 2017; Hacker 2020), not least due to its impact on job markets and inequality (Goolsbee 2018). As a matter of fact, AI use is considered as having the potential of subjecting humanity to a Malthusian destiny (Korinek and Stiglitz 2017). This has generated calls to adopt the kind of AI with better economic/social outcomes (Acemoglu and Restrepo 2019). It thus comes as no surprise that law-makers at the national and international levels have actively considered regulating AI (Shackelford and Dockery (2020), engaging in what is already called regulatory competition (Smuha 2019).

4. Regulatory proposals range from exclusive de facto control over machine learning (Kop 2020), to enacting smart/public interest oriented AI regulation (Zetzsche et al. 2017; Australian National University 2018; Dignam 2019), to requiring the regulation of AI used in the financial sector (Truby et al. 2020). In this context, it is suggested to delegate implementation to an international organisation (Erdelyi and Goldsmith 2020). These proposals are said to reflect four models: the black letter model, the emergent model, the ethical model, and the risk regulation model (Petit and De Cooman (2020). Nonetheless, given the emerging nature of AI technology development, it could be preferable to continue to facilitate market developments. To that end, suggestions range from a “permissionless innovation” approach (Thierer et al. 2017) to fairness assessments of AI systems (MacCarthy 2019).

5. Regulatory issues such as the principal/humans – agent/AI problem are relatively new for computer scientists (Hadfield-Menell and Hadfield 2018). However, they have been extensively studied by economists and legal scholars. In theory, the best way to align principal and agent interests is to design a so-called ‘complete’ contingent contract (Schwartz and Scott 2003; Bolton and Dewatripond 2004). In practice, jurisdictions generally aim at setting-up regulatory

frameworks that are both AI-friendly and safe (Erdelyi and Goldsmith 2020). Courts, for their part, provide AI-related backstops — especially in common law jurisdictions (Cuéllar 2019). However, the possibility remains that AI could subvert any control method devised by a non-AI entity (Gans 2018). In this context, it has been predicted that regulators will have to embrace data-centric approaches, for cost-cutting and accuracy purposes (Snow 2019a). In addition, it has been proposed to subject AI to codes of ethics and ethical principles (Gasser and Schmitt 2019).

2.4 AI Lawmaking and Enforcement

1. AI-driven regulatory developments may go hand-in-hand with artificial codes, data bias, virtual threats, and systemic risks (Lin 1979); moreover, when it comes to finance, the use of AI may exacerbate human error (Magnuson 2019). These perils and pitfalls should not be underestimated. On the other hand, advances in mathematics and machine learning are likely to significantly improve automated regulation (Mormann 2000). According to one view, while AI will significantly contribute to public policy, simple rules will remain the fundamental guideline for the design of legal institutions and environments (Fernandez-Villaverde 2020). According to a more dominant view, ML and AI algorithmic developments are expected to significantly reduce lawmaking and enforcement costs (Zuckerman 2020). In other words, AI should facilitate the determination of what is 'legal' in any particular situation (Casey and Niblett 2016), and will contribute to improving the accuracy of legal prediction (Park and Ko 2020).

2. AI and ML learning already play a significant role when it comes to automated vehicle liability (Abraham and Rabin 2018), disclosure and advice (Williams 2020) and labor market (Zhang 2019). In the financial sector, AI is increasingly used by both risk managers and supervisory authorities. To be sure, AI reliance may amplify or create new tail risks, due to its endogenous complexity and opportunistic use (Daníelsson et al. 2019). At the same time, AI is considered a good candidate for predicting bank distress (James et al. 2013; Suss and Treitel 2019) and evaluating the market risks associated with regulatory changes (for machine learning. see already Ni et al. 2020). AI is also a promising contributor to fraud detection (Abu-Elyounes 2020). This is especially true for bank customer fraud (see McPhail and McPhail 2019 for ML) and money laundering (Bertrand at al. 2020), where current detection systems are said to generate 90% of false positives (IBM 2019).

