Università
Ca'Foscari
Venezia

Master's Degree

in Economics and Finance

Final Thesis

RegTech and SupTech: Opportunities and Challenges in the Financial Sector

Supervisor
Prof. Andrea Minto

Assistant supervisor
Prof. Marco Palmieri

Author
Foteini Michailidou
Matriculation number
873790

Academic Year
2019 / 2020

Table of Contents

1 Abstract

In this thesis, a systematic literature review is going to be conducted regarding the various applications, prospects and challenges of the emerging fields of Regulatory and Supervisory Technology, or in short, "RegTech" and "SupTech". These terms refer to the use of innovative technologies to facilitate regulatory and supervisory processes. The analysis will start with the evolution of these industries, an overview of the technologies employed and the current applications. Moving on, the potential risks and limitations of the use of technology in regulation as well as the various opportunities for the improvement of the regulatory framework will be thoroughly analyzed. It should be argued, that these emerging fields could potentially transform the regulatory and supervisory system and why such a reformation may be needed. Innovation could provide the necessary tools to supervisors and financial institutions to address the needs of the IT-focused 21st century but before proceeding with their mass adoption, several operational challenges should be addressed.

2 Acknowledgments

First and foremost, I owe my greatest gratitude to my supervisor Dr. Andrea Minto for his guidance and valuable help during the development of this thesis. I would also like to thank in advance the assistant supervisor Dr. Marco Palmieri as well as professors Urbani Alberto, Martina Giuliana, Pizzigati Mauro, and Onnis Cugia Federico for examining my thesis.

I would like to express my sincere gratitude to the University of Ca' Foscari for giving me the opportunity to improve my knowledge and grow as a person. I would like to thank all the professors and administrative staff for their constant support and guidance throughout the academic period. Being a foreign student, this support in all aspects of academic and living conditions has been of utmost importance to me.

I am extremely grateful to all my friends for their encouragement and help during my academic career. I would like to thank my closest friends for always being by my side. To all of my new Italian friends, thank you for readily accepting me into your group, showing me your beautiful culture, and making this whole experience unforgettable. Without you, I would have missed out on many beautiful memories, and probably wouldn't learn to speak Italian so well. To my international friends, thank you for the great memories and help at the start of our life in Italy.

Lastly, none of this would have been possible without the constant support from my family. Thank you for giving me the chance to live and study abroad. I would not be able to fulfill my dreams had it not been for your constant encouragement and help. Thank you for helping me deal with the stress and difficult times during my academic career and for always being my source of strength.

3 Abbreviations

AI	Artificial Intelligence
AML	Anti-Money Laundering
API	Application Program Interface
ARTEMIS	Advanced Relational Trading Enforcement Metric Investigation System
ASIC	Australian Securities and Investments Commission
AUSTRAC	Australian Transaction Reports and Analysis Centre
BCBS	Basel Committee on Banking Supervision
BIRD	Banks' Integrated Reporting Dictionary
BNR	National Bank of Rwanda
BoI	Bank of Italy
BSP	Central Bank of Philippines
CAT	Consolidated Audit Trail
CDD	Customer due diligence processes
CFT	Countering the Financing of Terrorism
CNBV	Mexican National Banking and Securities Commission
DLT	Distributed Ledger Technology
DNB	De Nederlandsche Bank
ECB	European Central Bank
EDW	Electronic data warehouse system
FATF	Financial Action Task Force
FCA	Financial Conduct Authority
FINTRAC	Financial Transactions and Reports Analysis Centre of Canada
FIU	Financial Intelligence Unit
GDPR	General Data Protection Regulation
IoT	Internet of Things

IReF	The Integrated Reporting Framework
KYC	Know your Customer
KYC	Know-your-customer
MAI	Market Analysis and Intelligence
MAR	Market Abuse Regulation
MAS	Monetary Authority of Singapore
MIDAS	Market Information Data Analytics System
MiFID II	Markets in Financial Instruments Directive
ML	Machine Learning
NLP	Natural language processing
OeNB	Oesterreichische Nationalbank
R^2A	RegTech for Regulators Accelerator
ROFIEG	Expert Group on Regulatory Obstacles to Financial Innovation
ROSFIN	Financial Intelligence Unit of Russia
SEC	U.S. Securities and Exchange Commission
UIF	Financial Intelligence Unit of Italy

4 List of Figures

5 Introduction

The financial crisis of 2008 served as a wake-up call to the systemic risks underlying the global economy as well as the insufficient regulation of financial institutions. The deregulation of the markets, excessive leverage, and inadequate monitoring of financial entities amplified the intensity of the global crisis and demonstrated the need for stronger surveillance mechanisms. As a result, financial institutions were faced with stricter regulations in order to regain the trust of the public. This transformation of financial regulation entailed complex and costly regulatory processes for financial entities and was the breeding ground for what is known today as "RegTech".

Regulatory Technology, or RegTech, is an emerging field that aims to utilize innovative technology in favor of regulatory processes. Supervisory Technology, or "SupTech", could be considered as a sub-category of RegTech that seeks to support supervisory activities. While the combination of technology and regulation has existed in the past, the term first appeared in the aftermath of the 2008 financial crisis along with other movements such as "Fintech" and "InsurTech". At the time, "RegTech" companies offered to limit the burden of high monitoring and compliance costs for financial entities by deploying technological means for the fulfillment of regulating obligations. "Regtech", however, has a much larger potential than simply automating regulatory and supervisory process.

The 2008 global financial "contagion" highlighted the gap between financial development and the corresponding regulatory framework. Whereas markets became increasingly interconnected, regulation and supervision remained mostly at a national level. This time, while the financial sector is transforming to embrace revolutionary technologies, the regulatory system is left to cope with the numerous legal implications that may be caused. Technological advances have brought disruptive changes in the financial sector. A new field called "FinTech" has emerged, referring to the use of technological advances for the automation and transformation of traditional financial processes in order to increase efficiency and reduce costs. These technologies include, among others; cloud computing, blockchain technology, smart contracts, Artificial Intelligence (AI) and machine learning. These new innovations may cause several legal challenges in the future and have already raised questions regarding the appropriate regulatory response. Issues related to cybersecurity, the use of sensitive data, and innovative business models and products, to name a few, are becoming increasingly prominent as the financial sector actively adopts these technological

breakthroughs. As a result, regulators and supervisors are faced with a plethora of challenges while they are equipped with only a limited set of tools.

"RegTech", along with "SupTech", could provide the necessary toolkit for supervisory agencies and financial institutions to address the needs of the IT-focused 21st century. Instead of focusing only on the implications of these disruptive technologies, initiatives should be made to explore how they could be utilized in favor of regulation and supervision. Perhaps it is time for a reformation of the current financial regulatory regime in order to match the fast-paced development of the financial market infrastructure.

The opportunities of these new fields are endless and they could be expanded to several other sectors besides financial markets. In the future, they could enable the real-time monitoring of data and enforce a significantly more efficient control over the cyberspace. In regards to financial entities, "RegTech" could improve compliance procedures and regulatory reporting. Innovative technologies could, additionally, assist in risk management and identity control as well as efficiently monitor transactions and trading in financial markets. In that aspect, "RegTech" could prove to be particularly helpful in detecting money-laundering, fraud, and other activities of financial crime. In the case of supervisors, "SupTech" could contribute to more efficient micro- and macro-prudential supervision as well as improve the overall market surveillance. Data collection and management processes could be significantly enhanced while powerful processing, predictive and visualization tools could improve the analytical capability of supervisory authorities. Most importantly, emerging technologies could increase the harmonization and cooperation between the different financial actors.

Such an interconnected system, however, could be a risk on its own. Operational failures of single points could influence the whole system while the concentration of power in the hands of the main technology providers could create a sort of monopoly. Moreover, all the technical limitations hindering the fast growth of "Fintech" influence "Regtech" in the same way, including the various operational and cyber risks as well as the potential legal issues stemming from the use of sensitive data. Lastly, one important consideration is whether the dependence on algorithms may violate the core principles of law. Law allows for flexibility but machines are accurate and act upon the data inserted and generated. Functions such as deep learning could prove to be dangerous due to their independence and therefore, there should be an adequate control and knowledge of these technologies before their mass adoption.

Concluding, a thorough literature review is going to be conducted regarding the various applications, prospects, and challenges of the emerging fields of "RegTech" and "SupTech". It should be argued, that

these fields could potentially transform the regulatory and supervisory system and why such a reformation may be needed. Firstly, a retrospect of the evolution of RegTech is going to be conducted, followed by an overview of the innovative technologies used in the fields of RegTech and SupTech. The third section is going to analyze the applications of emerging technologies in the regulatory processes of financial institutions while the fourth section will focus on supervisory agencies. Moving on, the opportunities of these fields as well as the various risks and barriers are going to be thoroughly examined. The last section concerns the recent initiatives undertaken by competent authorities in order to promote innovative RegTech and SupTech solutions under the appropriate supervision.

6 Evolution of Regulatory and Supervisory Technology

The financial crisis of 2008 was the turning point for the deployment of technological means in the regulatory and supervisory framework. Even though the term "RegTech" was coined shortly after the crisis, along with "FinTech" and "InsurTech", the origins of the utilization of technology for regulatory purposes could be traced back to the economic growth in the 1990s.

6.1 REGTECH 1.0: 1990-2008

The use of technology in regulatory processes is not a new phenomenon. While the field has gained momentum shortly after the financial crisis of 2008, the concept of introducing technology into the regulatory framework dates back to the 1990s. At the time, financial institutions started applying technological solutions for the purpose of internal risk management and monitoring processes. Along with the rapid growth of financial institutions and markets marking that period of time, the increase of cross-border transactions raised concerns regarding the measures that should be taken against the rising operational and regulatory challenges. This fact, in turn, led to the development of compliance and risk management departments within financial institutions that incorporated technology to cope with the increased complexity of their operations[1].

Risk management, as a concept, became an important parameter for financial institutions following the introduction of the Basel I accords in 1988. The Basel Committee on Banking Supervision (BCBS) was founded in 1974, by central banks of the G10 countries[2], as an international forum for the collaboration of member countries on banking supervision matters. BCBS decisions focused on the standardization and harmonization of banking regulatory practices in order to promote financial stability. The first Basel Accord published by BCBS set a minimum capital requirement for internationally active banks as a measure against credit risk[3]. Initially, the proposed guidelines entailed simple methods for the computation of the required

[1] Arner, Douglas & Barberis, Janos & Buckley, Ross. The CFA Institute Research Foundation (2017). *FinTech and RegTech in a Nutshell, and the Future in a Sandbox*.
[2] The G10 countries consist of Belgium, Canada, France, Germany, Italy, Japan, the Netherlands, Sweden, Switzerland, the United Kingdom and the United States. Since then, the members have expanded to 45 institutions from 28 jurisdictions.
[3] Bank for International Settlements (BIS). *History of the Basel Committee*.

threshold. However, in the amended versions that followed, the use of internal or value-at-risk (VaR) models was recommended instead.

Value-at-Risk is a risk measure that calculates the potential loss of an investment portfolio over a given period of time, expressed as a single number that can be used to compare various types of assets[4]. This simplicity and flexibility of VaR quickly gained the preference of financial entities over other traditional risk measures. This statistical technique could take into consideration the diversity of assets and risk factors while summarizing them into a single value. It could therefore provide useful insights regarding the required capital levels needed to address possible losses.

In 1996, the Basel Committee published the "Market Risk Amendment", a reform of the Basel I Accord intended to take account of market risks. It was the first time that banks were permitted to use internal value-at-risk models for estimating the market risk component of capital requirements[5].

From then onwards, the financial sector began investing in IT systems and methods in order to develop quantitative risk management models that could help them manage potential losses. Financial innovation was looked upon favorably by market participants and regulators. Financial institutions, in particular, started using technology for the analysis and monitoring of risks related to their operation and for the regulatory obligations imposed on them by the Basel Accords. It has been argued, however, that this over-reliance on quantitative risk models exhibited by banks and regulators in the years leading up to the crisis, may have clouded their judgment regarding their real exposure to market risks[6]. This fact could also be part of the reason why the attitude towards financial innovation and technology changed completely after the crisis.

Besides risk management, another example of the combination of technology and regulation at that time could be considered the monitoring system of securities markets. Stock exchanges began applying trade-reporting systems for the surveillance of markets and specifically, to uncover and report any abnormal activity such as insider trading[7]. Since the financial crisis, however, several implemented market regulations and systems for surveillance have been updated or reformed due to their previous insufficiency in correctly monitoring market transactions. The new reporting standards imposed on financial markets and institutions, along with the general reformation of financial regulation, have generated the need for advanced

[4] Corporate Finance Institute (CFI). *Value at Risk*.
[5] Bank for International Settlements (BIS). *History of the Basel Committee*.
[6] Ashby, S. (2010). *The 2007–2009 Financial Crisis: Learning the Risk Management Lessons*.
[7] Arner, Douglas & Barberis, Janos & Buckley, Ross. (2017)

technological tools, able to address the new complexity of the regulatory landscape. In a few words, the transformation of the financial regulatory framework following the crisis led to the creation of the RegTech industry.

6.2 REGTECH 2.0: 2008-present

The second phase of RegTech could be attributed to three principal factors; significant developments in innovative technologies, the post-crisis transformed regulatory standards and the increased reliance of the financial sector on technology.

The enabling factor of the RegTech evolution has been rapid technological progress. Recent developments and breakthroughs have enabled the creation of innovative products and services that can make possible the humanly impossible. The endless possibilities that technological advances could offer have incentivized creators to come up with new and revolutionary business ideas to solve existing and emerging problems.

One of these challenges that technology seeks to address is the regulatory complexity and uncertainty following the financial crisis of 2008, which could also be viewed as the main driver of the RegTech phenomenon.

In the aftermath of the 2008 crisis, financial entities were faced with a drastically reformed regulatory system of increased complexity and scope. The transformation of the financial regulation in response to the crisis has been a long-term effort that continues to this day. New regulatory requirements and standards are constantly being introduced to financial institutions and markets in order to regain the trust of the public and ensure that a similar future crisis could be averted. The ongoing digitalization of the economy further raises new challenges that need to be addressed. As a result, aside from adjusting capital and liquidity requirements as a response to the crisis, regulation has expanded to encompass rules related to consumer protection, data privacy, cybersecurity, money-laundering and terrorist financing, to name a few[8].

[8] Roy S., Heaney M. & Seibert H. Oliver Wyman (2018). *Regtech on the rise: Transforming compliance into competitive advantage*

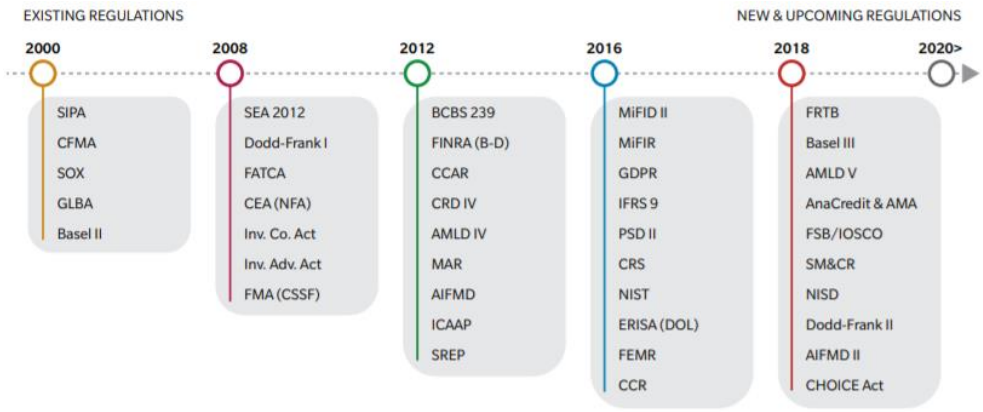


Figure 1: Evolution of Regulatory Burden. Source: Oliver Wyman

These developments, while justified, have significantly increased compliance costs for financial institutions, which alternately face strict penalties in case of nonconformity. According to a research published by RegTech company Fenergo in January 2020, since the financial crisis of 2008, a total amount of $36 billion in global fines have been issued against financial entities for non-compliance with Anti-Money Laundering (AML), Know your Customer (KYC) and sanctions regulations[9]. This amount is only a small part of the penalties against financial institutions, with a Boston Consulting Group report estimating a staggering amount of approximately 321$ billion dollars in fines between the period 2007-2016.

Nevertheless, fines are only part of the problem. The reputational damage caused by such negative press can shake shareholders' and depositors' confidence creating a variety of implications for financial institutions. In order to avoid the heavy repercussions of noncompliance, financial entities spend a substantial amount of financial and human resources on compliance and monitoring processes. The compliance spending of the financial system is estimated to be around $270 billion per year[10]. According to Oliver Wyman, around 10% to 15% of financial services employees are appointed to compliance and risk management processes, mostly occupied with regulation-related paperwork[11]. Despite the substantial allocation of resources to such functions, compliance remains a complex and difficult task due to the ever-changing regulatory framework. The report by the Boston Consulting Group evaluated that global regulatory changes applicable to banks have more than tripled in the period between 2011 and 2016, to an

[9] Fenergo (2020). *Another Fine Mess: A Global Research Report on Financial Institution Fines and Enforcement Actions.*
[10] KPMG (2018). *There's a revolution coming: Embracing the challenge of RegTech 3.0*
[11] Roy S., Heaney M. & Seibert H. Oliver Wyman (2018).

average amount of 200 revisions per day[12]. According to the annual survey of 2020 on the cost of compliance by Thomson Reuters, the most commonly cited challenge for the financial sector remains the ongoing regulatory change and the accompanying costs, resources, and burdens[13].

The increased regulatory scrutiny has therefore limited the profitability of financial institutions and the range of activities that they choose to engage in. However, the cost of compliance does not concern only financial entities. By reducing profitability, customers and shareholders are greatly affected through higher prices and lower returns. Additionally, the possibility of hefty fines has led financial services providers to avoid markets and individuals that are deemed risky or difficult to identify, a fact that has negatively affected the international agenda of financial inclusion. Another implication worth questioning is whether high regulatory restrictions increase the entry barriers of the financial system to small, innovative players, and whether ultimately they hinder growth.

Consequently, the right balance must be found between ensuring the safety of the financial system and promoting innovation and growth. The answer to this challenge could be provided by technology.

The use of technology in regulatory processes was first termed "RegTech" by the Financial Conduct Authority (FCA) of the UK in 2015[14]. According to FCA, new technologies that help firms comply with the higher regulatory and reporting requirements following the crisis, should be supported in order to facilitate innovation and competition in the market.

RegTech companies emerged as a response to the long-lasting ramifications of the financial crisis. The promise to limit the high burden of compliance by deploying technological tools and methods for the fulfillment of regulatory obligations has quickly gained the interest of market participants. In a constantly changing environment, keeping up with regulation can prove to be a very challenging task. RegTech solutions could be the answer to regulatory uncertainty by helping financial institutions stay up-to-date with new rules and requirements and enhancing their adaptability to new regulatory norms, all the while mitigating associated costs and risks.

Another considerable factor contributing to the growth of the RegTech industry was the rise of "Fintech" and the increasing use of technological advances in the financial sector. Fintech innovations brought disruptive changes in the market and along with them a variety of new regulatory challenges, for instance, related to data privacy, customer protection, and facilitating illegal financial activities. The development of

[12] The Boston Consulting Group (2017). Global Risk 2017: *Staying the course in Banking.*
[13] Hammond S. & Cowan M. (2020). *Cost of Compliance Survey 2020: New Decade, New Challenges*
[14] Financial Conduct Authority (2015). *Call for Input: Supporting the development and adoption of RegTech.*

digital and automated methods for regulation could provide the necessary foundation for the expansion and successful adoption of FinTech products and services by enabling competent authorities to oversee more efficiently this increasingly interconnected and digitized financial sector.

All in all, FinTech and technological innovation along with the need of solutions to address the problem of post-crisis regulation, marked the second stage of RegTech and brought attention to the potential use of technology in dealing with regulatory challenges.

In a Thomson Reuter survey of 2019, respondents believed that one of the biggest possible changes in compliance for the next 10 years would be the successful use of technology in the automation of compliance activities[15]. Indeed, there has been a growing number of RegTech initiatives in the last few years, both from high-tech startup firms and from in-house expertise of financial market participants.

According to a Deloitte analysis of 360 RegTech companies active in 2020, the provided solutions generally focus on the fields of regulatory reporting, risk management, identity management& control, compliance, and transaction monitoring[16].

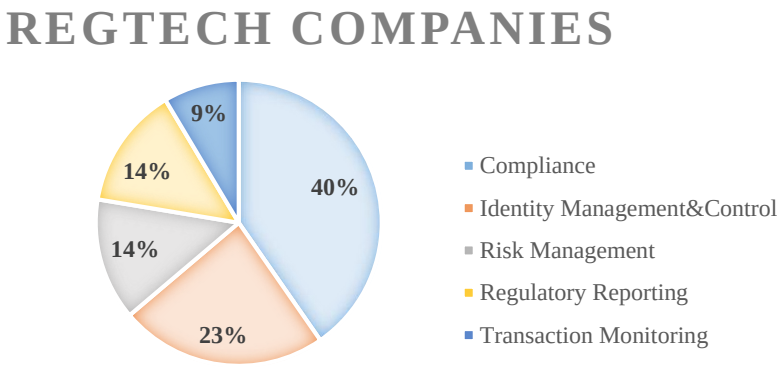


Figure 2: Segmentation of the RegTech market in 2020. Source: Deloitte

Most of the RegTech applications are currently focused on compliance processes and identity management or Know-your-customer (KYC) controls. This seems reasonable considering the fact that the EU published the Markets in Financial Instruments Directive (MiFID II) and the General Data Protection Regulation (GDPR) in 2018. MiFID II introduced enhanced reporting requirements and regulations on financial

[15] Hammond S. (2019). *Cost of Compliance Survey 2019: Nothing is certain except regulatory change.*
[16] Deloitte (2020). *RegTech Universe 2020: Take a closer look at who is orbiting in the RegTech space.*

markets to increase their transparency, reduce dark pools (private exchanges that do not require the disclosure of the trader's identity) and protect investors[17]. GDPR, on the other hand, concerns every organization that handles personal data of EU citizens. It aims at firmly protecting data privacy and customer protection in a digitalized economy[18]. This new legislative framework created several implications for financial institutions and markets, which is probably why the RegTech industry observed a spike in investments in the first six months of 2019, an amount almost quadruple of 2014 investments[19].

Figure 3: Global RegTech Investment, 2014-H1 2019 (USD, number of deals). Source: FinTech Global

The Regtech sector is on the rise. While the main focus of Regtech 2.0 is the automation and digitalization of regulatory compliance and reporting, in the future it could bring about a powerful change in the financial sector. This movement could effectuate a reformation of the financial regulatory landscape that could match the fast-paced development of the financial market infrastructure.