3. More generally, the financial services industry is likely to increasingly rely on AI for decisions that, by design, cannot be fully understood by their developers. As a ripple effect, one can expect regulators to increasingly confront AI models they cannot fully comprehend. In fact, several jurisdicitions plan or already do use AI to decide small claims cases, in particular Australia, China, Estonia and the Netherland (Sourdin 2018; Deng 2019; Casey 2020; Deng). This is probably due to AI providing affordable avenues for routine litigation (Findlay 2020), in particular when it comes to class action settlement (Erickson 2019). AI is also increasingly put to use in the arbitration area (Eidenmueller 2020)—especialy when it comes to legal research, translation of documents, case management, and arbitrator assistance or even substitution (Scherer 2019). On the other hand, we are not yet at the stage where arbitration by a computer is a generally acceptable norm (Marrow et al. 2020). On the other hand, there is concern about Courts facing "black boxes' when confronted with machine learning algorithms (Deeks 2019).

Similarly, while AI is a good candidate for felony sentencing, judges have shown some reluctance to use AI-driven risk scores (Stevenson and Doleac 2019).

4. The increasing reliance on AI has fairness, opportunism and bias implications (US Big Data Report 2016). For example, algorithms permit to detect when it is most likely that extralegal biases influence judicial decision-making (Chen 2019). At the same time, the use of AI for tax return purposes could widen the legal advice access gap between high-income and low-income individuals (Blank and Osofsky 2021); similarly the presence of AI could have a feedback effect on corporate disclosure decisions, i.e. companies could adjust the way they talk knowing that machines are listening (Cao et al 2020). As a result, policy makers across jurisdictions are adopting, respectively consider adopting fairness-related regulations for algorithms (Cowgill and Tucker 2019). It is too early to tell whether these social concerns are justified. To begin with, cost savings generated by AI-reliance are likely to increase the demand for labor in non-automated tasks (Acemoglu and Restrepo 2018). In addition, there is evidence of algorithmic lending reducing discrimination, possibly because it has increased competition or facilitated shopping (Bartlett et al. 2019). Finally, there is no evidence of AI-prediction of recidivism being less fair than predictions made by people with little or no criminal justice experience (Dressel and Farid 2018). Obviously, reliance on AI may reduce administrative and judicial discretion; however, to the extent state powers are discretionary, that discretion should remain significant (see also Koopmans-Van Berlo and De Bruijn 2005).

5. Finally, while human-AI interactions are increasingly common, people seem averse to machines making moral decisions (Bigman and Gray, 2018). There is also reluctance to entitle AI to a status comparable to natural persons, i.e. legal personality (Chesterman 2020). To be sure, there is empirical evidence of people actually prefering advice from algorithms to advice from people (Logg et al. 2019), especially when robo-advisors exhibit limited human characteristics (Hodge et al. 2018). However, it is important to note that still little is known about human willingness to make trust-based investments with non-human agents (Schniter et al. 2018).

3 Supervision Review

3.1 International Organizations

1. The AI for Good Global Summit is the leading United Nations platform for global and inclusive dialogue on AI. The 2019 Summit continued the dialogue with AI innovators and other stakeholders (including more than 37 United Nations agencies and bodies), to identify strategies ensuring that AI technologies develop in a trusted, safe and inclusive manner. When it comes to financial regulation, research originated within the Bank for International Settlments (BIS) shows that a significant number of financial authorities use or plan to use information technology for microprudential and macroprudential supervision. However, the relevant applications are in different stages of development and implementation, ranging from academic research questions through proofs-of-concept stage to fully operational.

2. The Organisation for Economic Cooperation and Development (OECD) has adopted principles for responsible stewardship of trustworthy AI. In particular, the 2019 Recommendation of its Council on Artificial Intelligence (2019) encourages governments to promote a policy environment that generates trustworthy AI systems. To this effect, States should use experimentation, with AI systems being tested and scaled-up in a controlled environment. In addition, States should review and adapt, as appropriate, their AI systems policy and regulatory frameworks to encourage innovation and competition for trustworthy AI. To support these efforts, the OECD launched an AI Policy Observatory in February 2020. It aims at helping States to enable, nurture and monitor the responsible development of trustworthy AI systems for the benefit of society.