[17] ESMA (2020). *MiFID II*.
[18] Ben Wolford (2020). *What is GDPR, the EU's new data protection law?*
[19] FinTech Global (2019). *The first half of 2019 marked the strongest start to a year in RegTech to date.*

6.3 REGTECH 3.0: The future

A new report by Grand View Research, Inc. estimates that the global RegTech market is expected to grow at a compound annual growth rate of 52.8% from 2019 to 2025, reaching a total size of $55.28 billion by 2015[20]. Key drivers of this growth are considered to be the high compliance costs and penalties as well as the development of regulatory sandboxes supporting RegTech initiatives.

RegTech holds great potential for the reconceptualization of financial regulation on the road to enhancing the efficiency and transparency of the sector as well as coping with the increasing digitalization of the 21st century. Well beyond the automation of mundane compliance processes and regulatory requirements, RegTech could increase the overall efficiency of the regulatory and supervisory system with innovations such as machine-readable and executable regulation, interconnected data centers, and self-learning systems. Most importantly, this movement could enable the active cooperation between financial market participants, regulators and supervisors within and outside the borders of jurisdictions for a greater oversight of the global financial system. After all, the harmonization of compliance and reporting approaches and regulatory norms as well as the collaboration in detecting emerging risks may be essential in the future due to the increasingly globalized financial sector.

In the future, RegTech could enable the real-time monitoring of data and enforce a significantly more efficient control over the cyberspace. A new generation of RegTech is around the corner, as financial institutions and markets place greater importance on data and treat regulation as a data-driven problem that could be solved by technology. A paradigm change from a "Know your Customer" (KYC) to "Know your Data" (KYD) approach is expected to occur in the financial sector and regulation, driven by the central role of data in RegTech and FinTech solutions[21]. Data quality is therefore a fundamental variable that is expected to drive the development of the market. Digitalized and automated reporting systems as well as the advanced data storage, management and processing capacity of market participants and supervisory authorities could potentially become the focus of the next steps of incorporating innovation in the context of regulation.

Additionally, the rising digitalization of the economy and the development of revolutionary financial products and services could increase the need for an advanced regulatory response and therefore, prompt

[20] Grand View Research (2019). *RegTech Market Size, Share & Trends Analysis Report By Organization Size, By Application (Risk & Compliance Management, Identity Management), By Region, And Segment Forecasts, 2019 – 2025.* Report ID: GVR-2-68038-960-9.
[21] KPMG (2018). *There's a revolution coming: Embracing the challenge of RegTech 3.0*

the growth of the RegTech sector. As the data volume generated and managed by the financial sector increases, so does the corresponding regulation. Data protection laws are steadily becoming stricter and the demand for technological tools ensuring cyber resilience and digital compliance rises. As the economy transitions into the new era of digitalization, regulation and supervision may have to move from monitoring human behavior to overseeing automated processes, and digital transactions and conduct[22]. RegTech could therefore become a necessity.

[22] Zetzsche D., Buckley R., Arner D. & Barberis J. (2017). *Regulating a Revolution: From Regulatory Sandboxes to Smart Regulation*.

7 Overview of the underlying technology

7.1 Application Program Interface (API)

An Application Program Interface is a set of tools, protocols, and rules that allows software programs to interact with each other[23].

APIs are software intermediaries that enable the communication between applications and specify how this interaction should be conducted. They ensure that information can be correctly transferred despite the architectural differences of the various software programs. In other words, APIs could be viewed as messengers that connect requestors and providers of data and services[24]. They can be public, private, or partner; that is, they can be published online, used only in internal company systems, or become available upon an agreement with the publisher.

One key feature of APIs is that they allow developers to build upon pre-existed codes and programs. Instead of writing the code from scratch, developers can simply utilize existing APIs in order to apply specific data or functionalities to their applications[25]. Similarly to built-in functions in programming languages, developers can "call" these APIs in their code. Then, this piece of code offered by a third-party can be used as a building block in their programs. For instance, Google's public map API enabled developers to use the offered mapping functionality in their applications, saving them the effort and time of creating this function themselves. In a sense, APIs could be considered as a form of "outsourcing" pieces of code. In this example, Google gave access to a part of the company's code to the general public in order to share with third-parties limited access to their data.

APIs facilitate the flow of data between institutions, increase developers' productivity, and enable the development of numerous innovative products. The collection and management of data is fundamental to financial services, which is why a technology that encourages data distribution can be particularly useful in RegTech initiatives.

[23] Basel Committee on Banking Supervision (2018): "Sound Practices: implications of fintech developments for banks and bank supervisors".
[24] Pearlman, S. (2016). *What are APIs and how do APIs work?*
[25] Berlind, D. (2015). *What Are APIs and How Do They Work?*

7.2 Artificial Intelligence

Artificial Intelligence is the computer science that seeks to build "intelligent" machines. It is concerned with the development of computer systems that are able to perform tasks requiring human intelligence and capabilities[26].

But what exactly is considered "intelligent"? Should intelligent machines mimic human behavior or act based on an ideal and rational performance?

This ambiguity has led to the emergence of various definitions of AI over the years. In general, these definitions could be divided into two broad categories in accordance to this question. Those in favor of a human-centered approach led their research based on the observation of human activity whereas those upholding a rationalist approach deployed mathematics and engineering properties in their work. Among those, one theory proposed by Alan Turing in 1950 is still relevant today. Turing's approach to machine intelligence was focused on the ability to exhibit human behavior. The Turing Test, as it is known, involves an experiment where a human judge should not be able to discern a smart machine from a human, based on a written conversation. This test was designed to evaluate four basic capabilities that computers must develop in order to simulate human intelligence[27]

1**) Natural language processing** to successfully communicate in a commonly agreed language, for example, in English.

2**) Knowledge representation** to store information.

3) **Automated reasoning** to analyze this stored information and answer to questions.

4) **Machine learning** to learn from past data by extrapolating patterns and successfully adapt to new situations.

[26] BCBS, 2018

[27] Russell, S. J., & Norvig, P. (2010). *Artificial intelligence: A modern approach* (pp. 1-3). 3rd edition. Prentice-Hall, Inc.

In the case of the "Total Turing Test", which involves a physical interaction, an intelligent machine should further exhibit the following two functions:

5) **Computer vision** to perceive objects

6) **Robotics** to be capable of movement and manipulation of objects.

In his work, Turing predicted many of the key components that would later concern the Artificial Intelligence research field. Most of AI applications focus on tasks such as language translation, problem-solving, learning, speech, and visual recognition. Or in other words, the functions that were expected by a machine that can "think" in Turing's test are being individually developed into sub-fields of Artificial Intelligence.

In fact, the current AI systems can be only considered weak forms of AI due to their limited abilities and narrow domains in which they operate. A weak or narrow AI system is designed to fulfill specific tasks and is bound by a set of rules. On the other hand, a strong AI system should be able to imitate the human brain. It should possess an artificial general intelligence (AGI) that would enable advanced functionalities and capabilities in a variety of sectors as well as the ability to understand and learn like humans[28].

Even though such an ambitious attempt is still far away from being achieved, advances in technology such as cloud computing, large datasets (or "Big Data") and enhanced computing power, support the development of AI applications. Specifically, they support a subfield of AI called Machine Learning, which has been accredited as the force leading the recent progress of the whole field.

Originally, intelligent systems were built upon symbolic manipulation, an approach known as "Symbolic AI". This approach was based on hand-coded "symbols" and logical rules set by programmers in the form of nested if-then statements. In simple terms, programmers manually inputted human-readable information and instructions in the system according to the function they wanted to develop. However, it soon became apparent that such an approach could be extremely complex and difficult in real-life situations.

This fact gave rise to the development of machine learning, an approach that utilizes statistical techniques in order to let the machine learn directly from the data without the need for human intervention. The main difference between these two AI implementations is the way they "learn". In Symbolic AI, programmers try to teach computers all the necessary information that they deem relevant as well as the way to carry out specific tasks. On the other hand, in machine learning, they seek to teach computers how to learn by

[28] Duke SciPol (2019). *Artificial Intelligence: An Overview.*

themselves. Machines analyze and extrapolate patterns from large amounts of raw data, draw conclusions, and formulate their own knowledge on how to perform a task. This is essentially a transition from logic-based methods towards data-based algorithms in AI applications.

Summarizing, Machine learning (ML) concerns the development of problem-solving algorithms that improve automatically through experience. ML algorithms enable computers to learn how to perform a task, find patterns and make predictions by utilizing data and experience, without the need for human intervention[29].

Machine learning can use three types of techniques[30]:

- Supervised learning: Computers are trained on a large dataset where input and output data are known. By analyzing the known responses to the input data, supervised learning enables the development of predictive models for the response to new data.
- Unsupervised learning: Computers are given only input data, from which they must derive hidden patterns and structures.
- Reinforcement learning: Computers learn through a process of trial and error in the interactions with their environment. Reinforcement algorithms operate on a "reward" system that influences the system's future set of actions.

Artificial Intelligence is a broad term that encompasses various important sub-fields, such as machine learning and natural language processing, that are becoming increasingly relevant not only in the fields of SupTech and RegTech but also in the general economy.

[29] BCBS, 2018
[30] Matlab (2020). *What Is Machine Learning?*

7.3 Distributed Ledger Technology (DLT) and Blockchain

Distributed Ledger Technology (DLT) enables the recording, sharing and synchronization of information across multiple data stores. A distributed ledger is essentially a database that is commonly shared and updated by the network participants. "Blockchain" is one implementation of DLT.[31]

DLT is a system that records transactions in different computer servers, also called "nodes", at the same time. Distributed ledgers could be viewed as synchronized digital copies of data that exist in different locations. The key property of DLT is decentralization, which means that there is no central database and no need for a third-party intermediary for the processing and verification of transactions. The possibility of circumventing human intervention in the processing of transactions is what makes distributed ledgers so appealing. DLT and blockchain could significantly increase the efficiency of numerous processes and decrease operational costs and errors.

Despite popular belief, these two terms are not equivalent. Blockchain is only a type of distributed ledger technology that became widely known following the emergence of the Bitcoin platform. In 2008, a groundbreaking white paper introducing bitcoin and its underlying blockchain technology was released under the pseudonym Satoshi Nakamoto, whose vision became a reality later in 2009. As described in the 2008 paper, Bitcoin is a peer-to-peer digital cash system that allows participants to make direct online payments without relying on financial intermediaries. It uses cryptography and a type of decentralized ledger, the blockchain, which ensures that money is only spent once[32]. Bitcoin was the first implementation of blockchain technology and brought disruptive changes in peer-to-peer computing. Nakamoto's work was able to achieve true decentralization and eliminate the double-spending problem of previous works, i.e. the possibility of the same asset being sent to many parties. While electronic currencies already existed as a concept for several years, bitcoin was the first to be successfully implemented, partly due to the underlying blockchain protocol that appeared as a solution to the trust issues surrounding digital currencies. By acting as a public decentralized and time-stamped record for all the bitcoin transactions, the protocol was able to reinforce the trust in digital currencies and ensure their transparency.

[31] Natarajan, H., Krause S. K. & Gradstein H. L. World Bank Group. (2017). *Distributed Ledger Technology (DLT) and blockchain*

[32] Nakamoto, S. (2008). *Bitcoin: A Peer-to-Peer Electronic Cash System*

The term blockchain refers to the data structure that is used in a distributed ledger, or in other words, the way that information is stored and organized. Transaction data are sorted into groups called “blocks”. Each new “block” is connected with the previous ones through a digital “chain”, the database of transaction records. In detail, new entries are encrypted and added in a data “block”, which is then verified by the network participants before being accepted to their respective ledgers. The validation method used by the nodes to ensure the legitimacy of new data entries is called “consensus mechanism”, which is essentially a pre-defined programmed set of rules that is commonly agreed between the network participants. The new block is added to the distributed ledger only after it has been validated by the whole network. In the case of blockchain technology, the consensus mechanism that is used is called “proof-of-work”. It is a protocol that demands the use of significant processing power in order to defend the system against attacks and ensure the security of the transactions.

The linear relationship between the blocks makes the modification of previous entries a very difficult task. This is why blockchain transactions are said to be immutable. Generally, the architecture of these software protocols entails a variety of benefits:

- **Improved security and transparency**

  As it was mentioned above, every network member has access to the same information which can, further, only be updated after the general consensus of the participants. Transaction records are immutable thanks to the “chain” system that demands, upon the alteration of a single entry, the modification of all subsequent data entries. The complexity and difficulty of such a task is designed to discourage any attempt to tamper with the transaction data. These features combined promote transparency in the system and trust between the parties. In addition to that, the use of cryptography and the lack of human intervention ensure the security of the system and reduce the possibility of fraud. Lastly, thanks to their decentralized nature, DLT systems are considered to be more resilient against cyberattacks in comparison with conventional centralized systems.

- **Increased efficiency and reduced costs**

  DLT systems are able to streamline several processes by limiting the extensive paper-work and documentation employed in traditional business models and promoting trust between the network participants. At the same time, the lack of third-party intermediaries increases the speed of transactions and reduces the associated costs, human errors and risks.

There are two types of distributed ledgers; permissioned and public or permissionless networks[33]. As the name suggests, public distributed ledgers can be accessed by anyone that possesses the necessary software. There is no control over who joins or leaves the network. On the other hand, permissioned distributed ledgers have a central authority or administrator that selects the members that can join the network and decide the rules governing the system. While this feature limits the independence of the network, it could also facilitate the regulation and monitoring of distributed ledgers and alleviate several concerns that regulators have regarding this technology. For example, it could provide a solution to network participants' identity verification issues as well as appoint an entity accountable for the regulation and licensing of this system.

DLT and Blockchain have gained significant traction in the fields of RegTech and SupTech as a result of their transformative potential. They could bring about significant efficiencies in the field of compliance and surveillance by transforming reporting and data sharing functions between financial entities. However, it may still be early for their adoption due to several operational and legal risks that need to be addressed.

7.4 Smart Contracts

> Smart Contracts are self-executing and self-verifying software programs that carry out the terms of an agreement upon the occurrence of a trigger event.

Smart contracts utilize blockchain technology to automate the execution of agreements and business processes while eliminating the need for a third-party agent. They are designed to automatically carry out contractual obligations between parties upon the verification of pre-defined conditions, through the use of logical algorithms based on "if-then" statements. The idea was first proposed in 1994 by Nick Szabo who defined it as "a computerized transaction protocol that executes the terms of a contract"[34]. However, it wasn't until the invention of blockchain technology that this concept was first successfully implemented.

[33] Natarajan, H., Krause S. K. & Gradstein H. L. World Bank Group. (2017). *Distributed Ledger Technology (DLT) and blockchain*

[34] Szabo N. (1994): *Smart Contracts*.

A unique type of smart contracts does not exist. Adjustments and alterations can be made according to the corresponding needs of the contracting parties. They can be written entirely in code, along with a natural language version or in a natural language with an embedded code for the execution of the transaction.

Despite their misleading name, smart contracts are not legal contracts. They are computer codes that automatically execute orders written in a programming language. Legal contracts must be carried out by the judicial system or any other legal intermediary and must abide by specific conditions depending on the case. Smart legal contracts are a middle-ground solution that seeks to take advantage of the cost-efficiency of smart contracts while ensuring that they operate on a legally-enforceable basis.

Smart legal contracts refer to legally binding agreements that incorporate computer codes in order to automate part or all of the execution of the terms and conditions. In other words, it could be said that they consist of pieces of smart contract code while maintaining a legally contractual relationship between the parties. For instance, they may be expressed in natural language, in digital or written form, but carry out the contract through computer code[35].

This digital evolution of conventional contracts could entail a variety of benefits for businesses, governments, and other stockholders[36]. The architectural characteristics of smart contracts promise increased accuracy, transparency, and security of transactions. The execution of the contract is based on a formal programming language, clearly defined terms, and a distributed ledger. The lack of human intervention diminishes the possibility of manual errors and misunderstandings that may be observed in common contracts. The use of a decentralized database further fortifies the security of digital transactions owing to the consensus mechanism of DLT and the public access to the same documentation. Most importantly, smart contracts are considered a cost-efficient alternative to traditional processes. As an immediate effect of automation, smart contracts contribute to the increase of efficiency and speed in the execution of business deals. They decrease costs by transferring tasks traditionally handled by employees and third parties to computers. Summarizing, smart contracts hold great potential for more efficient, reliable, and faster processes in the financial sector.

[35] ISDA (2017). *Smart Contracts and Distributed Ledger – A Legal Perspective*.
[36] Nzuva S. (2019). *Smart Contracts Implementation, Applications, Benefits, and Limitations.*

7.5 Big Data Analytics

The term "Big data" broadly refers to the large volume of structured and unstructured data that is generated by the increasing use of digital tools and information systems[37]. Big data analytics are the various methods employed for the analysis of these massive and complex datasets with the purpose of extracting useful information.

The undergoing digital transformation of the economy has resulted in a phenomenon called "Big Data". Every day a large amount of different types of data, arriving from various sources at a high frequency, is being produced by the use of IT systems and online services. Networks, social media, and devices, to name a few, generate new types of data that were previously unattainable and which can be used to extract valuable and hidden information.

In broad terms, big data sources could be categorized in three groups[38]:

- Social networks and digitized human-sourced information (networks, blogs, google searches, social media, etc.)
- Traditional Business systems (transactional data, e-commerce, etc.)
- The Internet of Things and machine-generated data (devices, sensors, computer logs, etc.)

There is no clear definition of what constitutes data "big"; after all, the significance and size of data is a subjective variable that constantly changes as technological innovation and society evolve. A generally accepted perception of big data is summarized in the so-called four 'V's. According to Stucke and Grunes[39], big data are characterized by high volume, variety, velocity, and value. In other words, big data can be considered as large volumes of data that can be heterogeneous in form, produced and processed at high speeds, and can be useful in producing valuable information.

Technological progress in data collection, storing, and management has facilitated the use of big data for business, regulatory, and public purposes. Big data, however, cannot be analyzed using traditional processing methods and tools. For this reason, advanced analytics techniques are being deployed in order

[37] BCBS, 2018

[38] Wibisono O., Ari H.D., Widjanarti A., Zulen A.A., & Tissot, B. (2019). *The use of big data analytics and artificial intelligence in central banking – An overview*. IFC Bulletins chapters, 50

[39] Stucke, M.E. and A.P. Grunes (2016). *Big Data and Competition Policy*. Oxford University Press, United Kingdom.

to discover hidden patterns and provide valuable insights from sources that used to be unreachable. These techniques include, among others, machine learning, predictive analytics, data mining, text mining, and statistical analysis.

Big data and big data analytics can be a powerful tool for businesses, institutions, and supervisors. They are an important source of knowledge that can contribute to decision making and problem-solving processes as well as uncover market trends and correlations. Some indicating benefits of big data include improved product development and marketing strategies, enhanced customer experience and satisfaction, operational efficiency, efficient monitoring of investor and customer behavior, and improved fraud detection and compliance procedures[40].

7.6 Internet of Things

The Internet of things (IoT) refers to the concept of interconnected devices through the use of internet. In this system, "smart" devices are able to communicate and share data by connecting to a network and/or to one another, reducing the need for human intervention[41].

Any object can become an IoT device as long as it can connect to a network. For instance, aside from electronic devices, IoT may refer to vehicles, home appliances and even buildings. Besides networks, there are two additional key technologies underlying the IoT ecosystem; that is, sensors and data analytics.

IoT or "smart" devices are embedded with sensors or actuators that collect data from the physical world. By employing networks, they can transfer these data to a cloud server and subsequently transmit them to other devices of the system. Data analytics are then used to derive useful information and patterns from this dataset in order to "learn" about the user and improve the provided services. Networks can also enable the interaction between devices. What this means, is that users can remotely control devices by using another device connected to the internet.

This technology could play a central part in the shift of the financial regulatory framework towards a more data-centric approach. The ability to connect devices in order to collect, share and analyze data can bring

[40] Wibisono O., Ari H.D., Widjanarti A., Zulen A.A., & Tissot, B. (2019).
[41] Figliola P. M. (2020). *The Internet of Things (IoT): An Overview.* Congressional Research Service (CRS).

significant changes in the financial industry, yet the legal risks stemming from the use of privacy data have to be considered.

7.7 Cloud Computing

> Cloud computing refers to the on-demand provision of computing services over the internet (the "cloud"). These services may include servers, storage, datasets, networking, software and even blockchain and artificial intelligence applications.[42]

Cloud computing enables users to access computing resources without owning and maintaining the respective IT infrastructure. Instead, users utilize remote and shared servers on the internet provided by Cloud services companies that get paid per use. Specifically, cloud computing models follow five central characteristics[43]:

1) Resource Pooling: Computing resources are pooled to serve multiple clients by being dynamically allocated and adjusted according to demand.

2) On-Demand Self-Service: Consumers can automatically use cloud services on request.

3) Rapid Elasticity: Users should be able to use computing resources in any quantity they desire at all times. What this means is that the applications and capabilities of the cloud should be elastically scalable in line with demand.

4) Broad Network Access: The cloud network should be accessible by any standard device such as computers and mobile phones.

5) Measured Service: The use of computing resources is measured and monitored for each user in order to bill them appropriately. Computing services payments are based on a "pay per use" system.

There are three main cloud architectural structures; public, private and hybrid clouds[44]. Public clouds are addressed to the general public. They are managed by cloud service providers that deliver their services over the internet. On the other hand, private clouds are designed exclusively for the internal network of a

[42] Microsoft Azure (2020). *What Is Cloud Computing? A Beginner's Guide.*
[43] Mell P. & Grance T. (2011). *The NIST Definition of Cloud Computing*. Technical Report. National Institute of Standards and Technology (NIST).
[44] Microsoft Azure (2020).

single entity. A company, for instance, may create or outsource a private cloud to distribute computing services over its various departments. A hybrid cloud combines public and private clouds by enabling the sharing of data and applications between them.

Moreover, there are three types of cloud services[45]:

Software as a Service (SaaS), in which, providers of software applications allow customers to use their services over the internet by using, for instance, a web browser.

Platform as a Service (PaaS), in which, cloud providers allow customers to use cloud infrastructure as a platform to develop and run their own applications.

Infrastructure as a Service (IaaS), in which, cloud providers become the hosts of the customer's infrastructure, or in other words, they rent to them computing resources.

Cloud computing is being increasingly adopted by a variety of entities as a solution to the heavy burden of investing in IT infrastructure. Possibly the most appealing benefit is the avoidance of the costly initial capital expenditure as well as the subsequent maintenance and management expenses needed for IT systems. Cloud computing offers cost-efficient services that allow businesses to scale and improve their productivity at an increased operational and strategic flexibility. Another significant advantage is that by achieving economies of scale, cloud providers can constantly update their services and invest in innovative technology in order to keep up with the competition. This fact, in turn, results in a competitive advantage in favor of the customers, for whom the task of exploiting technological advances would be extremely difficult to achieve on their own, either due to the associated expenses or due to the lack of specialized personnel. Lastly, clouds can become a reliable and secure alternative to the company's IT infrastructure. They are able to store multiple copies of data and ensure the continuity of business operations despite any system failure or malfunction. As far as security is concerned, clouds are strongly equipped to fight off any outside threats and protect the integrity of business data and applications.

[45] Mell P. & Grance T. (2011)

7.8 Biometrics

Biometrics is the field of science concerned with the identification of an individual based on their unique characteristics and the use of computer technology. Biometric technologies measure and analyze physical and/or behavioral characteristics to recognize, authenticate and identify an individual.[46]

Biometrics is a mature field with a wide variety of applications, ranging from law enforcement to mobile commerce. In the financial sector, biometric technologies are being mainly employed to improve the security and convenience of financial transactions. They offer an improved and more secure alternative to the conventional authentication methods of passwords and tokens. In fact, customer identification is the main application of biometrics at the moment. Other important cases include their use for secure access control (that may allow, for instance, only authorized individuals to enter specific areas), as well as their deployment in the public sector (digital identity, border control, security information monitoring, etc.). With the rise of digital banking services and processes, biometrics are being increasingly deployed by financial institutions for the identification of employees and customers. They are being used in a variety of banking services such as online banking, fraud control, transactions, and payments in order to improve customer experience and enhance their security measures.

There are two principal categories of biometric identifiers:

• *Physiological traits* such as fingerprints, face, iris, retina, and hands.

• *Behavioral traits* including recognition of voice, signature, and typing patterns.

Biometric solutions prevail over traditional methods of identification in that biological characteristics can hardly be forged, stolen or tampered. At the same time, they cannot be lost or forgotten like passwords. There can be, however, errors and system failures in the processing of biometric data. Users may be falsely rejected or accepted during identification while biometric data can be hacked. Such concerns should be considered and countermeasures should be predetermined in order to fully unlock the potential of biometrics.

[46] Digital Transformation Monitor (2018). *Biometrics technologies: a key enabler for future digital services.* European Commission.

8 Regulatory Technology

8.1 General Applications

8.1.1 Compliance

The post-crisis reformation of the global financial regulation has resulted in a significant rise in the cost and complexity of compliance processes for market participants. Financial institutions and markets are faced with higher regulatory standards and reporting requirements in a landscape that constantly changes. This increase in the scale and scope of regulation has directly affected the profitability of financial institutions. The higher operational costs and errors as well as the increasing allocation of financial and human resources to compliance processes entail a substantial amount of investment in compliance and risk management functions. Failure to comply with regulation translates into heavy penalties and reputational damage. In the highly competitive conditions of the financial market, non-compliance may prove to be critical for the future of any financial institution. Especially for smaller firms, this regulatory burden may become unbearable and lead to an unleveled playing field where innovation is stifled and entry barriers are fortified.

RegTech solutions could alleviate the compliance concerns of financial entities by streamlining processes and reducing risks through the use of technological advances. They could provide an alternative to the labor-intensive tasks designed to keep up with regulatory changes by facilitating the identification and interpretation of upcoming rules as well as ensuring their subsequent compliance.

The majority of RegTech solutions in this area focus on the *automation of compliance procedures*[47]. Machines can accurately carry out straightforward tasks in unmatched speeds, which could subsequently increase the efficiency and productivity of the financial entity. At the same time, due to the limited human intervention, manual and human errors could be mitigated, and operational costs could be greatly decreased. A strong compliance system, in turn, would be less probable to allow any deviations from normal activity that may result in heavy penalties and fines.

RegTech, however, could be deployed in a much greater degree that exceeds the simple automation of mundane tasks. "Dynamic" compliance systems could be developed to allow the *real-time monitoring of compliance levels and risks*. They could do so, by examining a number of operational data and analyzing

[47] Deloitte (2016). *RegTech is the new FinTech: How agile regulatory technology is helping firms better understand and manage their risks.*

human behavior on the basis of IT-embedded regulatory requirements[48]. These requirements, in turn, could be automatically updated upon the emergence of new legislation and rules. This level of automation could be a cost efficient alternative to the current labor-intensive, manual procedures and legacy systems.

Moreover, this emerging industry could be the key to the uncertainty surrounding the regulatory environment by helping institutions *stay up-to-date with upcoming regulations and laws*. RegTech solutions could increase the flexibility and adaptability of financial institutions to regulatory developments. They could achieve this by automatically identifying any changes in the regulatory requirements relevant to the financial entity and notifying the user, or possibly even proceeding with the necessary modifications upon request.

By *streamlining compliance processes*, the implementation of Regtech initiatives offers a competitive advantage in a market of increased costs, multiple risks and established players. At the same time, the freed up capital can be re-allocated to more productive and profitable uses, improving the market position of the institution.

According to an analysis conducted by Deloitte, current compliance applications focus on four functions[49]:

1. Regulatory watch and online library
As the name suggests, they are platforms that display all the current and upcoming regulations. They are designed to provide notifications for every new regulation applicable to the company.
2. Compliance project management
These tools assist financial institutions in preparing against upcoming regulations. The user can manage beforehand the tasks, resources and schedules for the application of new legislation.
3. Compliance health check
This function enables the user to keep track of their compliance state. The user can see in real-time whether their company is compliant with the regulation through the use of indicators and other similar tools.
4. Web due diligence and security
These tools seek to manage compliance issues related to data privacy and data security. By using mainly AI and machine learning applications, the user is able to better detect fraud cases and avoid data loss.

[48]Toronto Centre (2017). *FinTech, RegTech and SupTech: What they mean for financial supervision*. TC Notes.
[49] Hugé F.K., Duprel C., & Pescatore G. (2017). *The Promise of RegTech.*

8.1.2 Identity Management and Control

Identity management and control functions are an integral part of financial regulation practices. Financial institutions conduct business with a variety of entities and clients across the world. In order to protect themselves against the possibility of financial, reputational and legal damage, it is fundamental that they carefully review the counterparty of an agreement before engaging with them. For the identification and screening of potential and current clients and business partners, financial institutions are obligated to perform customer due diligence processes (CDD).

An important part of due diligence obligations is a process labeled as "Know your Customer" (KYC). A KYC or Know Your Customer check is the process used by financial institutions to verify the identity of a client and assess the risk of starting a business relationship with them. This process normally entails the collection, verification and analysis of several personal documents as well as the assessment of the costumer's financial activities and their risk factors[50].

Due diligence requirements are imposed by Anti-Money Laundering (AML), Countering the Financing of Terrorism (CFT) and Sanctions policies, and are an essential step on the onboarding and monitoring of customers[51]. The Financial Action Task Force (FATF) has developed international standards for CDD procedures that have been adapted by the domestic legislation of different jurisdictions across the world. By ensuring that the clients are who they claim to be, banks can detect and prevent financial crimes such as money laundering, tax evasion, fraud, corruption and terrorism financing.

Although necessary, these procedures are rather costly in their application and inconvenient for clients and partners. KYC processes are time-consuming and expensive, due to the nature of the authentication process that may require various informational sources and documents in different formats and languages[52]. Starting from the human capital and IT infrastructure required to perform KYC checks, to possible customer frictions, to the reputational damage and heavy penalties in case of failure to uphold the regulatory requirements, the costs are quickly accumulating. According to a Thomson Reuters survey, KYC and CDD processes cost on average $150 million annually for major financial institutions, with an average of 307

[50]Adl, M. & Haworth W.C. (2018). *How a Know-Your-Customer Utility Could Increase Access to Financial Services in Emerging Markets*. EMCompass;no. 59. Washington, D.C.: World Bank Group.
[51] FATF (2012-2019). *International Standards on Combating Money Laundering and the Financing of Terrorism & Proliferation*
[52] Institute of International Finance (2016). *RegTech in Financial Services: Technology Solutions for Compliance and Reporting.*

appointed compliance officers and an average of 32 days for the onboarding of new customers[53]. Additionally, due diligence and KYC requirements have grown significantly over the years and continuous regulatory changes makes compliance with AML/CTF policies a challenging task. This is especially true for institutions operating at a global level, since they have to take into consideration the various differences in jurisdictional interpretation of FATF standards.

As a result, AML and KYC processes have been a driving force in the demand for RegTech and have become of the main applications of the industry. The rising costs and implications of cross-border inconsistencies in these procedures have generated the need for tools that simplify compliance at a global level[54]. Technological advances hold great potential for a more effective, time-efficient and interconnected identity management and control system[55]. RegTech solutions could drive down compliance costs and speed up the onboarding and monitoring process of prospective and existing clients.

Identity management solutions facilitate onboarding and KYC processes for customers and business partners. On the other hand, identity control applications focus on the ongoing relationship with these parties. AML controls and client reports, for instance, are an important part of these processes.

In the identity management department, RegTech solutions could facilitate the digitalization and automation of customer and partner onboarding processes. Technology can be used to streamline onboarding processes by replacing repetitive, manual tasks with a standardized automated set of steps. The use of machines can increase the accuracy and speed of the process while minimizing the probability of error and enabling human personnel to spend that time in a more profound investigation of the concerned party. The key advantage of machines, however, is their advanced capability to collect and analyze data. Machines can access and examine a wider set of data, increasing the efficiency of KYC processes and providing a more complete image of the counterparty. For instance, they can utilize text and multimedia unstructured data (such as emails, social media, documents etc.) that assist in the identification and risk assessment during the process of accepting a new client.

Besides the initial identification process, banks must continuously be alert to ensure compliance. RegTech applications can be deployed to assist with the periodic review and management of clients' identity and their transactions. Technological advances can collect and analyze a wide variety of data to verify the

[53] Thomson Reuters (2017). *Global KYC Surveys Attest to Even Greater Compliance Pain Points.*
[54] Arner D. W., Barberis J. & Buckley R. P. (2017). *FinTech, RegTech, and the Reconceptualization of Financial Regulation*
[55] Institute of International Finance (2017). *Deploying Regtech Against Financial Crime.*

identity of the counterparty and update their profile when necessary. Additionally, they enable the real-time monitoring of their transactions and the detection of any suspicious or possibly illegal activities.

Lastly, probably the most talked-about application of RegTech in due diligence processes, is the creation of KYC utilities[56]. A KYC utility refers to a central repository that stores due diligence related data. It is essentially a shared identity database between member financial institutions. Once a user uploads the required documents to the specified portal (the KYC utility), his personal information is immediately available to all the authorized financial institutions. The member institutions can then use this shared information to conduct their own in-house processes. For each new client, they can cross-check their identity with the central records. In the case that the prospective customer is registered, they can ask for permission to use the provided data. Otherwise, they will make a new data entry that will be available to the other network participants. In short, KYC utilities create economies of scale .They enable financial institutions to share customer and partner data in order to promote standardization in KYC processes, enhance efficiency and customer experience, and avoid duplication of work. Standardization can improve regulatory compliance as well as the quality of KYC data. Additionally, sharing a centralized database can substantially increase operational efficiency, decrease individual related costs and detect easier fraud and money laundering activities. Moreover, customers have to go through the KYC process only once, a fact that improves their experience and saves them valuable time.

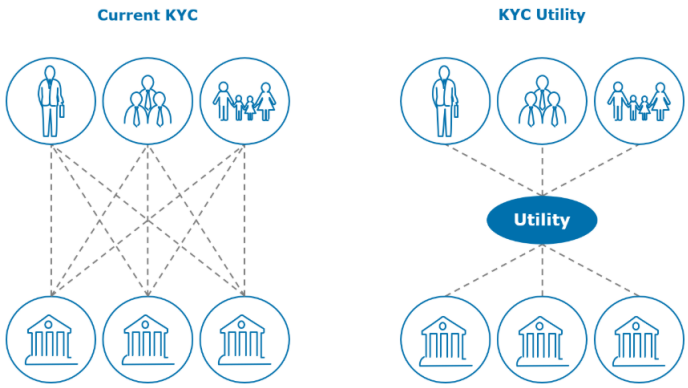


Figure 4: KYC Utility Structure. Source: Capgemini

[56] Randis P. (2019). *KYC Utility: why should you consider it?*

8.1.3 Risk Management

Financial institutions face a plethora of risks in their everyday operations which is why a robust and efficient risk management function is indispensable for their protection against financial and reputational damage. Risk management practices focus on the assessment, monitoring and reduction of potential risks as dictated by the internal management decisions and most importantly, by the law. Banks are obliged by the law to conduct a thorough analysis of possible risks and take action for their mitigation. Since the financial crisis, this obligation has been amplified and past acceptable risk measurement methods, such as VaR platforms, are not considered enough anymore. Regulatory reforms, such as Basel III and MiFID II, have imposed stringent risk management requirements on financial institutions regarding the collection and analysis of data, the performed controls, and the reports addressed to regulators.

These increased legislative demands have led institutions to seek new approaches to risk management that can keep up with regulatory obligations while decreasing the associated costs and effort. Emerging Regtech solutions are increasingly viewed as an appealing alternative to legacy systems by proposing new risk management techniques that can better safeguard financial institutions and respond to regulators' requirements.

Firstly, technological advances can enable the *automation of risk management processes* for improved compliance, efficiency and decision-making at a significantly lower cost. Regtech solutions could facilitate compliance by creating automatic systems that identify, evaluate and monitor risks based on the relevant regulatory requirements and internal practices. These systems would be able to notify the user and automatically take pre-defined actions upon the occurrence of a trigger event. For instance, they could alert the user if specific limits or risk levels have been exceeded and/or proceed with a sequence of pre-programmed steps[57].

Regtech solutions could additionally facilitate *risk data aggregation and management processes*. In 2013, the Basel Committee published guidelines directed at Global Systemically Important Banks (G-SIB's) in order to set a common framework regarding risk data aggregation techniques and infrastructure. According to this publication[58], risk data aggregation refers to "defining, gathering and processing risk data according to the bank's risk reporting requirements to enable the bank to measure its performance against its risk tolerance." The proposed set of requirements entails significant costs and challenges for financial

[57] Toronto Centre (2017)
[58] Basel Committee on Banking Supervision (2013). *Principles for effective risk data aggregation and risk reporting.*

institutions. This is evident from the fact that none of the concerned financial institutions has managed to completely adhere to these rules, according to a report by ECB[59]. Data quality, therefore, remains a significant problem for the financial sector. Regtech solutions could provide automated and efficient risk data aggregation practices that enable the generation of high quality risk data.

Another important risk management function that RegTech could improve, is *risk modeling and forecasting*[60]. Financial institutions are required to use modeling and analytical tools in order to forecast future possible losses and needs, and perform scenario analysis. The computation of capital and liquidity requirements, as specified in Basel III, as well as stress testing and risk assessment are all based on risk modeling. Considering that in the last few years, the quantity and quality of the tests that banks are obligated to perform has significantly increased, the importance of risk modeling is even more prominent.

The prediction of future data is fundamental for risk management and is one of the most complex and costly procedures in this department. Financial institutions allocate significant amounts in order to provide the computing power and human capital that is required to conduct these processes. Regtech companies could bring substantial efficiencies in risk modeling by providing automated processes, enhanced data collection and management functions, and a set of powerful technological tools for analysis. As technology evolves, a wider amount and variety of data is available to financial entities that can be processed using advanced analytics tools for valuable insights. With the use of technology, RegTech solutions could improve risk modeling by extracting relevant information from a vast amount data and analyzing those using advanced methods and technologies.

There are several RegTech companies today that focus on the need of financial institutions for enhanced risk management processes. They offer technological solutions for a variety of risk management functions, including data management, risk assessment and risk reporting[61].

[59] European Central Bank (ECB) (2018). *Report on the Thematic Review on effective risk data aggregation and risk reporting.*
[60] Institute of International Finance (2016). *RegTech in Financial Services: Technology Solutions for Compliance and Reporting.* & Financial Stability Board (FSB) (2017). *Artificial intelligence and machine learning in financial services.*
[61] Hugé F.K., Duprel C., & Pescatore G. (2017).

1. Scenario modelling and forecasting
Risk modelling tools focus on generating predictions of future data that are used in risk management practices. They facilitate, for instance, banking stress testing requirements.
2. Risk assessment
Technological solutions for risk identification, evaluation and control. They estimate, at all times, the risk exposure and asset qualities of a bank. Regarding regulatory needs, they can be deployed for the calculation of capital and liquidity ratios.
3. Risk reporting
In this area, tools are designed to facilitate risk reporting requirements

8.1.4 Regulatory Reporting

Another important focus of RegTech is the improvement and facilitation of regulatory reporting. Similar to the other regulatory requirements, reporting obligations have greatly expanded over the last few years to encompass a wide variety and frequency of high-quality information needed for supervision and statistical researches.

This area of RegTech is of utmost importance for both supervisors and financial institutions. The systemic importance of financial actors constitutes necessary their close supervision to prevent high exposure to risk and ensure that they will be able to meet their future obligations; and ultimately, promote financial stability.

RegTech solutions focus primarily on the *automation of the reporting process* in order to transform manual procedures into an efficient workflow and ensure the consistency and accuracy of the reported content. Automated processes may decrease the administrative and operational costs while reducing the probability of manual errors. At the same time, they may improve the accuracy, quality and timeliness of reports and make the whole process much easier and less time-consuming.

The degree of automation may vary according to the needs of the financial institution. It can range from simple automated tasks to an end-to-end reporting cycle that includes data sourcing, aggregation and

processing functions to send the end report in a correct format[62]. High-tech technologies could even enable real-time reporting[63].

Furthermore, RegTech solutions could be particularly useful in the *integration of regulatory reporting requirements.* Financial institutions that operate in a variety of markets and countries may face very different reporting obligations, a fact which eventually may lead to duplicate work and inconsistencies, increasing the demand for human and financial resources as well as the possibility of noncompliance. The lack of harmonization and the sheer amount of reporting requirements that financial entities have to address is a challenging task that can be facilitated by the use of technological advances.

Generally in this area, RegTech focuses on the delivery of solutions that facilitate the generation and distribution of regulatory reports. It provides tools that are able to process a vast array of data in a small amount of time and distribute it to the relevant regulatory authorities. All in all, RegTech can contribute to the streamlining of reporting processes, result in significant cost savings and enable the re-allocation of the focus of human capital into more analytical and critical business processes.

8.1.5 Transaction Monitoring

In accordance with Anti-money laundering regulation, financial institutions have to track and monitor transactions in order to detect any suspicious or illegal activity. In order to achieve that, they analyze metadata of transactions and identify, flag, and report any possible noncompliant transaction.

The fact that there are no single universal payment standards makes the interpretation of transaction metadata a very difficult task[64]. Traditionally, transaction screening is done in batches and case-by-case examination of suspicious movements, which is then followed by the appropriate reporting to the competent authority. Conventional AML systems rely heavily on manual processes and rule-based applications such as blacklist screening and customer profiling. These approaches may be responsible for a large number of false alerts, especially in the case where banks implement stronger rules out of caution[65]. These false alerts translate into additional investigation and consequently into time and effort lost. Traditional approaches can thus be very costly, labor-intensive and error-prone processes that could significantly benefit from

[62] EY (2019). *Regulatory technology (RegTech) brief.*
[63] IIF (2016).
[64] IIF(2016).
[65] Deloitte (2018). *The case for artificial intelligence in combating money laundering and terrorist financing.*

automation and high-tech tools. Generally, RegTech focuses on anti-fraud and market abuse identification systems, end-to-end integrity validation, risk alerts and back-office automation[66].

The inherent challenges of fraud detection processes have resulted in the development of several RegTech initiatives. Technological innovation can be used to increase the effectiveness of AML actions and enable a stronger surveillance in real-time. Advanced technologies can be employed to monitor transactions in a much faster and accurate way. By combining transaction data with a customer's personal information and historical performance, they derive a comprehensive overview of the customer's profile, evaluate fraud risk and notify the user of any suspicious activity. They can screen a vast amount of transaction data, connect it with customer profiles and identify any suspicious behavior in a quick and accurate manner. Moreover, sophisticated technological tools can provide a thorough data analysis and extract patterns that may go unnoticed under current systems.

An important focus of RegTech in this area is the development of DLT-based monitoring systems. The advantages of decentralization can realize a greater degree of transparency in transactions while a DLT-based system can be particularly useful for the monitoring of cryptocurrency platforms. Such a system can enable the real-time identification and prevention of malicious intentions. With the additional integration of smart contracts, financial institutions can apply specific capital limits and restrictions in the processing of transactions to block and report any transaction that does not comply with these rules.

8.1.6 Additional Remarks

Summarizing, Regulatory Technology can be the answer to the ever-changing regulatory environment. It can address the regulatory challenges of financial institutions by incorporating innovation and automation in compliance, reporting and risk management processes. Some of the offered RegTech opportunities are provided below[67].

[66] Toronto Centre (2017)

[67] Deloitte (2017). *The Future of Regulatory Productivity, powered by RegTech*.

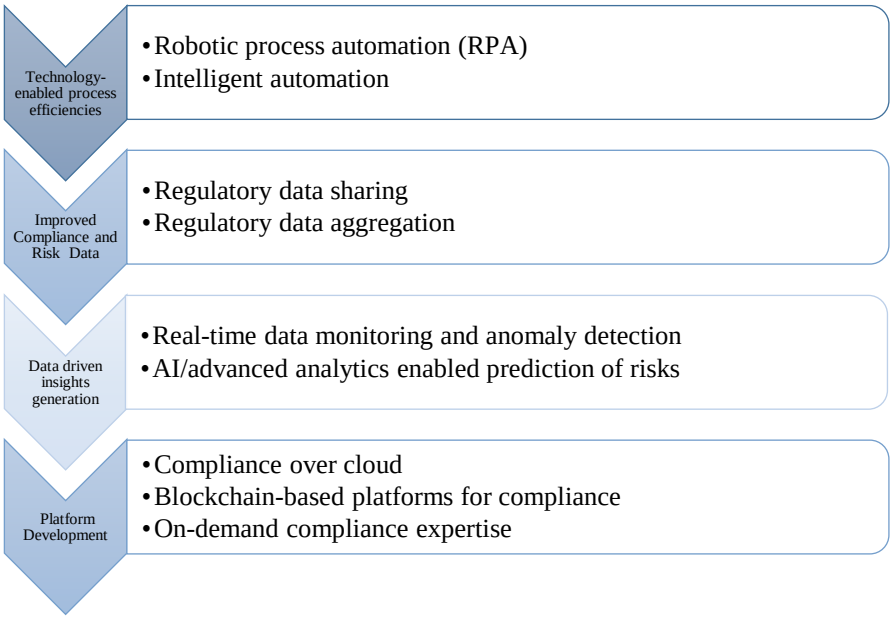


Figure 5: Opportunities for financial institutions to leverage RegTech for compliance. Source: Deloitte.

- Emerging technologies enable the automation of several manual processes, which in turn leads to increased efficiency, higher consistency and accuracy, and reduced costs. Robotic process automation (RPA) can be used for repetitive and logic-based processes whereas intelligent automation (a combination of AI and RPA) can be deployed for intuitive tasks.
- Efficient sharing and aggregation of regulatory data drives efficiency and cost savings while providing a more comprehensive overview of clients and processes. RegTech provides a secure network for the distribution of necessary data for compliance across partners and regulators. It also enables financial institutions to draw large volumes of structured and unstructured information from a diversity of sources to enhance the accuracy of compliance, reporting and risk management processes.
- RegTech provides financial institutions with data-centric procedures that can facilitate compliance and decision making. The offered solutions enable the real-time monitoring of transaction and compliance data. At the same time, they improve the detection of possible fraud cases, illegal activities or any other deviation from regulatory requirements. Furthermore, they offer advanced analytical tools for the assessment and prediction of regulatory and compliance risks. By conducting a thorough data and behavioral analysis, they assist financial entities in addressing regulatory risks and remaining compliant.