3. The Group of Twenty (G20) has more directly targeted AI actors. Its 2019 AI Principles require them to respect the rule of law, human rights and democratic values, throughout the AI system lifecycle. In particular, AI actors should commit to transparency and responsible disclosure regarding AI systems. Implementation of these Principles is deemed critical for G20 members to continue their leadership on AI policy issues, given that the use of AI is still at an early level of maturity across many countries and firms.

4. The Financial Stability Board (FSB) has identified a number of potential benefits and risks for financial stability to monitor while AI technology is adopted and more data becomes available. In particular, applications of AI could result in new and unexpected forms of interconnectedness between financial markets and institutions, for instance due to the common use of previously unrelated data sources.

5. Finally, the Council of Europe has set up an Ad hoc Committee on Artificial Intelligence. The Committee is responsible for examining the feasibility and potential elements of a legal framework for the development, design and application of AI, based on the Council's standards in the field of human rights, democracy and the rule of law. The Ad hoc Committee has published a compilation of national perspectives from different States in order to support the development of an international legal framework. 46% of the respondents were based in Council of Europe member countries, 32% in observer countries and 21% in other countries.

It is worth noting that African and South-American countries are not represented independently from international organizations.

3.2 European Union

3.2.1 European Institutions

1. In February 2020, the European Commission (EC) published a White Paper on Artificial Intelli-gence. It builds upon the 2019 Ethics Guidelines for Trustworthy AI issued by the EC's Independent High-Level Expert Group on Artificial Intelligence. These Guidelines highlight that trustworthy AI has three components: it should be lawful, ethical and robust, both from a technical and social perspective. The 2020 White Paper accordingly supports a regulatory and investment oriented approach, with the twin objective of promoting AI and addressing the risks associated with this new technology. It also emphasizes the need for a common European approach to AI, for two fundamental reasons. First, a common approach allows for sufficient scale and avoid single market fragmentation; second, na-tional initiatives would endanger legal certainty, weaken citizens' trust and prevent the emergence of a dynamic European industry.

2. The European Central Bank (ECB) has stressed that supervisors have a large access to data, which is critical for an efficient use of AI (ECB Annual Report 2018). Therefore, the ECB expects AI to make supervision more informed and agile by flagging anomalies to supervisors in real time; for example, AI is deemed to have the capability of identifying bank liquidity issues by itself. The ECB has already launched various AI-related projects, e.g. on using natural language pro-cessing to improve the search for unstructured information and on using machine learning for work-intensive processes. However, the ECB approach remains cautious: experience has shown that the more one relies on new technologies, the higher the risks associated with it. It is worth noting that the ECB's cautious approach is not merely due to operational considerations. It has explicitly indicated that, in case of AI failure, supervisors (and not technology) are the ones that will get blamed for it (see www.bankingsupervision.europa.eu).

3. The European Banking Authority (EBA) has identified the use of artificial intelligence as a promis-ing and growing technological innovation for financial services (Annual Report 2019). However, many AI applications still deal with a limited number of intelligent tasks (January 2020 Report on Big Data and Advanced Analytics). More specifically, financial institutions appear to be at an early stage of ML use, with a focus on pre-dictive analytics. Essentially, they mostly rely on simple models that are used for customer engage-ment and process optimization purposes (with a growing interest in the area of risk management). Issues such as accountability, ethical aspects and data quality have yet to be addressed in depth.

3.2.2 Member States

France and Germany are among the most advanced users of AI for supervisory purposes, whereas Italy and Spain are among those lagging behind.