- RegTech solutions can be delivered to financial institutions in a variety of ways. They can be distributed with the use of cloud computing, which allows for a more flexible and less costly implementation, or even through blockchain technology that creates a secure and immutable database of compliance records.

8.2 Use Cases of underlying technology

According to a survey conducted by CCAF[68], most of the offered RegTech solutions deploy technologies such as cloud computing, machine learning, natural language processing, predictive data analytics and data transfer protocols (Figure 6). Regtech services are being delivered primarily with the use of cloud computing and most commonly through Software-as-service (SaaS) platforms. The development of DLT and smart contract technology is still in its early stages which explains their limited use in current applications.

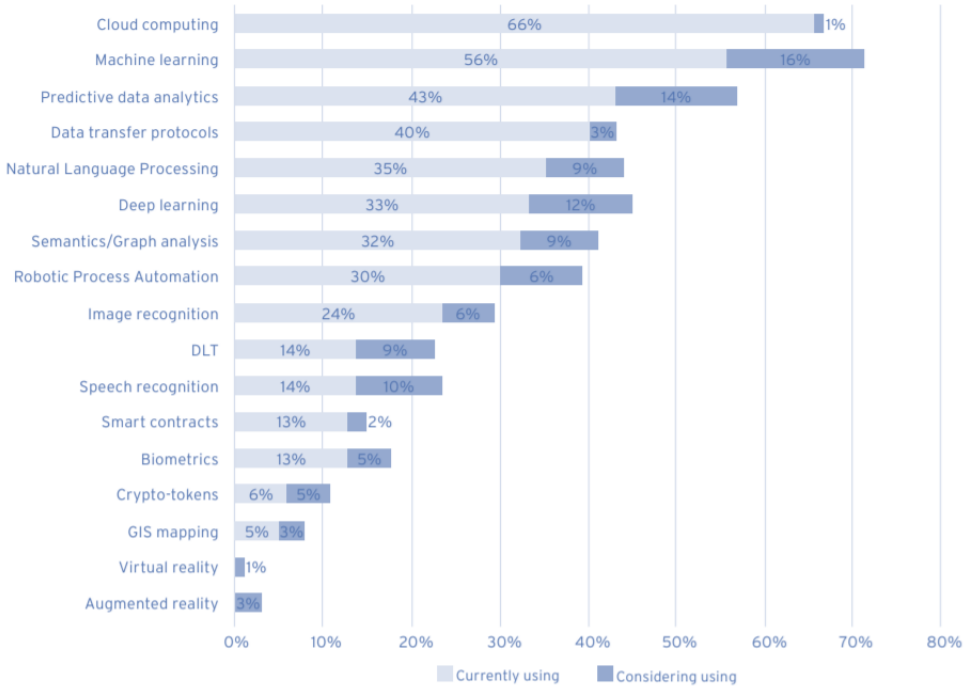


Figure 6: Technologies reportedly used by RegTech firms. Source: CCAF (2019)

[68] Schizas E., McKain G., Zhang B., Ganbold. A, Kumar P., Hussain H., Garvey K. J., Huang E., Huang A., Wang S. & Yerolemou N. (2019). *The Global RegTech Industry Benchmark Report*. Cambridge Centre for Alternative Finance (CCAF).

RegTech applications enable numerous technological tools and systems to provide automated solutions. Some indicative uses are provided below. Some of them are currently applicable whereas others may still be in the development phase or being explored as a possibility.

8.2.1 Artificial Intelligence and Machine Learning

Artificial Intelligence is utilized by the majority of RegTech solutions. Financial institutions are increasingly allocating resources in the development of AI-based systems in the "front" and "back" offices in an attempt to increase efficiency and reduce costs associated with regulatory compliance. Among the various AI branches, machine learning (ML) and natural language processing (NLP) are the ones gaining the highest momentum in RegTech applications. AI and ML technologies are used to detect underlying patterns, correlations and trends in Big Data; that is, in large volumes of structured and unstructured data, generated at high velocity by a diverse set of sources. NLP technology enables the transformation of unstructured information into structured data; that is, it converts data with no pre-defined form such as the human language (for instance, text, images, audio and other related formats) into a form that computers can understand.

Machine learning in combination with NLP enables the interpretation and analysis of unstructured data such as emails, documents, transaction metadata, social media, chat transcripts and even spoken word. Therefore, AI-based systems can be applied in a variety of cases to enhance monitoring and compliance. Ranging from the financial markets to internal processes, these systems can be deployed to monitor trader and employee behavior and ensure business conduct, transparency and compliance in financial transactions and operations.

In a few words, AI technology finds many uses in RegTech thanks to its ability understand and manage large amounts of data, detect underlying patterns and extract useful information for compliance, reporting and risk management. Some of the most prominent RegTech uses are examines below[69].

[69] Financial Stability Board (FSB) (2017). *Artificial intelligence and machine learning in financial services*

(1) KYC/AML checks and fraud detection

KYC checks are fundamental for the protection of an institution's reputation, credibility and compliance. Financial institutions currently spend a significant amount of time and resources on KYC processes. They mainly rely on manual processes to screen and filter customer data in order to detect malicious intents and high risk cases. AI technology can be leveraged to streamline and automate initial and ongoing customer due diligence processes. In particular, Machine learning and NLP can facilitate the identification and background investigation of a prospective client during onboarding procedures. They can additionally enhance the scope and frequency of later KYC controls by enabling the real-time monitoring of clients and partners. They can achieve this by:

i) Comparing information and images in identifying documents to ensure that the individual is who they claim to be.

ii) Creating risk profiles. AI-based systems can analyze multiple external sources of data to evaluate the potential risk or malicious intent of the prospective counterparty. They subsequently compute risk scores and decide whether a case needs further investigation.

iii) Updating customer risk profiles. Risk scores are periodically updated based on relevant new information, structured or unstructured, such as police registers, legal documents and negative news.

(2) Transaction monitoring and fraud detection[70]

Traditionally, transaction monitoring systems rely on a set of rules that indicates which transactions are to be considered abnormal and subsequently, should be reviewed by investigatory teams. These systems automatically filter transaction data and notify the user in case of violation of the applied rules. The compliance department is then responsible for the examination of the flagged transactions. This rule-based system commonly generates a large amount of false positive alerts, which implies increased costs, time and effort spent on investigation. After all, rules are arbitrary and rely on internal standards and beliefs.

Machine learning algorithms can be used to enhance transaction monitoring and fraud detection processes, generating significant savings in compliance procedures.

Supervised algorithms are mainly employed for the refinement of pre-existing rules of transaction monitoring systems whereas unsupervised learning can be useful in discovering new patterns.

[70] Kraft O. (2018) *Financial RegTech: Opportunities and Obstacles.* CapTech consulting.

Supervised algorithms are trained on a dataset of previously reviewed transactions. They compare applied rules and investigatory results in order to make recommendations for the improved accuracy of the process. As the training of supervised algorithms goes on, they are able to provide increasingly reliable rule refinement recommendations. On the other hand, unsupervised algorithms are given a large amount of transaction and alert data in which they search for patterns and similarities without considering rules. This is the reason why this type of machine learning is indicated for the identification of new and complex money laundering and fraud techniques.

(3) Regulatory tracking

Natural language processing (NLP) refers to the ability of machines to understand human language. NLP algorithms enable computers to "read" and process a large volume of data in a small amount of time. For this reason, NLP is increasingly deployed in regulatory compliance solutions in order to assist financial institutions to remain compliant in an ever-changing regulatory landscape.

Natural language processing can be used to keep track of regulatory changes that are relevant to the financial entity. This task is usually a labor-intensive and complex process that may lead to high compliance penalties if not done correctly. This is especially the case for institutions engaging in cross-border operations. NLP algorithms allow RegTech solutions to "read" and analyze numerous regulatory documents, recognize the elements applicable to the financial institution and alert the user of any new requirements or changes.

In combination with other AI applications, it is even possible to automatically identify and alert all the internal stakeholders influenced by a regulatory change as well as examine the possible effect on internal systems[71].

(4) Financial and Model Risk Management

The advanced ability of AI applications in extracting insights from a vast array of data can be significantly useful in financial risk management. Operations such as risk modeling, scenario analysis and forecasting can be benefited from the advanced processing and predictive power of Machine learning and AI tools. In particular, regulatory stress-testing is an increasingly complex process that can be facilitated and improved

[71] Kraft O., (2018)

with the use of machine learning. AI-based solutions can produce more accurate results and provide more transparent models.

Other possible areas of application could be back-testing and model validation, which are used to assess the performance of the applied risk models. These processes intend to verify that the internal and regulatory risk models, such as stress-testing, are operating as expected and do not deviate from their original objective[72].

8.2.2 Robotic and Intelligent process automation (RPA)/ (IPA)

Financial institutions are increasingly moving towards RPA for the automation of repetitive and rule-based tasks in order to increase productivity and redirect the freed-up resources into more strategic and value-adding processes. By replacing tedious manual tasks that do not necessarily require human judgement with software-enabled robots, financial institutions can improve efficiency and gain significant cost savings. Human errors and risks are mitigated while new opportunities arise. Machines are available full-time and can provide continuous and consistent services, enabling real-time processes. Additionally, robots create audit trails of their operation, both of self-executed and human directed tasks, which may be essential for compliance controls.

The leverage of robots can therefore result in more accurate and robust regulatory compliance and risk management processes. A further step into that direction is the combination of RPA with artificial intelligence in order to enable robotic software to develop cognitive capabilities. Intelligent process automation (IPA), as it is called, allows the automation of more intuitive tasks which may include communication, enhanced data processing and decision-making besides the execution of pre-defined tasks. This shift from simple to intelligent automation can create important opportunities for financial institutions[73].

Some indicative uses of RPA are provided below[74]:

(1) Internal and External Regulatory Reporting: Automating data collection and consolidation in order to prepare accurate reports in a small amount of time. The responsible business teams can then focus on more critical tasks and provide improved insights and higher-quality reports.

[72] FSB, (2017)
[73] EY (2019). *Regulatory technology (RegTech) brief.*
[74] Katara A. (2018). *RPA as a Compliance Enabler – Exciting Times Ahead.*

(2) KYC/AML processes: Automating customer onboarding and CDD procedures. RPA can collect related data from a variety of internal and external sources, such as regulatory or law enforcement agencies, and execute the steps included in KYC checks.

(3) Financial crime investigation: RPA/IPA can automate the examination of alerts generated by transaction and AML monitoring systems.

(4) Stress testing and Model Validation

Besides the aforementioned, there can be several applications for a virtual 24-hour workforce. The automation of high-volume, standardized workflows can benefit a variety of regulatory compliance operations and improve the accuracy of reporting and monitoring.

8.2.3 DLT and Blockchain[75]

Distributed ledger technology enables the creation of shared compliance records that are tamper-resistant, secure and commonly approved by all the network participants. Current Blockchain applications primarily focus on AML/KYC controls, transaction monitoring, and reporting.

(1) AML / KYC and Fraud Prevention

Distributed ledger technology could enable the creation of a single record shared between member institutions, containing every client's information needed for KYC and AML processes and controls. Besides the inherent benefits of security and transparency, financial institutions could be able to share the costs associated with the onboarding and monitoring of clients as well as being able to assess potential customers more accurately and quickly. Prominent examples in this category are the cases of KYC utilities and digital identities. A digital identity refers to the electronic information about an individual that is compiled and assessed through authentication methods such as passwords, smartcards or even biometrics. It can be viewed as an equivalent of ID cards but in an electronic form that can be understood and used by IT systems. The importance of digital identities is that they enable users to be in control of their data. They aim to provide each individual with the freedom to choose whether and which personal data to disclose as well as the recipients of this information. Digital identities could reduce the cases of identity theft and other

[75] Lootsma Y. (2017). *Blockchain as the Newest Regtech Application—the Opportunity to Reduce the Burden of KYC for Financial Institutions.*

data-related fraud incidents, reduce the costs of KYC processes and build trust in the business relationships between financial institutions and individuals.

Specifically, DLT and blockchain can assist in the following functions:

- *Client Identification and Verification/ Onboarding processes*

  This step commonly includes the review of personal information according to an ID card or other state documents. Blockchain provides a secure way to use and store digital identities in order to digitalize and improve this manual process. Prospective clients could upload their personal data, necessary for a KYC check, in a platform and then disclose this information to the financial institution through the use of credentials. Blockchain could ensure the secure management of digital identities and facilitate the exchange of client information between authorized financial institutions and third parties. As an example, Dutch banks offer a service called IDIN that allows their clients to use their banking ID in their interaction with other companies and institutions.

  A further step in this direction is the creation of KYC utilities supported by distributed ledger technology. As mentioned above, KYC utilities are common databases of customer information, shared between member financial institutions. In this case, once a client is verified by a bank in the network, their personal data are available to all the other participating institutions.

- *Customer screening*

  Financial institutions screen their clients for prohibited activities such as money laundering, terrorism financing, fraud, etc. in respect to lists provided by external agents and governments. In the development of a blockchain, the capability to automatically screen a client before accepting them could be included to ensure real-time monitoring. The authentication process of a customer would be halted in case of a match within the list until a thorough investigation by the responsible team within the bank would be carried out. Additionally, financial institutions could have access to a greater amount of customer information that exceeds KYC basic processes and allows for a better understanding of clients' risk profiles. For instance, they could view customers' previous suspicious or risky behavior that may change their risk assessment of these individuals.

- *Surveillance Reviews and Transaction Monitoring*

  KYC information is regularly reviewed in order to keep track of changes in client information and adjust respectively their risk profiles. A blockchain database is dynamic, which means that any update in customer information would be immediately available to all the network participants. This function

of blockchain could improve KYC efficiency and facilitate fraud detection. Because of the system's architecture, changes in the database are traceable and must be accepted by the whole network, a fact which ensures the reliability of the stored data. Transaction monitoring can also be benefitted by storing transaction data in the blockchain. Transactions could be traced with more ease and suspicious activities could be better identified.

(2) Regulatory reporting

Regulators could access directly the blockchain database to extract the required information for supervision. Blockchain technology is transparent and tamper-free which entails that the documented transactions and information are reliable and traceable. This capability would also entail a real-time reporting and monitoring capability. Therefore, such a system would enhance the efficiency of regulatory reporting and auditing and reduce the costs of financial institutions associated with complex reports.

An important consideration regarding DLT and Blockchain is that they are still immature technologies that face a variety of legal issues and technical limitations such as the limited scalability and speed of execution. Therefore, their application in RegTech is still narrow and requires further examination and technological advancements in order to fully utilize their potential.

8.2.4 Cloud Computing[76]

At present, many RegTech solutions are provided over the cloud. This essentially means that services such as datasets, computing power and software are stored and assessed over the internet. Cloud computing is characterized by high flexibility and ability to quickly distribute services over multiple users. Since resources are delivered over the internet and are not part of the user's IT infrastructure, businesses can adapt with ease into new variables while avoiding the high up-front and maintenance expenses. This feature is particularly important for regulatory compliance. Considering the ongoing regulatory changes, financial institutions could take advantage of the agility provided by cloud services to successfully adapt to new requirements and laws.

[76] Confluence (2016). *RegTech: Bringing New Meaning to Compliance and Cloud Technology in Asset Management*

One important aspect of cloud computing is that it provides to financial institutions a single, common data storage. All available information is stored in the cloud and can be assessed by every authorized user of the financial institution. This, in turn, could facilitate the distribution of information, necessary for regulatory reporting, among internal and external responsible parties.

Storing and sharing financial data is a sensitive issue that poses a challenge for financial entities. Cloud services ensure data integrity by providing increased security measures, for instance, against cyberattacks as well as data backup in case of unexpected events.

Another point of interest, is the creation of a single platform across the company. This fact may lead to increased efficiencies and improved workflows, while it may even enhance the monitoring capability of institutions by bringing transparency into application use over company devices.

All in all, the main benefit of cloud computing in RegTech is the opportunity to utilize up-to-date IT systems and shared databases in order to perform regulatory compliance in a more efficient and timely manner at a fraction of the cost for similar in-house infrastructure.

8.2.5 Application Programming Interface (API)

The significance of APIs lies in their ability to directly connect different systems and share information. APIs enable applications and devices to interact and exchange data without the need for human intermediation. This important feature constitutes APIs a fundamental part of any RegTech solution and is one of the reasons why real-time communication and monitoring is possible. At the same time, APIs may allow the integration of RegTech solutions with the existing IT-infrastructure of financial institutions, providing a convenient way to deploy emerging technologies without fully replacing the current core systems[77].

One important use case of APIs in RegTech is the automation of regulatory reporting. Instead of manually filling and submitting reports, APIs can realize the direct, possibly even real-time, exchange of data between financial institutions and regulators. By allowing regulators to have democratized, or open, access to data, APIs can facilitate the automatic processing of compliance reports[78].

[77] IIF, (2016)

[78] di Castri S., Grasser M.& Kulenkampff A. (2018). *Financial Authorities in the Era of Data Abundance: Regtech for Regulators and Suptech Solutions*.

8.2.6 Biometrics and Cryptography

Data privacy concerns are rising along with the ongoing digitalization of the economy. New data protection policies, such as GDPR, progressively put pressure on financial institutions regarding the secure management and distribution of personal data while AML regulations necessitate the use of stronger identification methods. Cryptography is fundamental in RegTech solutions whereas biometrics are increasingly viewed as an improved alternative of conventional passwords for authentication processes.

Biometrics employ a variety of physical and behavioral features to identify an individual, with the most widely known being fingerprints and facial recognition. Biometrics could provide the means for an accurate and quick identification process which in turn would be particularly useful in the fight against financial crime. The automation of customer identification and verification could significantly facilitate onboarding and KYC/AML processes.

Cryptography can be used to store and share data in a more efficient and secure manner within the financial institutions, with partners or clients and supervisors. Cryptographic technology is deployed in a variety of data sharing, management and aggregation RegTech solutions in order to protect personal data and ensure compliance with the relevant legislation. For instance, blockchain-based systems rely on cryptography for the security and integrity of transaction data.

9 Supervisory Technology

Emerging technologies are commonly associated with the generation of new challenges for supervision. The incorporation of advanced technological solutions into the operational framework of financial entities along with the creation of new products and services brought forward a number of legal implications needed to be addressed by regulators and supervisors. Issues related to data privacy, consumer protection and even the facilitation of illegal actions through new platforms have created an ambiguous attitude towards technological innovation entering the financial sector. At the same time, a movement called "SupTech" has emerged to demonstrate that technological innovation can bring substantial efficiencies in the supervision of the financial sector. Instead of viewing innovation as only a challenge, it should be considered as an opportunity to upscale the capabilities and scope of supervisory agencies in order to exercise a greater control over the financial sector. Instead of remaining reactive in the ongoing transformation of the regulated entities, supervisors should be trying to stay ahead of the game and embracing technological advances may be the best method to achieve this. After all, one of the principal problems supervisors and regulators face is the lack of resources and tools in comparison with the financial entities they supervise. Therefore, turning to emerging technologies might be unavoidable.

As it has been previously mentioned, Supervisory Technology refers to the use of technological innovation to assist supervisory agencies in their efforts. The role of supervisors and regulators is progressively becoming more complex and difficult while the public's expectations grow in response. SupTech can support supervisors address the growing and ever-changing needs of the current digitalized economy in a cost efficient manner by streamlining several key functions and processes. In particular, SupTech solutions could automate several operational and administrative tasks, digitalize regulatory and reporting procedures and enhance the management and analysis of risk and compliance data. Most importantly, technological advances could effectuate the transformation of financial supervision from reactive and backward-looking into a proactive and predictive model[79]. The current supervisory framework relies heavily on the examination of past data and onsite inspections, a fact that often leads to the late response of the competent authorities. Emerging technologies could enable supervisors to adopt a more forward-looking approach by enhancing data collection, management and analysis processes to better understand and predict various risks and trends.

[79] Toronto Centre (2017). *FinTech, RegTech and SupTech: What they mean for financial supervision.*

Currently, SupTech solutions focus on two principal areas of applications; data collection and data analytics. Considering the significance of data for supervisory agencies, any solution that could improve the quality, accuracy and quantity of data would naturally assist monitoring and decision-making processes. Data collection applications mainly pertain to reporting, data management and virtual assistance processes whereas data analytics focus on market and misconduct surveillance and micro-/macro-prudential supervision[80].

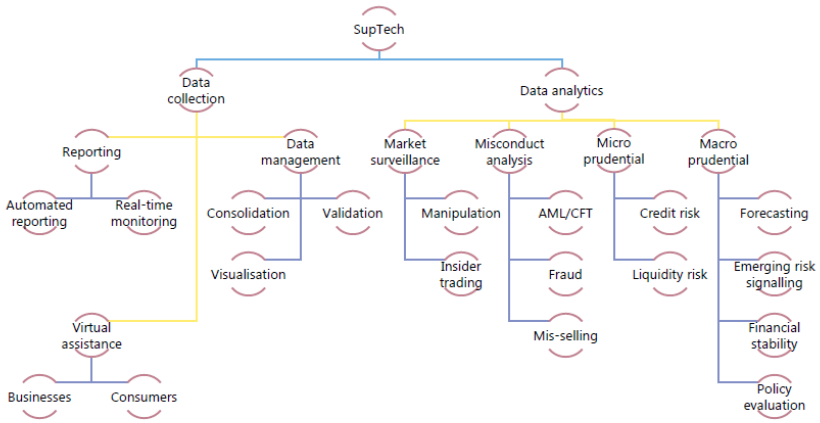


Figure 7: SupTech Applications. Source: FSI Insights.

9.1 Data Collection

Data collection refers to the necessary infrastructure and procedures that support the delivery and management of reporting data from regulated institutions and other relevant sources to supervisory agencies. This process is crucial to supervision but can be a rather complicated and costly matter for both supervisors and financial entities, especially in light of the recent regulatory and market developments. New and increased regulatory requirements along with innovative financial products and services have necessitated an increase on the scope and quality of the data required by supervisors to conduct their duty. In particular, good data are fundamental for an effective risk and compliance monitoring of financial institutions. The quality of data can be generally evaluated by three distinct characteristics; that is,

[80] Broeders D. & Prenio J. (2018). *Innovative technology in financial supervision (suptech): The experience of early users.* FSI Insights, No 9.

completeness, timeliness and accuracy[81]. Good data should be able to serve the purpose of supervisory agencies by offering an accurate and complete overview of the regulated subjects at the right time.

SupTech could substantially improve the quality and quantity of data available to supervisory agencies while increasing the overall efficiency of regulatory reporting. At present, the most common way of collecting regulatory data involves standard reporting templates that are periodically compiled and submitted by financial institutions. Reports can be electronic or paper-based and may take various forms depending on the recipient. These report templates may vary between different supervisory authorities even in the case where most of the reported data are the same. Template-based reporting has several limitations but most importantly, it could be said that it diverts the focus from the underlying data to the report or document itself. There is greater concern about the creation of report templates than the primary data of which they consist.

Template reports include mostly aggregated data that do not allow supervisors to analyze the data themselves in order to draw their own conclusions, create new indicators or even ensure that calculations are done correctly. In other words, they limit the flexibility of supervisors to interpret and analyze granular data on their own by providing predefined aggregated figures. When granular or other data are reported using a template-based system, the modifications needed to achieve this are usually very time-consuming and resource-intensive. Additionally, it is not uncommon for errors and differences to exist across various reports due to different aggregation methods and even misinterpretations in regards to the required data fields[82].

Post-crisis regulation, however, has resulted in greater demands regarding reporting data. Supervisory requirements are steadily moving away from aggregated information towards granular data along with a parallel increase in the reporting frequency. This shift towards more detailed sets of information could enhance supervisory efficiency and facilitate the harmonization of reporting standards across regulated institutions. Granular data allows for a wider set of options for supervisors, ranging from conducting their own analysis and reports to extracting useful and timely information.

Besides the implications of aggregated data, the general template-based reporting system can affect negatively the quality of data and the supervisory process. Templates usually entail time delays in data delivery, duplicate data, cumbersome validation and consolidation processes, and a general lack of

[81] Dias, D. & Staschen S. (2017). *Data Collection by Supervisors of Digital Financial Services.* Working Paper. CGAP.
[82] CGAP, (2017).

consistency and accuracy across them. In the case of regulatory changes, the respective modification of the current templates can be a further complicated and costly process for everyone involved while the substantial time needed to implement the changes may decrease supervisors' flexibility for quick modifications in reporting requirements. All of these implications translate into high operational costs for both supervisors and supervised entities[83].

However, the core of these problems remains the lack of the adequate IT infrastructure needed to cope with the fast-paced progress of the financial sector. Burdensome manual processes, legacy systems, and the lack of internal and external coordination among supervisory agencies and financial entities result in an inefficient reporting regime. Inadequate data storage, management and processing systems cause several implications and hinder the fast and accurate supervisory action. The increased regulatory and supervisory control over financial entities requires initiatives that can support large and timely amounts of granular data. Emerging technologies could facilitate this growing need of granular information in supervisory and reporting processes. Not only that, but SupTech solutions could potentially reform data collection mechanisms so as to mitigate the shortcomings of traditional supervisory approaches and focus on the data instead of the report. They could enable the automated collection of high-quality granular data that can be manipulated by supervisors to run their own analysis and create their own harmonized and consistent reports. This can subsequently enhance harmonization and comparability across financial entities and periods of time. Some of the main applications in this area focus on supervisory reporting, data management and virtual assistance.

9.1.1 Supervisory Reporting

Currently, most financial institutions report their business data via templates determined by supervisory agencies. SupTech proposes a new approach to data reporting by offering automated and real-time solutions to data collection.

9.1.1.1 Automated reporting: Data push or input approach

In this type of approach, financial institutions automatically gather and upload business data in a central database owned or accessed by the supervisory agency. This reporting information is delivered in a standardized granular form according to the respective supervisory guidelines and specifications.

[83] Toronto Centre (2018). *SupTech: Leveraging technology for better supervision.* TC Notes.

Therefore, in contrast with traditional template reports, supervisors receive the data prior to aggregation, which mitigates compliance costs and mistakes for the regulated entities, and fortifies supervisory capabilities. It also allows the standardization and harmonization of data collection.

One case example is the joint initiative of the Austrian central bank (OeNB) with regulated banks and supervisory agencies to create a single platform that revolutionizes the reporting process from a template-based model into a forward-looking data-input approach[84]. This reporting platform was established in 2014 via a buffer company named Austrian Reporting Services GmbH (AuRep) that acts as the central interface between the regulated banks and OeNB. The main objective of this initiative was to integrate and harmonize IT systems and reporting data across supervised institutions and supervisory agencies. Banks upload the requested business data in the AuRep platform, in a standard format, forming a "basic data cube". This basic data cube is afterwards transformed into several smart cubes that can be "pushed" towards OeNB. Smart cubes are created depending on the business type, for instance a smart cube for deposits or another one for loans, and they are prepared in accordance to supervisory demands[85].

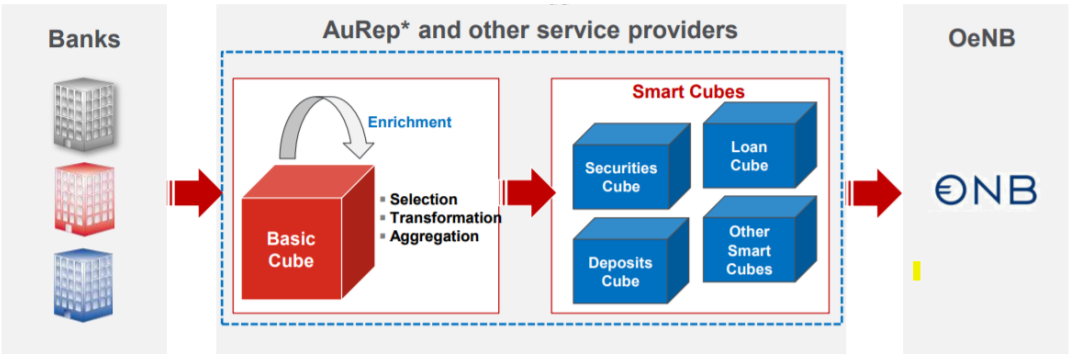


Figure 8: Austrian Reporting System. Source:EIFR.

Basic cubes include all the input data of banks that supervisors require, but it is smart cubes that are delivered to supervisors. Therefore, any ad hoc data request can be simply completed by revising smart cubes instead of the traditional case of filling several templates. After all, basic cubes are harmonized granular datasets that can be utilized and examined in a variety of ways at any time, allowing for greater

[84] Piechocki M. & Dabringhausen T. (2015*). Reforming Regulatory Reporting From Templates to Cubes.* Bearing Point.
[85] Turner J.(2016). *New Ways in Reporting for Austrian Banks.* European Institute of Financial Regulation (EIFR).

flexibility and efficiency in supervisory efforts. At the same time, the regulated entities may enjoy substantial cost-savings in the long run through the creation of economies of scale.

A similar initiative is being developed by the European Central Bank (ECB) for the standardization and harmonization of reporting data across European Banks. The Integrated Reporting Framework (IReF) seeks to integrate reporting requirements into a single, standardized approach to data collection[86]. For this purpose, an appropriate scheme for the collection, organization and distribution of reporting information has been developed to support the realization of this long-term objective. The Banks' Integrated Reporting Dictionary (BIRD) provides a set of rules and guidelines for the transformation of banks' input data, extracted by their internal IT systems, into reporting data[87]. This system essentially shifts the responsibility to correctly interpret and implement new reporting requirements from European banks to specific task forces within the National Central Banks, as shown below.

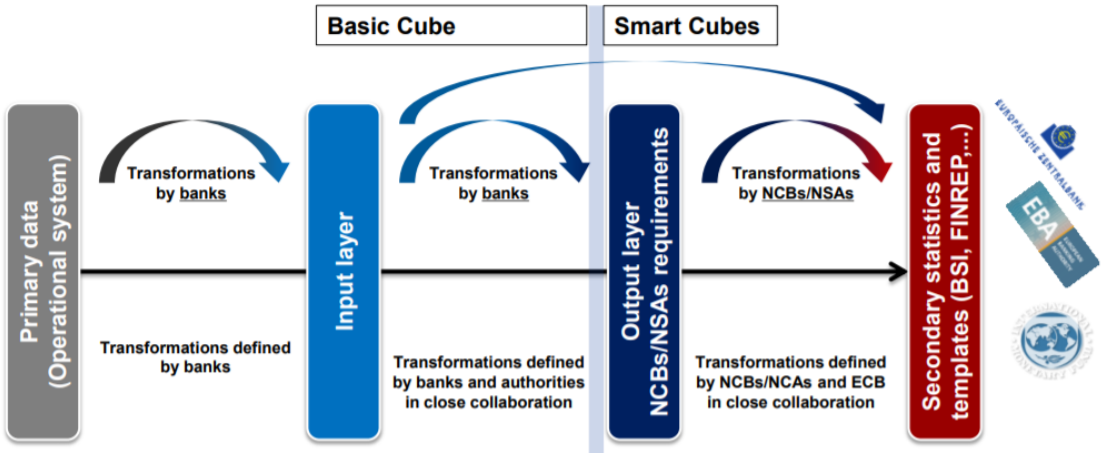


Figure 9: The data production process of the BIRD. Source: EIFR.

9.1.1.2 Automated reporting: Data pull approach

In this approach, supervisors automatically "pull" or extract raw data from the IT systems of the supervised financial entities at certain predefined periods of time or at the occurrence of trigger events and thresholds. This unprocessed granular information is only standardized at a later stage by the supervisory agencies.

One of the earliest applications of a pull-data reporting approach was adopted by the National Bank of Rwanda (BNR) back in 2017. In that case, data would be extracted automatically from the operational

[86] ECB (2020). *The ESCB's long-term approach to banks' data reporting*.
[87] ECB (2019). *What is the BIRD?*

systems of the supervised entities on a frequency that would depend on the type of data; some were to be collected every 24 hours, while others every 15 minutes. This process would be carried out through an electronic data warehouse system (EDW), created by BNR in partnership with Sunoida Solutions. This SupTech solution could be viewed as part of the financial inclusion agenda of Rwanda which, besides facilitating reporting processes, would be able to deliver relevant data of the financial inclusion progress[88]. Another case example is the Central Bank of Philippines (BSP) which partnered with RegTech for Regulators Accelerator (R^2A) to create an API-based prudential reporting system. The growth of the Philippine financial system highlighted the weaknesses of the prior reporting system. Despite the existence of some automated processes, reporting was heavily dependent on Excel-based templates and required significant time spent on manual tasks and cross-validation processes. This system was unsuitable to handle the large amount of new data and requirements produced by market developments and to provide good data to supervisors. The proposed SupTech solution utilized APIs to enable the transmission of data from the IT infrastructure of the supervised entities to supervisors without the need of human interference. The extracted unprocessed data was to be converted in encrypted XML-based files which were able to be delivered to supervisors without the need of emails or web portals. This proposed solution could support a larger amount of granular data at faster time intervals with fewer duplications. The prototype was delivered in July 2018 and the findings so far have indicated several efficiency gains and benefits for reporting processes[89].

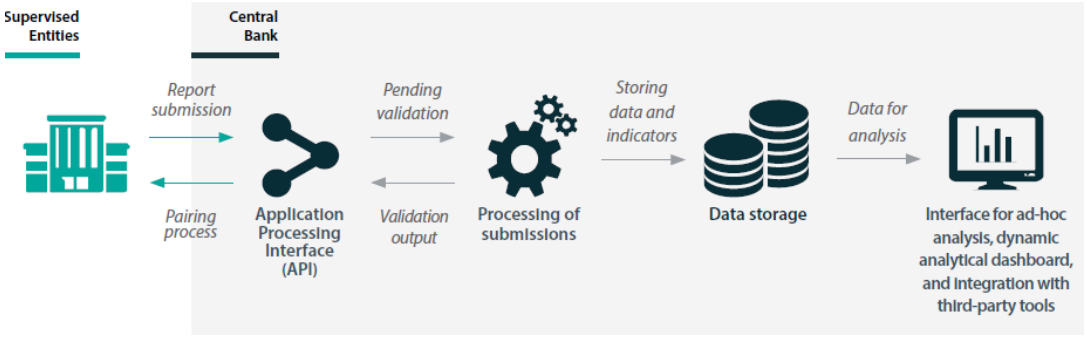


Figure 10: BSP's API-based reporting system. Source: R^2A Whitepaper.

[88] Broeders D. & Prenio J., (2018)
[89] di Castri S., Grasser M.& Kulenkampff A. (2018). *An API-based Prudential Reporting System for the Bangko Sentral ng Pilipinas (BSP): R^2A Project Retrospective and Lessons Learned.*

9.1.1.3 Real-time monitoring

A further step into the automation of reporting processes is the development of a system that allows supervisors to have real-time access to the financial institutions' business data. Unlike the data pull approach which delivers reporting data at specific time intervals, supervisors could be able to directly access the IT systems of the supervised institutions to extract the data they need at any time. In other words, these SupTech solutions could enable the real-time monitoring of financial transactions and markets. One example of this is the Market Analysis and Intelligence (MAI) system in Australia. The Australian Securities and Investments Commission (ASIC) has developed the MAI system in order to supervise the Australian primary and secondary capital markets at the same time transactions are made. Transaction data are transmitted to the MAI system in real-time, which is able to recognize any abnormalities and issue risk alerts that require further investigation[90].

9.1.2 Data management

SupTech could substantially enhance data validation, consolidation and visualization processes while at the same time provide new data management and storage platforms.

9.1.2.1 Data Validation

The assurance of data quality is of utmost importance for the supervisory process. If the initial data input is incorrect or unsuitable, the result is not going to be accurate no matter the methods and efforts applied. SupTech solutions could provide supervisors with advanced data validation processes to ensure the accuracy, completeness and timeliness of the collected data.

For supervisors, data validation processes usually entail reviewing whether[91]:

- Reports have been received within the specified deadline.
- The reporting data are complete and correct, meaning that every data field in the report has been filled out and that this information has been derived correctly and in accordance with regulation.
- Reports are consistent and plausible in comparison with peer groups, industry, past and current reporting periods.

[90] Broeders D. & Prenio J., (2018)
[91] Dias, D. & Staschen S., CGAP ,(2017)

SupTech applications focus on the automation of data validation checks to provide quick and efficient solutions to what can be otherwise a rather cumbersome process. Manual processes are usually error-prone and time-consuming while they may allow a lower quality of data. The recent surge of data volume, sources and types, has further highlighted the need for some sort of automation in the validation process.

SupTech data validation applications usually include data cleansing and data quality checks. Data cleansing refers to the identification and correction or removal of errors and unsuitable data from a database. Data cleansing tools detect data that may be incorrect, inaccurate, incomplete, corrupt or irrelevant and proceed with the necessary actions to provide a consistent and "clean" dataset to the operational systems. Data quality checks ensure the high-quality and usefulness of the dataset for the purposes of the supervisors[92]. Emerging technologies can be deployed in a variety of ways to improve validation processes. An example of that is the use of machine learning in the detection and flagging of abnormalities for a proceeding investigation by the responsible department. Examples of this area of application are the Monetary Authority of Singapore (MAS) and the OeNB.

9.1.2.2 Data Consolidation

Another significant part of SupTech solutions concerns data consolidation. SupTech can automate and improve data consolidation processes by utilizing technological innovation to aggregate and combine a vast amount of data from diverse types of sources and formats. It can enable the collection and integration of both structured and unstructured data into a single destination or dataset, creating valuable insights for supervisors. In particular, SupTech may facilitate the aggregation of micro data (e.g. institutional or individual-specific information) to form macro data. In other words, to create a bigger picture of the financial markets and sector, and answer questions regarding the level of risk exposure and interconnection of financial entities, underlying trends or correlations, to name a few.

Some case examples include the Bank of Italy (BoI) and the BNR. In the first case, BoI consolidates structured reports of suspicious transactions and unstructured press articles in order to enhance AML efforts whereas BNR combines internal and reported regulatory data to extract useful insights for regulators[93].

[92] Gogineni C. (2019).*How Automation of Data Validation Works?*
[93] Broeders D. & Prenio J., (2018)

9.1.2.3 Data visualization

Technology is commonly used by supervisors and regulators to enable the meaningful and comprehensible visualization of data. Visualization tools are deployed for a graphical or pictorial representation of data that can better convey information to supervisors. After all, images can be understood more easily than numbers. Supervisory agencies use visual information to detect hidden correlations, trends or patterns and gain valuable insights. Ranging from simple charts and graphs to interactive tools and dashboards, advanced visualization tools are used by the majority of supervisory agencies to derive and communicate information from data. Especially with the emergence of big data, visualization techniques are rising in importance as they are needed to cope with the complexity and quantity of new sources of data.

Some indicative uses of visualization tools are trend, sensitivity and scenario analysis, anomaly detection, and early warning and predictive modeling[94].

Moreover, dashboards can significantly facilitate supervisory efforts by providing a visual summary of information in almost real-time. Powerful visualization tools could improve the descriptive, diagnostic and predictive capability of dashboards, which in turn, would provide a more accurate and clear overview of the financial markets[95].

9.1.2.4 Data Storage

Data storage is becoming an important point of concern as the amount of regulatory and financial data handled by supervisors is evolving rapidly. Issues related to data privacy, the high costs of establishing and maintaining the necessary IT infrastructure, and the general implications of legacy systems cause several inefficiencies in data storage and management as well as hinder supervisors' ability to generate and use data. In some cases, a siloed approach to data storage may lead to access constraints, with only certain departments storing specific datasets. However, even centralized databases can be challenging due to their limited scalability.

Technological innovation including cloud computing and "data lakes" could ease the burden of data storage and management for supervisors. Cloud computing provides remote and shared servers that can be accessed and utilized by supervisory agencies over the internet. As it has been previously mentioned, cloud computing offers several advantages and allows for greater flexibility, storage, security and efficiency of

[94] EY (2019).
[95] di Castri S., Grasser M.& Kulenkampff A., (2018)

supervisors' data systems. The scalability of clouds enables supervisors to handle the vast amount of data requested from financial institutions.

In terms of computing power and scalability, a "data lake" is a type of data warehouse that offers advanced capabilities in comparison with conventional databases. They are storage repositories that are able to support big data; versatile, large quantities of data. Their main difference lies within their lack of data configuration. They are pools of raw data that have not been filtered or processed and can be manipulated by users in any way they want[96].

Cloud computing solutions are currently used by a variety of supervisory authorities. Examples include the UK Financial Conduct Authority (FCA) and the US Securities and Exchange Commission (SEC) which utilize cloud technology to store and process large amounts of data[97].

9.1.3 Virtual Assistance

9.1.3.1 Chatbots

Chatbots are computer programs powered by artificial intelligence that can simulate conversations with humans. Their presence in the supervisory environment is still relatively new yet they have great potential for simplifying and automating the interaction of supervisors with supervised entities and consumers. These emerging tools are designed to answer predefined or routine questions via text or voice from customers and financial entities, resulting in an improved consumer experience and automation of repetitive tasks. Valuable time and resources can therefore be redeployed in more analytical processes.

- **Chatbots can be used to address consumer complaints.**

  The central bank of the Philippines (BSP) in partnership with R2A and Sinitic has created a SupTech solution where chatbots can be deployed to receive consumer complaints, respond to simple questions and direct more complex ones to the call center of the relevant supervisory agency. Complaints can be easily made through a mobile app or SMS. A database of past complaints is then used to feed possible replies to the chatbot. At the same time, this initiative includes a processing utility that allows for the analysis and use of the data collected by chatbots for supervisory and policy-making purposes[98]. Besides the inherent benefits of automation, chatbots that collect and mine customer complaint data

[96] di Castri S., Grasser M.& Kulenkampff A., (2018)
[97] Broeders D. & Prenio J., (2018)
[98] di Castri S., Grasser M.& Kulenkampff A., (2018)

can be particularly useful for supervisors. Processing complaints can be help in tracing noncompliant or illegal behavior that may otherwise have gone unnoticed.

- **Chatbots can provide virtual assistance to supervised institutions.**

Supervisors can deploy chatbots to help financial institutions understand regulations, legislations and rulebooks. Chatbots and virtual assistants, which are a more advanced type of AI that can perform a wider set of functions, can assist supervised entities by answering their queries regarding regulatory requirements and procedures. The FCA, in their ongoing effort to incorporate emerging technology in their operation, has been developing a proof-of concept that utilizes chatbots for the response to everyday straightforward questions of financial institutions[99].

9.1.3.2 Machine readable regulation

SupTech solutions that focus on the transformation of financial regulation into a machine-readable format could bring about significant efficiencies in the sector by improving compliance and fostering innovation. SupTech could transform the way regulation is drafted, communicated and adopted, by converting the traditional regulatory text into a software that can be run by the operational systems of regulated financial entities.

Regulatory rules and requirements written in natural legal language can be programmed into codes that are automatically understood by the IT infrastructure of financial entities without the need for human intervention. The key advantage of this prospect is the accurate interpretation of the regulatory framework by the supervised institutions. Codes cannot be misinterpreted; they are clearly-stated rules that can be "read" by computers, a fact that leads to better compliance and supervision. This codified form powered by natural language processing technology, could, therefore, bridge the gap between regulatory intent and interpretation and increase the accuracy of data collection[100]. At the same time, regulatory changes in this format could be immediately communicated and assimilated by financial entities, helping them stay current and compliant with regulation. Financial institutions could save valuable time and effort that is currently spent on monitoring, interpreting and implementing regulatory changes while minimizing the probability of error.

[99] Broeders D. & Prenio J., (2018)
[100]World Government Summit & Accenture (2018). *RegTech for Regulators: Re-Architect the System for Better Regulation.*

An example of a directive in electronic form that can be "read" by both humans and computers is given below.

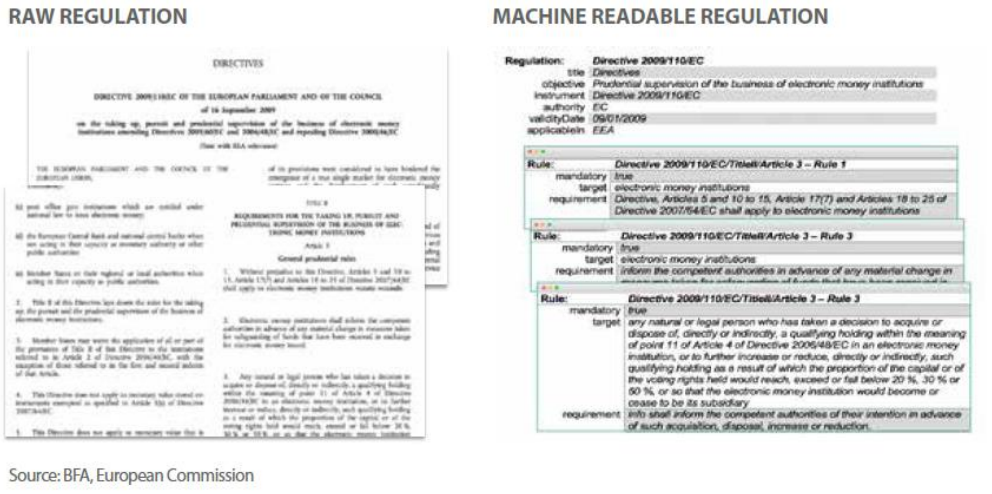


Figure 11: Machine-readable regulation. Source: R²A Whitepaper.