1. French supervisory authorities entered the big data world some years ago. Nowadays, the Autorité des Marchés Financiers (AMF) protects investors by using machine learning to detect market abuse or market anomalies that traditional algorithms would not have identified. Conversely, machine learning enables the AMF to reduce the number of false positives, thus halving the number of alerts generated by the system. The anti-money laundering, risk modeling and customer protection capabilities of these algorithms are currently tested; the goal is to verify their suitability from an auditing, explicability and governance perspective. In any event, AI has already significantly increased the Autorité de Contrôle Prudentiel et de Résolution (ACPR) ability to identify fraudulent websites for blacklisting and public information purposes (2019 Annual Banque de France Report). For its part, the Banque de France uses its central bank powers to operate Madre, a 'private' blockchain that enables it to address and disclose banks' identification requests in real time. Madre's IT and control are decentralized, which has been criticized from a maintenance perspective.

2. The German Bundesanstalt für Finanzdienstleistungsaufsicht (BaFin) uses artificial intelligence for supervisory purposes, for example to provide evidence of market abuse such as insider trading. Regulatory discussions are still going on when it comes to approving crypto-based business models, as demonstrated by Libra (a stablecoin with a value tied to a basket of different currencies). In this context, the BaFin's 2020 Report on "Big Data Meets Artificial Intelligence" discusses the impact AI has on a) product and process innovations and b) the emergence of new players and market structures. The Bundesbank's 2020 Policy Discussion Paper on "The Use of Artificial Intelligence and Machine Learning in the Financial Sector" underlines that the main supervisory focus should be on ML features which are novel to current regulation and supervisory practices. These include black box characteristics, data quality and model learning processes; in addition, supporting processes will become more important. The Bundesbank's paper also includes preliminary considerations for a supervisory strategy that is embedded into a tech-neutral, innovation-enabling and risk-sensitive approach.

3. Italy lags considerably behind in the artificial intelligence fields (Bank of Italy Annual Report 2018). However, the Bank of Italy has started to use artificial intelligence techniques to predict price moves on the real estate market. Moreover, its researchers have used big data methodologies to detect anomalous financial transactions (Batocchioni et al 2019). Similarly, Italian banks are catching up and investing heavily in projects that exploit big data, technologies for the development of digital platforms, cloud computing and artificial intelligence (Bank of Italy Annual Report 2019).

4. Like Italy, Spain had a slow start when it comes to using artificial intelligence. The Bank of Spain seems to be working on identifying how AI can improve the quality control of the information it collects and enhance its macroeconomic analysis (Fernández 2019). Officially, however, the Bank of Spain is focusing on coordinating its AI work with other international bodies (Report on Banking Supervision 2019). This approach contrasts with the one adopted by the largest Spanish banks, which are investing heavily in AI.

5. When it comes to other Member States, Cyprus, Denmark, Finland Latvia, Lithuania, Portugal, Luxembourg, Czech Republic, Sweden, Estonia, Malta, the Netherlands and Slovakia all had their AI strategies published by the end of 2019 (EC Joint Research Centre, National Strategies on Artificial Intelligence, A European Perspective, 2020). Hungary

published its AI strategy in May 2020, whereas Austria, Belgium, Bulgaria, Croatia, Ireland, Greece, Poland, Romania and Slovenia are expected to do so in 2021.

3.3 Singapore and Switzerland

1. Switzerland is the European country with the highest number of AI start-ups per citizen (SATW Recommendations for an AI Strategy in Switzerland 2019). AI is also reshaping core industries, in particular banking, insurance, pharmaceuticals and manufacturing. The Swiss Financial Market Supervisory Authority (FINMA) has long required that financial institutions document the key features of their algorithmic trading strategies (Circular 2013/8). More recently, FINMA pointed out that AI technical progress allowed for a leap forward in data management (Annual Report 2019). FINMA is also expected to set out supervisory expectations concerning the use of AI in business processes and the mitigation of associated risks. For its part, the Swiss government indicated in December 2019 that the Swiss regulatory framework does not require fundamental changes. Clarifications and adaptations being required in various areas (science and technology, mobility and security), the government has set up working group to coordinate its AI positions.