SupTech could interact with RegTech solutions to improve compliance and reporting. For instance, by notifying financial entities to proceed with certain actions or modify limits and requirements. By utilizing regulation written in code, supervisors and financial entities would be able to evaluate the impact of regulatory changes in a more accurate manner, and implement them more rapidly and efficiently. Moreover, industry consultations on regulatory reforms could be facilitated and regulatory complexity in general would be drastically mitigated[101].

Machine-readable regulation could go one step further to become machine-executable, for instance, with the help of smart contracts. By carrying out a sequence of steps upon the occurrence of a trigger event, compliance could be significantly improved. Once a certain condition such as the level of a risk indicator is violated, a report could be programmed to be automatically delivered to supervisors[102].

In 2017, the FCA developed a proof of concept that enabled the creation of machine-readable reporting rules that could be automatically understood and executed by computers. Machines were able to interpret these reporting rules and proceed with their fulfilment by gathering the required information from the firm's database[103].

[101] Toronto Centre, (2017)
[102] di Castri S., Grasser M.& Kulenkampff A., (2018)
[103] FCA (2018). *Call for Input: Using technology to achieve smarter regulatory reporting.*

9.2 Data analytics

The automation of data collection is only the first step for effective supervision. The main strength of innovative technologies is their processing and predictive capability. New types of data require new processing methods. As technology evolves, advanced analytical tools and models offer new opportunities for a deeper understanding of structured and unstructured data that can be used for the oversight of financial markets and entities. In the field of data analytics, SupTech solutions mainly focus on market surveillance, misconduct analysis, and micro- and macro-prudential supervision.

9.2.1 Market surveillance

Several SupTech solutions have been developed to assist market surveillance practices in the prevention and detection of financial market abuse, and the subsequent protection of investors. Market abuse may refer to any unlawful or manipulative trading behavior in financial markets that hinders market transparency and trust. In the context of MAR, market abuse encompasses practices such as "insider dealing, unlawful disclosure of inside information and market manipulation"[104].

Emerging technologies facilitate the analysis of large quantities of transaction data for the monitoring of financial markets and the identification of suspicious trading such as market manipulation and insider trading. Securities supervisors such as ASIC, FCA and SEC have incorporated advanced technologies in order to cope with the sheer amount of daily transaction data and enhance monitoring practices[105].

In 2013, ASIC launched the Market Analysis and Intelligence (MAI) platform; a SupTech solution meant to improve market surveillance by identifying anomalies in trading activity and issuing alerts for detection or investigation at the same time as the trade is executed. This system makes possible the real-time monitoring of primary and secondary Australian capital markets for the identification of suspicious behavior, such as insider trading, and market misconduct. It utilizes advanced data analytics and algorithmic trading technology in order to uncover patterns and correlations from the analysis of trade data[106].

[104]Regulation (EU) No 596/2014. Art. 7
[105] Broeders D. & Prenio J., (2018)
[106] ASIC (2013). *ASIC's next generation market surveillance system commences.*

The SEC deploys innovative technologies and big data analytics to exercise a better surveillance over the financial markets[107]. One such initiative is the Advanced Relational Trading Enforcement Metric Investigation System (ARTEMIS) which analyzes numerous trading and account holder records, along with other relevant data sources, in order to spot unusual patterns and relationships among traders. Another implemented system called Market Information Data Analytics System (MIDAS) uses big data generated by USA equity markets in order to monitor market behavior almost in real-time. The SEC is additionally developing a project called Consolidated Audit Trail (CAT) that theoretically will be able to provide a consolidated audit trail of all financial market activities, providing significant aid in market monitoring efforts. The FCA is similarly adopting innovative technologies, such as machine learning, to enhance market manipulation and insider trading detection.

9.2.2 Misconduct analysis

SupTech applications in the area of misconduct analysis involve solutions designed to facilitate supervisory action for AML/CTF, fraud and mis-selling. Digital services and innovative products have led to the emergence of new practices in financial crime that are difficult to identify without adequately advanced tools. AI and machine learning models are increasingly being used for the detection of potential fraud and mis-selling of financial products. One such initiative is the use of successive machine learning algorithms by SEC in order to identify fraud, for instance, in SEC filings[108]. This process starts from unsupervised algorithms that identify anomalies in the data, and is then followed by supervised models in order to incorporate human judgement into the analysis.

An area of particular interest is the use of innovative technologies in AML/CTF supervisory activities.

9.2.2.1 AML/CTF supervision

The role of AML/CTF supervisors is to ensure compliance of supervised financial entities with regulatory requirements for the prevention of money laundering (ML) and terrorist financing (TF). Supervisors are expected to evaluate and monitor the effectiveness of the measures undertook by financial institutions in order to prevent financial crime. They assess how well the processes dedicated to the detection and management of ML/TF risk are conducted as well as whether these abide by the requirements set out by

[107] Piwowar M.S. (2018). *Remarks at the 2018 RegTech Data Summit - Old Fields, New Corn: Innovation in Technology and Law*.
[108] Bauguess S.W. (2017).*The Role of Big Data, Machine Learning, and AI in Assessing Risks: a Regulatory Perspective.*

the relevant legislation. These controls may include off-site and on-site inspections, such as questionnaires and meetings. In the event that supervisors identify possible system weaknesses or noncompliance with AML/CTF regulation, they proceed with adequate remedial actions[109].

AML/CTF supervisors can cooperate with other national bodies for a broader oversight of the financial sector. One of these authorities are the Financial Intelligence Units (FIU), an integral part of the operational network against financial crime that may act as an intermediary between supervisors and supervised. These units serve as central agencies for the receipt of suspicious transaction reports and other relevant information filed by regulated entities, and are responsible for the analysis of this information and the dissemination of the results to relevant competent authorities[110].

Both authorities utilize a substantial amount of information in order to reach their objectives. They analyze transactional data reported by regulated entities and supplement this information with other relevant information (e.g. sanctions lists, business relationships, tax and property data) in order to provide a clear picture of the transaction. In addition to this traditional approach, supervisors are increasingly collaborating with other public authorities and private entities as well as using new unstructured data sources (e.g. social media, press releases) in AML/CTF supervision practices. This development has created new challenges for supervisors and has necessitated the shift towards advanced technological methods for the management and analysis of these large and complex datasets.

In response to this need, SupTech solutions could provide sophisticated data analytics tools such as machine learning, text mining and network analysis in order to increase supervision capacity and facilitate the integration of various data forms and sources.

For AML/CTF supervisors, SupTech applications focus on enhancing compliance assessment procedures of financial institutions. They achieve this by assisting supervisors determine the risk profile of individual financial entities[111]:

1. Risk scoring of financial entities

SupTech provides tools for the risk rating of supervised entities based on the probability of non-compliance with AML/CTF regulation. One case example is FINTRAC's (The Financial Transactions and Reports Analysis Centre of Canada) heuristic model, which ranks regulated

[109] FATF (2015). *Effective Supervision and Enforcement by AML/CFT Supervisors of the Financial Sector and Law.*
[110] FATF (2012-2019). *International Standards on Combating Money Laundering and the Financing of Terrorism & Proliferation.*Recommendation 29.
[111] Coelho R., De Simoni M. & Prenio J. (2019). *Suptech applications for anti-money laundering.* FSI Insights. No 18.

entities in accordance to a variety of risk factors including their compliance history and reporting behavior.

2. Exposure of financial entities to suspicious activities networks

In an increasingly interconnected economy network analysis is becoming a very complex task, yet it plays a central role in the AML/CTF framework. Innovative technologies could facilitate the conduction of network analysis in order to efficiently evaluate the exposure of financial institutions to networks of suspicious transactions and therefore to money-laundering risk. By employing technology, supervisors could save significant time in network analysis as well as uncover data patterns that may go unnoticed by humans. The Netherlands bank DNB has developed a SupTech application that analyzes transaction data in order to discover money laundering networks and the financial institutions that they usually target; thus, creating risk profiles for supervised entities based on this analysis.

Moreover, supervisors have the opportunity to use new forms of information, in particular, unstructured data. For instance, MAS is developing a network analysis that analyzes structured and unstructured data in suspicious transaction reports, by using NLP and ML technologies, in order to recognize relationships between parties and detect potential money laundering networks. Another example is the system that the Mexican National Banking and Securities Commission (CNBV) is developing, which creates networks of parties that may be engaging in unlawful activities by examining unstructured data for associated individuals to confirmed cases involved in money laundering.

3. Assessment of financial entities' compliance

Emerging technologies enable the analysis of large volumes of unstructured data, a fact that can substantially facilitate supervisory efforts. For example, DNB is exploring the possibility of utilizing advanced technological tools for the processing of systemic integrity risk analysis reports that banks compile and send to them. Supervisors would be able to ask straightforward questions and get an answer without reviewing all these lengthy documents. Another application in this area is CNBV's use of machine learning for the detection of unreported unusual transactions and thereby, the assessment of financial institutions' risk level. Financial institutions that appear at a large number of suspicious transactions that have not be reported may be considered high-risk and become subject to more extensive supervision.

On the other hand, SupTech solutions designed for FIUs are mainly concerned with the detection of suspicious behavior and underlying trends in financial crime in order to support their objectives and assist law enforcement authorities. SupTech applications employ a variety of automation and data analytics tools that enable supervisors to spot patterns in financial crime activity and keep up with money laundering practices. Some of these applications include[112]:

1. Identification of potential criminal networks

In this area, SupTech can improve network analysis in order to efficiently recognize networks of parties involved in suspicious transactions and subsequently detect money laundering and terrorist financing activities.

Advanced tools can be used to analyze suspicious transaction reports, submitted by a variety of financial entities, in order to identify relationships and networks of suspicious activity. There are several developing SupTech applications that focus on building networks. Examples include UIF, ROSFIN, FINTRAC and AUSTRAC.

2. Assessment of the likelihood of ML/TF activities

Another part of applications focus on the ML/TF risk assessment of individual transactions. The FIU of Finland, for example, rates suspicious transaction reports for the level of ML/TF risk in accordance with criteria such as criminal background or how many times a party has been reported. ROSFIN utilizes machine learning to recognize potential "shell" companies while UIF takes advantage of big data to supervise transactions between specific countries.

3. Detection of patterns in criminal activity

Sophisticated data analytics and visualization tools enable supervisors to identify and uncover underlying trends and patterns in financial criminal activity. They further facilitate the classification of suspicious transactions reports based on types of practices and geographical areas. For instance, some applications, such as UIF and FINTRAC, seek to classify suspicious transaction reports based on types of money laundering practices by using technologies such as text mining and machine learning. SupTech solutions could therefore help supervisors keep up with the constantly evolving money laundering techniques by providing powerful tools for quick identification and reaction to new criminal schemes.

[112] Coelho R., De Simoni M. & Prenio J. (2019). *Suptech applications for anti-money laundering.* FSI Insights. No 18.

Each country has its own unique supervisory system and thus the aforementioned applications may be adjusted or interconnected in accordance with the needs and objectives of each specific case. The principal idea is that innovative technology can facilitate AML/CTF supervisory efforts by identifying suspicious networks and activities, assessing ML/TF risk and utilizing both structured and unstructured data to derive useful information for their objectives.

9.2.3 Microprudential and Macroprudential Supervision

Prior to the financial crisis of 2008, regulators and supervisors were focused on the idiosyncratic risks of individual financial institutions to protect the economy. However, the outburst of the financial crisis highlighted the inadequacy of microprudential policies in ensuring financial market stability. Financial entities have been progressively becoming more interconnected, adding into the equation systemic risks stemming from the market and specifically from the possible failure of "big" players. Since then, regulation has evolved to complement microprudential policies with macroprudential measures in order to adequately assess the risk and uncertainty in the financial system. In order to achieve this, supervisors have to monitor both risks at an individual level and systemic risks threatening financial market stability.

SupTech solutions could improve micro- and macroprudential supervision by using innovative technologies, such as artificial intelligence, to provide sophisticated tools to supervisors for an efficient oversight and management over bank-specific and systemic risks.

In the field of **microprudential supervision**, many SupTech applications use machine learning to assess and monitor liquidity and credit risk as well as various other key risk metrics of financial institutions in a more timely and accurate manner. This in turn helps supervisors in prioritizing onsite inspections and keeping a close eye to the operations of supervised entities.

Banks provide long-term loans with funds from short-term deposits. This maturity mismatch, deriving from the very nature of banking operations, may leave banks vulnerable to liquidity problems. The inability to pay back deposits can even lead to bankruptcy, and worse yet, to an industry-wide bank run due to consumers' fear of losing their deposits. For this reason, supervisors monitor extensively the liquidity risk of financial institutions; that is, the risk that they will not be able to meet expected and unexpected future obligations.

Technological innovation can facilitate the recognition of early signs of liquidity stress. In particular, a paper by DNB developed a model predicting liquidity risk by using supervised machine learning. The authors proposed a framework in which supervised machine learning algorithms were trained to detect banks that face liquidity stress by analyzing historical transaction logs of stressed and non-stressed banks and recognizing their different characteristics[113]. A different paper by DNB explored the possibility of using neural networks for detecting potential bank runs by creating an auto-encoder that recognizes abnormal transaction flows from a real-time gross settlement system (a type of financial market infrastructure)[114]. Both models presented positive experimental results in the detection of liquidity risks. Another study used artificial neural and Bayesian networks to create a warning system about potential liquidity risk based on raw data from banks' balance sheets. The model was able to successfully identify the key risk factors and measure the liquidity risk of real bank data in an efficient and quick manner[115].

Advanced technologies could improve microprudential supervision in a variety of ways. Tools that enable the advanced analysis of complex and vast amounts of structured and unstructured data can improve several processes relevant to the assessment and monitoring of idiosyncratic risks that banks face as well as ensure compliance with regulation such as capital and liquidity requirements.

However, the main interest in this area is the potential contribution of emerging technologies to the efficient **macroprudential supervision** of the financial system. Advanced tools could potentially warn supervisors of impending financial stability risks by detecting underlying trends and correlations in the financial sector and the general economy.

Big data in particular could affect significantly macroeconomic supervision. The leverage of big data sources and tools could provide valuable insights that complement conventional statistical methods, such as surveys, and improve the aggregation, assessment and forecasting of price and inflation statistics[116]. According to surveys, there seems to be a great interest in the application of big data sources and analytics by central banks. Big data are expected to bring about significant efficiencies in macroeconomic analyses, particularly in the forecasting of economic indicators (such as inflation, housing prices, unemployment and

[113] Heuver R. and Triepels R. (2019). *Liquidity Stress Detection in the European Banking Sector.* DNB Working Paper. No. 642.
[114] Ron Triepels R., Daniels H & Heijmans R. (2017). *Anomaly Detection in Real-Time Gross Settlement Systems.*
[115] Tavana M., Abtahi A., Caprio D.D., & Poortarigh M. (2018). *An Artificial Neural Network and Bayesian Network model for liquidity risk assessment in banking*. Neurocomputing, 275, 2525-2554.
[116]Tissot, B. (2019). *The Role of Big Data and Surveys in Measuring and Predicting Inflation.* Journal of Mathematics and Statistical Science. ISSN 2411-2518, Vol.6, 9-17.

GDP) and financial stability analysis (by assessing risk indicators, bank-specific risks, financial market players' behavior and transactions, etc.)[117].

Text mining or natural language processing techniques hold great potential for enabling supervisors to make use of these new and diverse data sources that could not be analyzed previously. By processing, for example, articles, social media, written reports, contracts and other various documents, text mining could improve supervisors' understanding of the financial system and assist them in monitoring financial stability.

Textual information can be very powerful in assessing and forecasting economic conditions. New unstructured data can offer timely insights to supervisors in contrast with national economic statistics that are usually generated and issued with a lag. A study by McLaren and Shanbhogue (2011) used internet search data as indicators of economic activity. The research focused on unemployment and housing indicators, and found that data on the volume of online searches could provide valuable and timelier information compared to official statistical sources[118]. More recent researches seem to agree on the usefulness of online data sources for assessing and forecasting economic indicators. Particularly for low-income developing countries, where timely and accurate data are limited, the use of nontraditional online data sources could be beneficial in narrowing information gaps and facilitating real-time monitoring and forecasting of economic conditions[119].

A wide range of literature on the use of emerging technologies highlights the possibilities that they could unlock in macro- and micro- prudential supervision. In general, possible applications for macro-prudential monitoring are focused in four areas:

1) Identification of macro-financial risks

Innovative technologies such as machine learning can be leveraged for the detection, assessment and prediction of macro-financial risks including market volatility, financial and liquidity stress, housing prices and unemployment[120]. Several researches seem to suggest that the use of advanced technological methods

[117] Irving Fisher Committee on Central Bank Statistics (IFC) Survey (2015). *Central banks' use of and interest in "big data"*. & Wibisono O., Ari H.D., Widjanarti A., Zulen A.A., & Tissot, B. (2019). *The use of big data analytics and artificial intelligence in central banking – An overview*.
[118] McLaren, N. & Shanbhogue, R. (2011). *Using Internet Search Data as Economic Indicators*. Bank of England Quarterly Bulletin No. 2011 Q2.
[119] Narita, F., & Yin, R. (2018). *In Search of Information: Use of Google Trends' Data to Narrow Information Gaps for Low-Income Developing Countries*. IMF Working Paper No. 18/286.
[120] FSB (2017). *Artificial intelligence and machine learning in financial services.*

and new sources of data in forecasting macro-economic risk indicators may lead to more accurate and timely predictions.

The financial sector is widely exposed to the real estate sector, which constitutes housing trends and prices an important aspect of financial stability and thus macroprudential supervision. By employing big data and machine learning, BoI researchers were able to produce real-estate statistical data such as geographical demand and housing prices that were consistent with national statistical sources. They used a widely-known Italian website with housing advertisements as their database, on which they applied ML algorithms in order to delete duplicate ads of the same property. The results of this research indicated that the use of "big data" datasets, such as online granular housing data, could generate useful information and variables for the long-term economic situation of a country that could be otherwise unattainable. Most importantly, they found that online interest in a particular geographical area was a leading indicator for prices and therefore this model could be used to forecast aggregate and local price trends in Italy[121]. Another important macroeconomic factor is the expected inflation. Studies in this area seem to suggest that machine learning methods can forecast inflation more efficiently than benchmark and factor models as long as there is an abundance of data[122]. New data sources could be additionally useful in predicting inflation, as one study by BoI suggests, which developed a model that was able to derive inflation expectations from tweets[123].

2) Identification of emerging risks in the financial sector

The principal objective of macro-prudential supervision is financial stability. Several findings suggest that the use of innovative technologies, and particularly machine learning, could provide supervisors and policymakers with early signs and warnings of a financial crisis.

One academic study proposed a dynamic model that interprets emerging systemic risks and predicts financial instability using computational linguistics[124]. This model was able to detect the build-up of the financial crisis of 2008 by identifying systemic and bank-specific risks of the financial system (related to interest rates, capital requirements, mortgages, marketable securities, etc.) in a timely manner.

[121] Loberto, M., Luciani, A. & Pangallo, M. (2018).*The potential of big housing data: an application to the Italian real-estate market*. Bank of Italy. Working Paper No.1171.
[122] Medeiros, M. C., Vasconcelos, G., Veiga, A. & Zilberman, E. (2019). *Forecasting Inflation in a Data-Rich Environment: The Benefits of Machine Learning Methods.*
[123] Angelico, C., Marcucci, J., Miccoli, M. & Quarta, F. (2018) *Can We Measure Inflation Expectations Using Twitter?*
[124] Kathleen Weiss Hanley, K. W. & Hoberg, G. (2016). *Dynamic Interpretation of Emerging Systemic Risks.*

Another paper by the Bank of England (BoE) explored the potential use of machine learning for the prediction of a financial crisis. They applied machine learning algorithms on a macrofinancial dataset covering 17 countries over almost 140 years, using mainly as indicators the credit growth and slope of the yield curve. The proposed machine learning models were able to outperform logistic regressions in forecasting financial crises, a result that was similar to other related papers[125]. This research emphasized the fact that machine learning was able to generate accurate predictions despite the limited observations of financial crises in the relatively small dataset.

Besides the use of numerical data, the identification of emerging risks could be facilitated by the processing of textual data. One study found that applying supervised machine learning algorithms on textual data could substantially reduce false-positives and false-negatives of econometric models identifying and predicting financial crises[126].

These results could be crucial for macro-prudential supervision. Being able to identify the risk of potential financial distress in advance could facilitate the implementation of countercyclical policies needed to mitigate the severity of an impending crisis or avert it altogether.

3) Sentiment Analysis

There is a growing interest in literature about sentiment analysis and the correlation of financial risks or distress with textual big data. Sentiment analysis utilizes unstructured sources of data such as documents, news and social media, and can be used to identify peoples' opinions for a financial entity or the financial system. There are several researches that apply natural language processing on big data to measure sentiment both towards banks and financial markets. Specifically, there is a growing interest in the use of social media data to assess and predict financial events and information. A study by BoI uses data from the social platform Twitter to measure the sentiment of a population towards banks and relate this information with the behavior of depositors; namely, the growth of retail deposits and the perceived interconnection of banks. The study was based on the notion that social media contains important information regarding the perceived soundness of banks and the subsequent sentiment of depositors. The authors developed Twitter-based indicators of depositors' trust in banks that were able to enhance

[125] Bluwstein, K., Buckmann, M., Joseph, A., Kang, M., Kapadia, S. & Şimşek, O. (2020). *Credit growth, the yield curve and financial crisis prediction: evidence from a machine learning approach*. Bank of England. Staff Working Paper No.848

[126] Lee, S.J., Chen, M., Deininger, M. & Sicilian, M. (2019). *Identifying Financial Crises Using Machine Learning on Textual Data*. Federal Reserve Board. First Draft.

explanatory and forecasting retail funding models and detect possible spillover effects across banks. They found that negative sentiment generally corresponds to lower growth rates of retail deposits, while at the same time, this growth rate could be influenced by the sentiment towards other banks perceived as connected. In regards to this result, the authors suggest the use of Twitter data for the understanding of interconnections in the financial system and the potential "information contagion" that could lead to financial instability[127]. Another study by the University of Pavia developed a systemic risk model that combines financial market information with big data generated by the social media platform Twitter. They analyzed bank risk contagion based on financial market prices and financial tweets, which they later combined using a Bayesian approach[128]. A different sentiment analysis research deployed deep-learning techniques to combine textual data and basic event information in order to identify bank distress from the news. This research highlighted how beneficial textual data could be as a complementary information source for financial and systemic risk analytics[129].

4) Policy development and evaluation

Market expectations of future economic conditions play an important role in policy formulation and evaluation. For instance, if market expectations about a central bank's policy rate are different than monetary policy decisions, then there is a high chance of ensuing market volatility. Emerging technologies may facilitate the measurement of the publics' expectations in a variety of economic indicators. A study by the Bank of Indonesia, developed a machine learning algorithm for the automatic identification and classification of stakeholders' expectation on the policy rate, using as a data source newspaper articles[130]. Their model showcased a relatively good accuracy in comparison with the monthly expectation index generated by Bloomberg (based on surveys).