2. Six Singaporean government agencies work in partnership to direct AI Singapore (AISG). AISG activities are anchored in four key areas: funding AI research, applying AI technologies, helping small companies adopt AI, and developing AI talent. The Monetary Authority of Singapore (MAS) has issued principles to promote fairness, ethics, responsibility and transparency in the use of AI in the financial sector. In addition, MAS operates the Augmented Intelligence System to automate the computation of key metrics (MAS Enforcement Report 2019-2020). Operational since April 2020, this system should make it easier to detect certain types of suspicious trading activities, in particular market abuse cases.

3.4 China and Japan

1. China’s 2019 “Governance Principles for the New Generation AI” are designed to ensure AI safe-ty, reliability and controllability. They aim at supporting sustainable development economically, so-cially, and environmentally. Fundamentally, AI development should comply with 8 principles: harmony and human-friendliness; fairness and justice; inclusion and sharing; respect for privacy, safety and controllability; shared re-sponsibility; collaboration; agile governance. These Principles are similar to ethical frameworks laid out by Western governments; however, the Chinese approach is deemed to reflect a government-first approach. Going forward, the plan is to submit AI to a comprehensive legal regime by 2025, with the overarching aim of making China the world center of AI innovation by 2030 (Roberts et al 2020).

2. Japan has not subjected AI to an overarching regulatory framework, but the government has adopted various AI guidelines. In addition, it established a study group to formulate social AI princi-ples. This led to the March 2019 adoption of three basic principles: dignity, diversity & inclusion, and sustainability. At the same time, the Japan Exchange Regulation and the Tokyo

Stock Exchange announced that they would apply AI to market surveillance operations, in particular to detect market manipulation. This enables surveillance personnel to complete preliminary investigations more quickly and to focus on detailed investigations. For its part, Japan's Financial Services Agency (FSA) is planning a push into the world of artificial intelligence, in particular via a project aiming at using AI to examine securities reports.

3.5 United Kingdom and United States

1. The Bank of England (BoE) and the Financial Conduct Authority (FCA) have indicated their inter-est in how machine learning is deployed by financial institutions (Machine Learning in UK Financial Services 2019). More specifically, the FCA has reported that AI is increasingly used in UK financial markets (Artificial Intelligence in the Boardroom 2019). The BoE, for its part, emphasized that AI developments could fundamentally change the way businesses provide, and consumers use, financial services (BoE Annual Review 2019-2020). The recent Covid crisis may have reinforced this trend: 45% of the banks and insurers regulated by the BoE expect an increase in the importance of AI for their future operations (Dave Ramsden, Deputy Governor for Markets & Banking, speaking at the launch of the BoE and FCA Artificial Intelligence Public Private Forum, 12 October 2020). On the other hand, the FCA and the BoE have not proven very forthcoming when it comes to their own use of AI. For example, the only mention of AI in the BoE Annual Review 2019-202 has to do with Alan Turing appearing on the new £50 note.
2. The US is perceived as being less optimistic than Europe about the benefits of AI regulation. However, US lawmakers are increasingly dealing with AI related risks. While the US Congress adopted two bills mentioning AI in the 2015-2016 term, it passed more than 50 such bills during the 2019-2020 term (Chae 2020). The White House, for its part, has released a draft "Guidance for Regulation of Artificial Intelligence Applications" in 2019, which includes ten prin-ciples to be applied when deciding whether and how to regulate AI. At the State level, AI-related regulatory initiatives have flourished in Alabama, Arizona, California, Florida, Idaho, Illinois, Massachusetts, Nevada, New Jersey, New York, Vermont, and Washington. However, it could take time for any output to become binding. For example, Alabama has set-up a Commission on Artificial Intelligence and Associated Technolo-gies that has yet to deliver its report. The same is true for Washington's task force charged with iden-tifying policies to help its businesses and workers respond to rapid changes in emerging technologies such as AI. Similarly, Massachusetts is merely discussing a bill to establish a commission that would analyze the use of automated decision systems in the state, whereas bills to 'study and regulate' AI have been submitted in New York and New Jersey. To be sure, a few States have already reached the law-making stage. For example, Vermont's task force has recommended the adoption of a code of ethics to set standards for responsible AI. More importantly, California is working on AI-related legislative projects that target both the public and pri-vate sector. Hence, it is considering adopting guidelines to govern the use and implementation of AI technologies in state government functions. In addition, its Automated Decision Systems (ADS) Ac-countability Act of 2020 bill targets AI techniques to make decisions or facilitate human decision making. The act would require any business that uses an automated decision system to 1) continual-ly test for biases during its development and usage and 2) assess whether it has a disproportionate adverse impact.