One study by Columbia University combined observational methods with machine learning and natural language processing to analyze the structure of financial regulation in the United States and develop a tool that enables public authorities and market participants to understand the impact of policies on the financial market. They developed a model to automatically score policy choices and link them to indicators of

[127] Accornero, M. & Moscatelli, M. (2018). *Listening to the buzz: social media sentiment and retail depositors' trust.* Bank of Italy. Working Paper No.1165.
[128] Cerchiello, P., Giudici, P. & Nicola, G. (2016). *Big data models of bank risk contagion.* University of Pavia. DEM Working Paper No.117
[129] Rönnqvist, S. & Sarlin, P. (2016). *Bank distress in the news: Describing events through deep learning.*
[130] Zulen, A.A., & Wibisono, O. (2018). *Measuring stakeholders' expectations for the central bank's policy rate.* IFC Bulletins chapters, 50.

financial sector performance as well as simulate the impact of policies under varying economic and political conditions[131].

Another area of interest is the possible use of new data science tools in policy targeting. A study by BoI has explored the use of machine learning to assist policy decision-making by identifying those who are most likely to behave in the way that is desired by the policymaker. By accurately targeting policy-compliers, as they were labeled, policies could be customized to increase their effectiveness[132].

[131] O'Halloran, S., Maskey, S., Mcallister, G., Park, D. & Chen, K. (2015). *Big Data and the Regulation of Financial Markets. Foundations and Applications of Big Data*.

[132] Andini, M., Ciani, E., Blasio, G.D., D'Ignazio, A., & Salvestrini, V. (2018). *Targeting with machine learning: An application to a tax rebate program in Italy*. Journal of Economic Behavior and Organization, 156, 86-102.

10 Opportunities and Benefits

10.1 SupTech

Innovative technologies could narrow the technological gap between supervised financial entities and supervisory authorities caused by market developments such as the rise of Fintech and the ongoing digitalization of the economy. The established IT infrastructure and approaches to supervision are becoming outdated in comparison with the rapid evolution of the financial sector while the current data collection and analysis tools may be inadequate in monitoring financial stability. The sheer amount of new sources of data available to supervisors as well as the rising demands in reported data, require new structures for the storage and management of information. Moreover, identifying and containing systemic risks as well as protecting consumers against emerging financial products and services demands advanced predicting models and a pro-active approach to supervision. The existing gap in innovation results, instead, in a reactive supervisory response to market developments while the lack of advanced tools available to supervisors hinders their efforts in overseeing the financial system.

SupTech promises several benefits to supervisory authorities that could help them address the emerging challenges of a globalized and digitalized financial system. At the same time, it holds great potential for efficiency gains in a variety of administrative and operational processes. Some of these opportunities are presented below[133] :

1) Ability to collect, store and manage vast amounts of data from new and diverse sources.

Supervisors have a greater possibility to extract valuable insights and relationships from richer datasets of both structured and unstructured data. In particular, unstructured data can add a new layer to supervisory processes and create new opportunities for improved monitoring. Such information is plentiful and can provide timelier insights regarding the public's sentiment and financial market trends.

2) Advanced analytical capabilities.

Sophisticated data analytics can be a powerful tool for supervision. Emerging technologies can detect patterns and relationships that may be indiscernible by other traditional models and techniques. At the same

[133] di Castri S., Grasser M.& Kulenkampff A. (2018). *Financial Authorities in the Era of Data Abundance: Regtech for Regulators and Suptech Solutions*.

time, they can achieve this in a much quicker manner. For instance, spotting money laundering practices can now be done in a matter of minutes instead of weeks or months. Furthermore, they enable the development of powerful predictive and risk models that allow the timely identification of potential threats to financial stability and therefore can enable a preemptive approach to supervision.

3) Digitalization and automation of operational and administrative tasks.

Automating repetitive or mundane processes can improve efficiency, reduce manual errors and risks and allow for a quicker supervisory action. Most importantly, SupTech solutions could free up time and resources in order to redeploy the already limited supervisory personnel into more value-added projects, expand their oversight capability and do a more thorough investigation.

4) Increased efficiency and effectiveness in supervisory oversight over the financial system.

Sophisticated data analytics and visualization tools in combination with larger and more varied datasets could improve supervisory capacity to ensure regulatory compliance, including conducting risk assessments, monitoring market conduct and transactions and protecting consumers and market stability. SupTech proposes a data-centric and risk-based approach to supervision that is more in line with the risk profile of the supervised financial entities and system. At the same time, it enables a more accurate and timely prioritization in supervisory intervention, which subsequently translates into a greater oversight of the financial system with a more efficient and targeted allocation of resources. However, the biggest driver of efficiency is the use of technology to realize what could be humanly impossible. There are not enough resources to process the enormous amount of regulatory data in a thorough and timely fashion. Technology can contribute to this onerous task.

5) Fostering innovation and healthy competition in financial markets while promoting financial inclusion.

SupTech solutions could refine compliance and licensing procedures so as to mitigate related costs and entry barriers for financial institutions. By reducing compliance costs and streamlining processes, financial institutions would be able to allocate more resources and time on their operations and growth as well as invest in innovative projects. This would be particularly significant for smaller financial entities, which face significant difficulties bearing the current compliance burden. At the same time, SupTech solutions

could lower regulatory entry expenses and reduce licensing bureaucracy in order to encourage firms entering the financial market. Facilitating the entry of new players in the financial sector promotes healthy competition and drives efficiency and growth in the market.

SupTech solutions could additionally make possible the creation of open data sources and other related services to provide valuable market insights and intelligence to financial entities in order to stimulate market innovation. All of the aforementioned initiatives, in turn, promote financial inclusion. Open datasets give opportunities to small players and new entrants to take advantage of high-quality information that would be too costly to acquire, especially compared to established competitors. Data such as customer complaints and surveys or geotagged transactional data over maps could provide valuable information for untapped markets and needs unmet or poorly served. In other words, by allowing small entities to take advantage of supervisors' knowledge, strategic business opportunities could be assessed by a wider set of players, which could subsequently spark market innovation, new products and services, and fair competition.

6) Improved cross-sector and cross-border cooperation.

The use of innovative technologies could enhance the collaboration between supervisory authorities and the integration of their respective data structures. SupTech solutions could facilitate the flow of data and intelligence between supervisory authorities both at a national and at a cross-border level.

A growing point of concern with financial innovation is the increase of cross-border transactions over FinTech platforms. Digital financial globalization creates new challenges for prudential authorities that may necessitate cross-border collaboration for a harmonized effort against financial crime and an effective monitoring of the overall financial system. The same holds true for regulated financial entities. SupTech applications could bring significant efficiencies in monitoring the financial system by seamlessly connecting supervisors with regulated entities to ensure compliance.

SupTech solutions could enable the creation of secure centralized or decentralized models to data collection and management, shared by supervisory agencies of different departments, sectors and even countries. The development of data warehouses or individual data systems that are compatible with each other could offer a richer and integrated dataset to supervisors to conduct their duties in a more efficient and coordinated manner. This type of data sharing could be particularly useful in detecting and jointly acting upon signs of

stress or abnormalities in financial markets as well as addressing challenges caused by emerging FinTech services operating across different jurisdictions such as cryptocurrencies and ICOs[134].

Besides data distribution, sharing intelligence between authorities could contribute to substantial progress in the use of advanced techniques and tools. Collaboration on research could validate results and propose improvements. For instance, innovation hubs of different countries could collaborate to decrease the time and resources needed to develop effective and secure advanced models while experimentation on different markets may offer greater insights.

10.2 RegTech

RegTech, in a similar manner, may transform the way financial institutions handle their external and internal compliance obligations. Starting from short-term efficiencies, RegTech solutions could enable the automation and digitalization of several labor-intensive, mundane manual compliance processes. By leaving tedious and straightforward tasks to machines, financial institutions could focus on more strategic processes and reallocate valuable resources to the operation and growth of their business. Besides that, having automated processes in place can be viewed as having an employee for 24 hours a day. Machines do not take breaks and they only execute orders as they have been programmed to. They can process data in a much faster way than humans and identify patterns that may be difficult to notice otherwise. This fact, in turn, could create opportunities for real-time monitoring of financial transactions as well as offer 24-hour client assistance.

In general, RegTech solutions could streamline various compliance, monitoring, reporting and risk management procedures, as well as reduce administrative costs and operational risks associated with meeting regulatory needs. Therefore, they could substantially mitigate penalties and reputational damages resulting from non-compliance with regulatory requirements while increasing the efficiency of their compliance program at a lower cost.

In the same way as SupTech, RegTech could help financial entities to adopt a more proactive approach to risk management, resulting from better and timelier insights available from big data and big data analytics. Intelligently mining datasets from various sources and formats, RegTech could provide timely information and re-arrange datasets according to specific needs. This fact could therefore enable the harmonization with

[134] Toronto Centre (2018). *SupTech: Leveraging technology for better supervision.*

different reporting and risk management systems and automate regulatory reporting for the generation of high-quality, accurate reports to supervisors.

According to a Deloitte report[135], the key characteristic that differentiates RegTech from traditional approaches is agility. Traditional software programs cover predefined needs that can only be altered via configuration or updates in the event that the user's requirements change. In the current landscape of ongoing regulatory changes along with the rapid evolution of the financial sector and financial crime practices, this inflexibility of traditional approaches can be very costly and time-consuming for financial entities.

Many RegTech firms utilize cloud computing to offer flexible solutions to financial institutions while there is also a significant interest in building self-learning programs that can adapt to changes in regulatory requirements and internal compliance needs. At the same time, RegTech solutions can be set up quickly and be easily integrated with existing IT systems, allowing financial entities to take advantage of advanced tools without needing to replace their legacy systems.

From a long-term point of view, RegTech holds great potential for promoting financial inclusion. According to the World Bank[136], "financial inclusion means that individuals and businesses have access to useful and affordable financial products and services that meet their needs – transactions, payments, savings, credit and insurance – delivered in a responsible and sustainable way."

The first step towards broader financial inclusion is the access to a bank account. According to an IFC report, one RegTech initiative that could increase access to financial services is a KYC utility[137]. Particularly in emerging and developing markets, KYC utilities could facilitate customer due diligence processes in order to improve financial inclusion and integration. Anti-Money Laundering/Combating the Financing of Terrorism (AML/ CFT) regulations have unintentionally led to banks withdrawing from smaller markets in developing and emerging economies due to difficulties in verifying prospective costumers' identity and transaction records. Banks prefer to terminate relationships with customers, firms or local banks if a KYC process is too costly and complex. In the event that they cannot easily identify prospective clients and assess their associated risks, the rewards may not be worth the risk of heavy penalties resulting from non-compliance. This implication has caused the substantial limitation of financial

[135] Deloitte (2016). *RegTech is the new FinTech: How agile regulatory technology is helping firms better understand and manage their risks.*
[136] The World Bank (2018). *Financial Inclusion.*
[137] Adl, M. & Haworth W.C. (2018). *How a Know-Your-Customer Utility Could Increase Access to Financial Services in Emerging Markets*.

services that are available to poorer countries, where in fact, they are most needed for their integration in the global financial system and the opportunity to get out of poverty.

In few words, as the report highlighted "Customer Due Diligence requirements are disproportionately affecting small banks, small firms and low-income individuals in emerging and developing economies". KYC utilities could be the answer to this problem by providing a cost-efficient and secure solution to customer onboarding and therefore encouraging financial institutions to expand their operations in these markets. KYC utilities can be jointly developed by governments, financial institutions and private firms so as to share customer information and intelligence. An example of this initiative is the prototype that Egypt is developing in order to promote financial inclusion. Currently an electronic KYC, on the way to becoming blockchain-based, this project seeks to enable citizens to open bank accounts electronically without visiting the bank[138].

However, the impact of increasing compliance costs expands well beyond developing countries. Financial institutions all around the world are struggling to keep up with new regulations, which results in small firms closing their doors and big firms becoming bigger. RegTech could reduce compliance costs and thus create a level playing field for all the participants of the financial system.

The possibilities for financial institutions, regulators and supervisors are endless. As it can be seen by both SupTech and RegTech applications, innovative technologies could revolutionize the financial regulatory landscape. These emerging technologies, including artificial intelligence and blockchain, are like the internet some years ago. What is now considered a given fact, was at one point groundbreaking.

In some years, based on the evolution of the economy and financial markets, adopting emerging technologies may not be an option anymore. The increased and complex implications caused by technological evolution and societal needs could possibly only be addressed by embracing innovation. The underlying shift of the financial sector towards digitalization and data-centric approaches may leave no choice to financial institutions and supervisors regarding the adoption of technology in their regulatory, reporting and monitoring operations. The cost-efficiency of automated compliance and reporting processes may put in a disadvantageous position those that hold on to traditional manual processes. This is because the ever-changing regulatory and financial environment as well as the amount of information that is needed

[138] Hamilton, A. (2020). *Central Bank of Egypt pilots eKYC solution for financial inclusion.*

today for the monitoring of regulatory compliance state can be achieved seamlessly by IT systems. The same task would put a lot of pressure on the human staff and would result in high operational costs.

Furthermore, big data entails increasing regulatory challenges for financial entities that can be addressed only by the use of technology. The large volume of data that is currently available cannot be utilized without technological applications while the management of sensitive data is subject to increasing regulatory scrutiny. At the same time, data means nothing without adequate tools to transform them into information. Innovative technologies can extract valuable information that can then be used for enhanced risk management and compliance models. For supervisors, the significance of such a task is even more prominent since efficient and effective supervision is based on information derived from the market and its participants. All in all, innovative technologies can bring about significant efficiencies in a plethora of situations. However, they also entail several challenges and risks that should be addressed before their mass adoption.

11 Risks and Barriers

Technology is a double-edged sword. Machines are continuously becoming more capable and can even surpass humans in carrying out certain tasks in terms of both speed and accuracy. In fact, machines have been progressively replacing humans in a variety of processes. One may wonder where this situation leads. Are we relying too much on machines?

There has been an ongoing controversy surrounding the use of emerging technologies in core financial processes. Aside from ethical issues, there are several significant risks in adopting innovation and there are no definite answers due to the early stages of many of the proposed technologies.

11.1 Risks

11.1.1 Concentration and Systemic Risk

RegTech and SupTech promise to connect different market participants and supervisors to enhance efficiency. Such an interconnected system, however, could be a risk on its own. Operational failures of single points could influence the whole system while the concentration of power in the hands of the main technology providers could create a sort of monopoly[139]. Providers of innovative technologies would then become entities of systemic importance for financial markets, capable of jeopardizing financial stability. RegTech and SupTech solutions can help only if they are correctly developed. Errors in the system can be substantially more problematic than possible individual human mistakes in the absence of these solutions, due to the aforementioned systemic significance. Even the smallest error can cause great implications and systematic compliance failures that hinder correct decision making. This is particularly the case when RegTech solutions are provided to various financial institutions as "one size fits all" since tailored options are quite expensive. In the event of open-source solutions or simply of single RegTech products that are offered to numerous users, the systemic risk of possible operational mistakes in this single product is even higher[140]. An additional consideration is the event when financial institutions detect mistakes of their implemented programs but remain silent out of concern for possible claims against them and a tarnished reputation. They may fix the error but leave previous results unmodified or correct the system in delay.

[139] Gasparri, G., (2019)
[140] Colaert, V. (2018). *RegTech as a Response to Regulatory Expansion in the Financial Sector*.

11.1.2 Operational and Reputational Risk

All of the promised benefits of RegTech and SupTech can only be valid on the basis of system accuracy. As the complexity of a system rises, so does the possibility of an error.

Even the smallest mistake in the code or a bug in the system may cause the malfunction of RegTech solutions. Misunderstandings between software developers and users on the desired final product or even simple human errors in the development phase of the solution can lead to inadequate or malfunctioned systems. Besides this fact, even algorithms can fail. False alarms and inaccurate correlations and results caused by poorly made algorithms or low-quality data can pose severe reputational and operational risks, especially in the case of supervisors. Flawed solutions or unsuitable models for the specific needs of the user can have severe implications and reduce the effectiveness of risk management processes[141].

One important consideration is the possibility of hidden human bias in algorithm models that renders their results and decisions unfair. Computers may be objective, but the humans developing the programs carry their own biases and assumptions. Therefore, even unintentionally, developers' beliefs are embedded in the models they create. In the case of machine learning programs, this problem is even more serious due to the "black box" problem, since it is almost impossible to check whether the output was biased and which factor was responsible for that. According to a survey[142], examples of real-word algorithmic unfairness are plenty and this bias in AI and robotic models may be caused either by the coded algorithms or the datasets upon which they are trained.

Furthermore, it should be noted that the increased use of digital data and programs instead of physical documents and paper-based processes renders users more vulnerable to operational risks and system failures due to, for instance, electricity disruption, software malfunction or even cyber-attacks. External and internal factors beyond one's control may disrupt business operations, delete or alter huge amounts of data and create irrevocable damage.

11.1.3 Excessive reliance on machines and the "black box" problem

One important implication of the adoption of emerging technologies is that reliance on machines may cloud human judgement. Not every problem is visible in the dataset or can be measured quantitatively. Fully

[141] Toronto Centre, (2018)

[142] Mehrabi, N., Morstatter, F., Saxena, N., Lerman, K., & Galstyan, A. (2019). *A Survey on Bias and Fairness in Machine Learning*

trusting data analytics and not considering additional factors or contradictory information may weaken supervisory action, which requires the consideration of both quantitative and qualitative information. Over-reliance on data analytics could cause supervisors to become insensitive to qualitative factors not captured by SupTech solutions[143].

Moreover, IT systems can be biased or inaccurate. Yet sometimes people tend to disregard this fact and believe that machine-generated results are always correct, raising what is called an "automation bias". This automation bias may cause erroneous decision-making and diminish the sense of individual responsibility. It may lead financial institutions and supervisors alike to underestimate or overestimate risks, undertake overly risky decisions and follow damaging policies, all of which are justified on the basis of computer-generated results[144].

The most important implication, however, is that users may lose control of machines. AI models surpass traditional models in terms of processing and predictive power but they lack in one key aspect; that is, their explainability. Machine learning models, and specifically deep learning and neural networks, are opaque. The "black box" problem[145], as it is called, refers to the difficulty or incapability to understand how machine learning models generate their results. The human brain does not function the way that these models work and it is impossible to "look inside" to comprehend why they do certain things, which methods they follow and which data they use to reach conclusions and produce outcomes.

This causes serious issues of trust. How can users check whether decisions and outcomes produced by these models are correct? Or if their development and training were satisfactory? How can we give control to something that we cannot understand?

Currently, users cannot explain the results of deep learning models. Therefore, they cannot make changes to improve or fix them and they cannot be sure of their produced results. Decisions with higher stakes require full transparency of the followed process to reach a result. Otherwise, they may lead to erroneous and biased decisions, overlooked vulnerabilities and unsuitable risk models as well as reputational and legal issues[146].The stakes are even higher for supervisors, who risk losing their accountability due to lack of

[143] Toronto Centre, (2018)
[144] Panisi, F., & Perrone, A. (2018). *'Systems So Perfect That No One Will Need to be Good'? RegTech and the 'Human Factor'*.
[145] Zednik, C. (2019). *Solving the Black Box Problem: A Normative Framework for Explainable Artificial Intelligence.*
[146] Albinson, N., Thomas, C., Rohrig, M. & Chu, Y. (2019**).** *Managing the black box of artificial intelligence (AI): Future of risk in the digital era.* Deloitte Report.

transparency and incorrect judgement. However, it should be noted that there is an ongoing effort in addressing the black box problem, for instance, by developing explainable AI models[147].

11.1.4 Cybersecurity, third-party risk and data privacy

Cybersecurity is one of the primary reasons for the existing hesitance in adopting innovative technologies. Despite the strong measures taken by financial institutions and supervisors for data security, the evolving sophistication and frequency of cyber-attacks pose a real challenge to the financial sector. Complete data protection is almost impossible and this is apparent by the various real-world cases of malicious hacking attempts. On top of that, the ongoing digital and data-centric transformation of the financial system makes it even more vulnerable to cyber-attacks, security breaches and thefts[148]. This is because the increasing reliance on IT systems, the higher interconnection between financial market participants and the shift towards automated processes increase the exposure of the system to third-party risks. When data transfers over the internet or is handled by outsourced parties, such as cloud providers, many data security issues can occur; the risk of data being stolen, deleted, or altered is even higher as is the possible interruption of users' activities[149].

The same holds true for the risks associated with third parties having access to or handling sensitive data and systems. For example, interconnected reporting systems between financial institutions and supervisors have to take into consideration various possible data misuses.

Moreover, several legal issues with data collection and management may arise. In the past few years, data privacy regulation has been strengthened in accordance with the shift towards digital services, and users are becoming increasingly aware of their personal identity over the cyberspace. The collection and processing of personal data is allowed as long as the purpose and method used by the financial institution abides by regulatory norms. Regulation specifies legitimate reasons for the use of sensitive data but controls and restricts the extent to which these data can be collected and processed[150].

Noncompliance with data privacy rules can inflict severe reputational damage and legal penalties on financial institutions. Data mining techniques could possibly create several implications, especially when they concern unorthodox data sources such as social media. Furthermore, customers' sensitive information

[147] Zednik, C., (2019)
[148] Arner D. W., Barberis J. & Buckley R. P. (2017). *FinTech, RegTech, and the Reconceptualization of Financial Regulation*.
[149] Toronto Centre, (2018)
[150] Colaert, V. (2018).

circulating over the internet and being analyzed by various parties for their own objectives raises multiple questions in regards to how legal this process can be. The possibility of hacking attacks on data storage and management systems as well as the possible unauthorized use of clients' personal data entails various privacy and data protection issues. All in all, the potential legal and reputational implications because of intended or unintended violation of data privacy regulation pose a significant risk to RegTech/SupTech solutions[151].

11.1.5 Machines in the framework of law

One important consideration of adopting dynamic AI models and decentralized solutions is whether the dependence on algorithms may violate the core principals of law. Law allows for flexibility but machines are accurate and act upon the data inserted and generated.

The use of algorithms in decision making could lead to potential discrimination against individuals if not controlled adequately. Making decisions that affect the legal sphere of others by relying only on the results of algorithmic models raises serious concerns about the legality of the process in regards to traditional law principles.

In particular, advanced and fully automated functions such as deep learning could prove to be dangerous due to the "black box" problem. As has been aforementioned, deep learning models are self-learning, dynamic models that cannot be explained by humans. The thought that supervisors could simply accept decisions taken by these programs without understanding whether the rules applied by the machine for this decision abide by the law, could be frightening. At the same time, supervisors' discretion and flexibility could be replaced by machines' accurate data-based results, a fact that may violate the principle of equality of arms. The lack of human judgment and qualitative factors taken into consideration lead to incomplete investigations. Most importantly, the accused parties cannot adequately defend themselves against "accurate" machine-produced results since they do not have access to the evidence generated by machines against them. On that note, the rules created by machines that are unknown and variable are contrary to the fundamental principle of legal certainty. The relevant authorities should be able to explain to the concerned parties the reason why a certain decision was taken and how it abides by the law[152]. For instance, many times human bias is incorporated in AI models while the inputted data may be unfit or of lower-quality.