4 Conclusion

The social sciences related AI literature has been growing rapidly, especially in the past two years. However, the large majority of the law making and enforcement contributions still focus on ML: overall, the review points to the significant incompleteness of contributions in the ‘use of AI for law-making and enforcement’ purposes. For their part, supervisory authorities around the world are increasingly relying on AI for internal pur-poses. When it comes to regulating financial intermediaries, AI remains mostly used to detect illegal market practices, in particular market abuses. The exception is the United States, where States are the main players and the regulatory scope is broader than in the rest of the world.

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6 Appendix

6.1 Table I: Recent Literature

1. AI Definition	*2. AI Use in Finance*	*3. Regulating AI*	*4. Ongoing Law Making and Enforcement Developments*
Taking decision with some autonomy Combination of individual Machine Learning algorithms	**Increasingly supplanting humans** - ML: Financial analysis & Forcasting - AI: Cognitive tasks & Fraud detection	**Regulatory Vacuum** - Resilience - Accountability and Legitimacy - Privacy and fairness - Anti-competitive & criminal practices	**Very Few AI-related Contributions** - Reduce Law-Making Costs - Facilitate determination of what is legal
Essential Components - Domain structure - Data generation - Machine reading capability	**Use of AI** - Requires clear objectives - Algorithm aversion issues - Predictive vs causality value	**Regulatory Models** **-** Black Letter - Emergent - Ethical - Risk Regulation	**Market Impact** - Managing bank distress & market risks - Improved fraud detection - AI reliance for routine litigation
	Governance and Ethics Objectives - Democracy - Market integrity and investors - GDP and trade	**Current Approaches** - Regulators: AI friendly + Safety concerns - Courts: Provide backstops - Codes of Ethics	

6.2 Table II: Recent Supervisory Approaches

International Organizations	European Union	Singapore and Switzerland	China and Japan	UK and US
BIS Reports significant IT use	**EC** White Paper promotes AI and emphasizes need for common approach	**MAS** Principles to promote fairness, ethics, responsibility, transparency in AI use in the financial sector	**China** Requires AI development to comply with 8 principles. Similar to ethical frameworks laid out by Western governments	**FCA** reports increasing use of AI in UK financial markets **BoE** emphasizes that AI could fundamentally change provision and use of financial services
OECD Encourages AI experimentation Adopts Principles for trustworthy AI systems	**ECB** Cautious approach Expects AI to make supervision more informed and agile	**FINMA** Expected to set out supervisory expectations concerning use of AI	**Japan** AI not subjected to overarching regulatory framework, but adopted various guidelines	**US** Less optimistic than Europe about AI regulation 10 principles on whether/how to regulate AI AI regulatory initiatives at State level
G20 Rule of law & democratic values throughout AI lifecycle		**EBA** AI is promising for financial services Financial institutions at early stage of ML use		
FSB Monitors AI benefits and risks for financial stability		**France & Germany** Most advanced AI users **Italy and Spain** Lag behind		
Council of Europe Working on AI legal framework				

Acknowledgment

This work is an outcome of the Future Resilient Systems project at the Singapore-ETH Centre (SEC) supported by the National Research Foundation, Prime Minister's Office, Singapore under its Campus for Research Excellence and Technological Enterprise (CREATE) programme.

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Publisher: Singapore-ETH Centre