[151] Broeders D. & Prenio J. (2018).
[152] Gasparri, G., (2019)

Not to mention, the possible technical errors. Some of these examples may seem extreme but the possibility of such misuse of advanced technologies by both financial institutions and supervisory agencies should be considered.

In the case of blockchain and smart contracts, the main legal consideration is their immutability. One of the main characteristics of these technologies is that they cannot be modified once they are recorded. This can be particularly troubling for smart contracts since conditions can change and influence the legality of a contract. Changes in contracts may be required, for example, when there are modifications in the regulatory framework or in the business environment, which constitute the contract unsuitable or nullified. Law takes into consideration the uncertainty of the future but smart contracts fail to adapt to unpredictable events. Thus, there may be cases in which smart contracts bind the participants to actions that are no longer legally recognized.

12 Barriers

In the early stages of RegTech, the main barrier to adoption was uncertainty. Uncertainty over regulation, support from legal authorities and the credibility of innovative technology. Shortly after the introduction of the term, FCA issued a call for input on supporting the adoption of RegTech. The main challenges reported were the following[153]:

- **Regulatory uncertainty.**

  Respondents were cautious about adopting new technologies whose effects were still unknown and regulation was unclear. Financial institutions needed assurance that RegTech solutions were accepted and encouraged by regulatory and supervisory authorities.

- **Credibility of innovative technologies.**

  At the time, a deterrent factor of embracing innovation was the still immature phase of innovative technology which made investing in RegTech a highly risky decision. There was also no widely used example of such IT solutions.

- **Legal restrictions and lack of standardization regarding data aggregation and analysis.**

  The collection, sharing and processing of data was heavily regulated by legislative authorities. At the same time, there were no uniform standards for data storage, reporting and analysis. This complex regulatory landscape surrounding data was reported to be an important factor obstructing the development of RegTech.

- **Legacy systems of financial institutions.**

  The respondents preferred to continue investing in their maintenance instead of developing new IT solutions that could not be easily integrated with their current infrastructure.

- **Timing.**

  Respondents were additionally reluctant towards developing new RegTech solutions due to the timing of ongoing regulatory changes and the respective time needed for IT system changes. Many respondents felt that “the regulatory deadlines for implementing new IT solutions were short and focused on incremental improvement, complicating large-scale overhauls of IT systems”.

[153] FCA (2016).*Call for input on supporting the development and adopters of RegTech*. Feedback Statement FS16/4.

Since then, significant progress has been made into developing the RegTech and SupTech field while ongoing developments are breaking down inhibiting factors towards the adoption of innovative technologies. Yet some barriers still remain in varying levels.

12.1.1 Lack of standards across the industry

One important challenge remains the lack of standards in RegTech and SupTech solutions, processes and regulations across the sector.

The market is overflowing with RegTech products and vendors, yet none of these solutions "are aligned around a common model or infrastructure"[154]. This inhibits the widespread adoption of innovative technologies since there is a lot of complexity and "noise" surrounding this emerging field. Many financial institutions are confused over which compliance solution to choose while they may not be keen on combining different kinds of IT programs and proliferating their already many applications. Therefore, an attempt towards the harmonization of the design of RegTech and SupTech solutions across the financial industry may be needed. This could be achieved, for instance, by creating a set of guidelines and standards for the product development phase of innovative technology solutions as well as the legal requirements that it is desired to uphold[155].

According to ROFIEG's recommendations towards the European Commission[156], the joint implementation of a comprehensive agenda between EU and global authorities regarding the implementation of RegTech and SupTech solutions is necessary for the development of these fields. A set of common standards across these solutions is currently unavailable while experimentation and adoption of innovative technologies is done on an individual and uncoordinated manner by financial institutions and supervisors. Different jurisdictions have different supervisory expectations and capacities for addressing innovative technologies. This is particularly challenging for institutions operating across borders where the lack of harmonization of the financial system in the approach towards RegTech solutions poses significant challenges in implementing innovative solutions in all of their businesses.

However, the core problem remains the lack of a common legal language. The digital communication among market participants and supervisors requires a common financial and legal dictionary that helps IT

[154] Butler T., O'Brien L. (2019) *Understanding RegTech for Digital Regulatory Compliance*.
[155] Nizan G. P. (2018) *Regtech, Compliance and Technology Judgement Rule*.
[156] ROFIEG (2019). *30 Recommendations on Regulation, Innovation and Finance.*

systems interact, or in other words, enables the interoperability between digital products and services. A "Tower of Babel" has been developed in the financial sector due to the great variety in terminology used to describe very similar things. This lack of homogeneity in terms and concepts is a problem that can even exist within the same financial institution across its different departments. RegTech and SupTech solutions are not the panacea to the inconsistencies and confusion across the financial industry. If the fundamental problem of heterogeneity in legal language and taxonomy cannot be addressed, these solutions will simply end up digitizing the current framework and complicate things even more. According to ROFIEG, there is a need for "digital standards-based common classifications of actors, services, products, and processes in the financial sector for use by financial service provides, market participants, regulators, supervisors and standard setters" [157].

12.1.2 Technical Issues

12.1.2.1 Legacy systems

The integration of RegTech and SupTech solutions with legacy systems can prove to be a very challenging and costly matter. Connecting new and sometimes complex software to the existing IT infrastructure can require substantial amounts of money and time. At the same time, there can be serious issues of incompatibility that do not allow the use of old programs and datasets. Therefore, these advanced solutions often require significant amounts of investment that not every market participant can afford. For smaller financial institutions and less financially powerful supervisory agencies, such an amount can be hard to bear.

Another important consideration is when RegTech and SupTech solutions are incompatible with the IT systems of other concerned or connected parties. For instance, legacy systems and traditional processes of supervisory agencies could create several issues to financial institutions adopting innovative regulatory products and vice versa[158].

12.1.2.2 Computational capacity

Some other implications of the traditional IT infrastructure is the possible lack of storage capacity and necessary computing power to implement and maintain advanced technological solutions. For instance,

[157] ROFIEG (2019)
[158] Toronto Centre, (2018)

limited computational capacity may hinder the development of effective machine learning models due to the restrictive amount of training data that such an IT system can support[159]. Especially in the case of low-income countries and institutions, they may not have the institutional and technological capacity to support RegTech and SupTech initiatives. Often they must first optimize their existing processes and structures before even considering such advanced tools[160].

12.1.2.3 Data quality issues

The effectiveness of SupTech and RegTech solutions depends on data quality. However, collecting complete, high-quality data is a very challenging task in reality. Big data can often be of lower quality and possibly unreliable, especially in the case of unconventional sources such as social media. This is because digital data can be invalid or even easily be manipulated by third parties that want to influence the algorithmic outputs of supervisors and financial institutions.

At the same time, datasets used as input for the development of machine learning models and other data analytics can be inadequate in size and quality to have the desired result. One last important consideration is that the number of personal data that can be used for analysis is often limited due to data privacy laws[161].

12.1.2.4 State of technology

Emerging technologies come with their own problems. Not every technological innovation is mature enough to be safely implemented and offer competitive advantage against traditional systems. For instance, there are still issues to be solved in regards to the explainability of deep learning models and the lack of transparency, even though there are several attempts to address them. As it has been mentioned, a significant risk of RegTech and SupTech is the "black-box" problem of certain technologies. Due to the severity of possible implications, many market participants and supervisors may choose to avoid embracing something that they don't understand, or otherwise, they may simply utilize such systems as an additional insight on their decisions.

At the same time, some of the deployed technologies are still in their early stages and encounter several operational shortcomings. Namely, the use of blockchain technology and smart contracts is widely explored

[159] Broeders D. & Prenio J., (2018)
[160] di Castri S., Grasser M.& Kulenkampff A., (2018)
[161] Toronto Centre, (2018)

as a concept, yet technical limitations obstruct their widespread adoption[162]. One of the biggest issues remains the limited scalability of these technologies. The blockchain network and the performance of smart contracts fall short on the speed of transactional execution related to other legacy transaction networks due to the fact that all the transactions are recorded, verified and stored in every node of the network, which weighs down the speed of the system. The complexity of the whole process further delays the execution of smart contracts and these lags become even more evident in the case of large volumes of transactions. This fact results in greater costs and inconveniences for the participants. Therefore, until the performance of blockchain and smart contracts can become competitive in terms of speed and cost-efficiency without sacrificing on their decentralization nature, they have a limited appeal in the market.

12.1.3 Mentality and Organizational Resistance

The adoption of high tech solutions can bring significant changes in the existing business model of financial institutions and authorities, and transform for the better compliance and surveillance of the financial system. However, most people are reluctant to change, especially when the outcome is uncertain. Managers may feel that RegTech and SupTech solutions can be a very expensive and complicated procedure with implications that may not be worth the effort and allocated resources. Most importantly, they may face difficulties in understanding and implementing innovative technologies correctly. This lack of understanding is one of the main obstacles blocking the interest and investment in these solutions. For entities that do not have a great affinity for technology, it may take years for the adoption of innovative applications. One supervisory agency reported, for example, that it "may take between five and 10 years for SupTech solutions to be fully embraced and integrated into the organization"[163]. Usually, people are hesitant or suspicious to adopt measures they are unfamiliar with, and prefer to stick with traditional processes with comprehensible and predictable outputs. This is particularly true when there are few wide-spread RegTech and SupTech solutions on the market.

Even in the event that there is significant interest in these solutions, bureaucratic processes can lead to the abandonment of the project. Generally, large institutions may not be interested in large changes in their systems and the associated resource reallocations since those entail several implications considering the

[162] Carlo R.W. De Meijer (2020). *Remaining challenges of blockchain adoption and possible solutions.*

[163] Broeders D. & Prenio J., (2018)

scale of their business. Getting approval for advanced technological applications can be a very complicated and time-consuming procedure while internal politics may predefine the outcome. Most importantly, internal opposition is expected when the proposed solutions can lead to lay-offs. RegTech and SupTech promise increased efficiency at a lower cost through automation and digitalization; this entails that several work positions will not be needed anymore. This resistance from within can make RegTech and SupTech solutions "politically as well as economically costly"[164].

For supervisory agencies, an important challenge is additionally the capacity and attitude of supervised institutions towards SupTech initiatives. In the case of reporting, for instance, financial institutions would have to upgrade their IT systems and processes to complement the SupTech solution of supervisors. Unwillingness to do so would result in a dysfunctional system and significant delays in the implementation of new measures and structures. It should be noted, however, that this stance of supervised entities could be due to "legitimate concerns about intrusion of privacy, government overreach, or abuse of authority" while expensive legacy systems can be another important factor[165].

12.1.4 Resources

12.1.4.1 Financial resources

Budget constraints are often the inhibiting factor for the adoption of RegTech/SupTech solutions. RegTech promises substantial cost savings to compliance and reporting by streamlining and automating processes as well as reducing non-compliance costs and penalties. However, the high upfront capital expenditure and maintenance expenses for the development or purchase of such products drive away many market participants, especially smaller institutions that may lack the needed expertise and financial resources[166]. For supervisors, getting approval for government funding can be even more challenging.

12.1.4.2 Human capital

Since this industry is still relatively young, there is usually a need for both internal and external expertise for providing customized applications suitable for the specific requirements of each entity[167]. RegTech/SupTech initiatives require a vast array of specialized personnel both for the initial creation of the

[164] di Castri S., Grasser M.& Kulenkampff A., (2018)
[165] di Castri S., Grasser M.& Kulenkampff A., (2018)
[166] Colaert, V., (2018)
[167] Toronto Centre, (2018)

solution and the later upgrade and maintenance of the system. Supervisory agencies and financial institutions may face several challenges in finding the right people to add in their in-house expertise as well as external firms that meet their needs. There is usually a lack of data scientists and software developers that are experts in innovative technologies or/and are knowledgeable enough in compliance and supervision. In the event that financial institutions/supervisors do have such individuals, it may be instead increasingly difficult to retain them due to their high demand. Without the right in-house expertise, it is additionally difficult to find the RegTech/SupTech product that is best suited to their needs.

According to supervisory agencies, there is a need for talented individuals that have knowledge in three areas; data science, computer science and supervision. However, it is very difficult to find people with a background in all three areas while experts with significant experience are hard to attract. With such a limited amount of qualified people, SupTech solutions are often difficult to develop and maintain while continuity issues may arise when the few key talents supporting SupTech solutions decide to halt their relationship with the agency[168].

[168] Broeders D. & Prenio J., (2018)

13 The need for RegTech/SupTech and initiatives for their adoption

The financial crisis of 2008 was a crucial point in the regulatory approach towards innovation. The pre-crisis exuberance about financial innovation was replaced by suspicion and strict countermeasures. However, the growing interest in the use of innovative technologies for improved efficiency and financial inclusion as well as the inability to cope with emerging needs equipped only with legacy systems, has put pressure on regulators to support innovation. The evolution of industries such as FinTech demands regulators' attention in a variety of legal implications and barriers that have to be addressed.

There are various opinions on the appropriate regulatory approach towards innovation[169]. Some jurisdictions prefer doing nothing on the matter until it is necessary. They may choose to not regulate innovative products either by having a permissive stance towards new technologies or simply by not interfering with the industry. While this deregulatory approach may have positive results in some cases, it may also unintentionally stifle innovation and ignore emerging risks by making FinTech-related firms comply with traditional regulatory requirements that may be unsuitable for the nature of their products. On the other hand, a more cautionary approach to financial innovation involves the development of new legislation specific to innovative products and services. Somewhere in between is the preference to assess individual cases in order to decide whether and in which degree they need to be regulated. For instance, regulators may issue special charters or include exemptions in regulatory requirements for innovative technologies and firms.

It could be argued that innovation requires a new perspective on regulation that can cope with the increasing digitalization of the economy. RegTech and SupTech could provide valuable tools to competent authorities for a smooth transition into the new era of innovation. Digitalized and "smart" processes are needed for the emerging need for data-centric and risk-based regulation. Yet there are several challenges and risks in developing RegTech and SupTech solutions that halt their potential growth. Regulation is one important consideration for innovative firms while potential risks to market stability concern supervisors.

Regulation can be a significant barrier to innovation. While necessary, the large amount of new and complex measures implemented to protect financial stability may hamper the growth of the economy and the financial system. The regulatory complexity and uncertainty surrounding innovative products and

[169] Zetzsche D., Buckley R., Arner D. & Barberis J. (2017). *Regulating a Revolution: From Regulatory Sandboxes to Smart Regulation*.

emerging technologies as well as important cross-border inconsistencies can make the development of RegTech and SupTech solutions a very complicated issue in practice.

In response to this phenomenon, there has been an increasing effort by regulators and supervisors to facilitate innovation while ensuring that the necessary safeguards for financial stability and consumer protection are in place. Initiatives for this purpose include a variety of structures with the most prominent being regulatory sandboxes and innovation hubs. These schemes hold great potential for balancing the increased regulatory requirements with regulators' desire to promote innovation and efficiency in the market. They can help high-tech firms navigate the regulatory framework and at the same time facilitate a pro-active monitoring of emerging risks in the financial system. Their main objective is to bring together competent authorities and market participants in order to induce an open dialogue and cooperation in addressing matters and concerns of implications caused by innovation. This way, they facilitate the growth of the financial industry in a controlled and supervised manner.

13.1 Regulatory Sandboxes

A regulatory "sandbox" usually refers to an enclosed, "safe" environment in which participants can develop and test innovative products, services and business models under regulators' supervision. It provides a small scale, live market environment for firms to test their ideas under specific safeguards, rules and time limits. Most importantly, it allows private firms to have an active dialogue with regulators and supervisors, and work closely with them, in order to ensure the protection of consumers and financial stability[170]. There are several variations of regulatory sandboxes but their common objective is to offer a controlled environment for experimentation of financial innovation.

The concept of regulatory sandboxes was first introduced in 2012 by the U.S. Consumer Financial Protection Bureau (CFPB) as "Project Catalyst", while the term was coined by the FCA in 2015[171].

In 2015, the FCA established a regulatory sandbox with the aim of increasing market competition and encouraging innovation in the interest of consumers[172]. Since then, five more cohorts of firms have been

[170] FCA (2017). *Regulatory sandbox lessons learned report.*
[171] Jenik, I. & Lauer, K. (2017). *Regulatory Sandboxes and Financial Inclusion*. Working Paper CGAP.
[172] FCA (2017).

accepted into the sandbox while steps are being taken towards the development of this initiative at a global level[173].

According to a Deloitte survey on firms who participated in the regulatory sandbox of FCA[174], "the unequivocal message was that the sandbox has delivered real value to firms". The majority of the firms wanted to enter the sandbox in order to get guidance on the applicable regulation to their innovative projects. They wanted to understand the effect of legislative requirements on their developed product as well as the required process for authorization. Licensing could be much easier if regulation was considered as a variable from the start of the product development.

Others mentioned the opportunity to engage with real customers in order to assess their business model as the primary reason of applying to the sandbox while some sought to introduce their product in the market as soon as possible. At the same time, an important incentive for most of the participants was the increase of their credibility within investor and customer circles upon acceptance to the program.

Indeed, FCA's regulatory sandbox results indicate that they add value to innovative initiatives, a fact that reinforced by the continuation of this project. According to FCA's report one year after its initial operation, there were significant indicators of success in achieving the agency's objectives:

- Regulatory expertise offered by the sandbox assisted participants in getting their product to the market faster and at a reduced cost. They were able to benefit from direct feedback on the regulatory requirements that their proposition was subject to, facilitating the introduction of the product to consumers without the cost of external consultants.
- Acceptance to the program increased investors' interest in financing innovators due to the greater regulatory certainty that FCA's involvement assured.
- The sandbox could help innovators obtain authorization in a much quicker fashion.
- Participating firms could test their products and services in a live market, assess their commercial viability and technology resilience, and improve their business model based on feedback.
- The sandbox enabled the collaboration of regulators and innovative firms to implement consumer protection safeguards in the developing products and services.

[173] FCA (2020). *Global Financial Innovation Network (GFIN).*
[174] Deloitte Centre for Regulatory Strategy (2018). *A journey through the FCA regulatory sandbox: The benefits, challenges, and next steps.*

Since then, several jurisdictions across the world have established or are exploring the idea of developing their own sandboxes to carry out their respective objectives. The principal reason for the development of sandboxes seems to be regulators' desire to encourage innovation in the financial sector in order to increase competition and efficiency in the market[175]. Innovators can benefit from regulators' expertise while the open dialogue between the two can offer a new perspective to regulatory needs and changes. Financial market participants have reacted positively towards this new initiative and early results seem to indicate that working together with regulators to address regulatory risks and requirements of innovative products facilitates their safe introduction to the market. Nevertheless, it is still too early to draw conclusions due to the short history of this initiative.

13.1.1 Benefits and Challenges

There are several benefits to regulatory sandboxes, yet their greatest achievement is turning regulation from an obstacle into a facilitator of innovation. Regulators can use sandboxes as a countermeasure to the increased regulatory complexity and uncertainty in the financial industry that seems to hinder innovation. Regulators and supervisors can foster innovation and competition in the financial market while ensuring compliance with regulation and oversight of the associated risks. By providing the possibility of testing unique ideas without the fear of being penalized for noncompliance as well as having access to continuous assistance from regulatory expertise, sandboxes play a promising role in the transition of the financial industry into the high tech era. Most importantly, they allow regulatory and supervisory authorities to keep under control possible risks to financial stability and consumer protection as well as learn by the collaboration and dialogue with participant firms about new technologies and necessary changes or adjustments in regulation.

In detail, some of the expected and observed benefits are the following[176]:

- Sandboxes send a clear message to the financial sector that regulators encourage and welcome innovation. They are a standardized, public approach to addressing FinTech, RegTech and

[175] CGAP (2017). *Regulatory Sandboxes and Financial Inclusion*.
[176] Crane, J., Meyer, M.L. & Fife A.E (2018).*Thinking Inside The Sandbox: An Analysis of Regulatory Efforts to Facilitate Financial Innovation.* RegTechLab.

SupTech initiatives that allow the transparent collaboration and communication between regulators and prospective or existing regulated entities.

- They allow the supervised testing of innovative projects in a real market that enables supervisors to prevent the potential harm to consumers and financial system.
- They can reduce barriers to entry and streamline the authorization process to facilitate the introduction of innovations to the market.
- Regulators and supervisors can learn about new technologies and market trends, improving their knowledge about the market they oversee. They can understand whether new regulatory rules are required, or whether there should be adjustments and changes to existing standards. By conducting various tests, they provide regulators with empirical data and findings that can assist in policy making and support regulatory changes. After all, new technologies are difficult to integrate in the existing legal framework and better knowledge on their implications can enhance supervisory capacity and expertise
- Lastly, sandboxes can be used to promote policy goals such enhanced competition and financial inclusion.

Sandboxes can enhance regulators' ability to improve financial inclusion by allowing them to support FinTech, RegTech and SupTech solutions that can have a positive effect on reaching excluded customers. Innovation can promote financial inclusion by developing affordable products and services that reach underserved customers, increasing competition and offering a solution to several problems that financial institutions face with compliance and risk management processes in developing and emerging markets[177]. For instance, innovations such as biometric ID, e-KYC utilities and alternative credit scoring processes can deal with several legal, operational and physical obstacles to financial inclusion. As an example, a solution for remote customer identification via mobile phones was tested by Bank Negara Malaysia's sandbox and successfully implemented in the market upon exit. This initiative was able to increase the access of remote areas in financial services. Previously, such a project would not be acceptable by the laws in Malaysia but after testing it inside the sandbox, not only was it permitted to enter the market but also new guidelines were drafted to encourage similar innovations[178].

[177] CGAP (2017). *Regulatory Sandboxes and Financial Inclusion*.
[178] UNSGSA (2018). *Briefing on Regulatory Sandboxes.*

However, the success of regulatory sandboxes is subject to various factors ranging from the capabilities and expertise of regulators developing such methods to the underlying market conditions. There are several challenges that regulators have to address. First, they need to evaluate in advance the amount of the required resources and level of expertise in order to decide whether they can financially support this initiative. Limited capacity to undertake such a program can lead to inefficient processes and poor choices in the selection and guidance of sandbox firms, while it may expose regulators to higher reputational risk and unwanted consequences to the market. One size doesn't fit all and other less formal or alternative initiatives could be more appropriate for the capabilities and objectives of certain regulators as well as the state of their respective underlying market.

Regulatory sandboxes have multiple advantages yet an important consideration is the unintended side-effect of their implementation. As has been aforementioned, firms that are accepted into these kind of programs are usually perceived as more credible by investors and customers while they enjoy a wide variety of benefits. This may lead to the image of an unlevel playing field and market discrimination by providing these advantages to only the few firms that succeed in entering the sandbox. In order to limit this phenomenon, regulators should consider increasing the transparency of the whole process, consulting the public and setting objective and clear eligibility criteria[179].

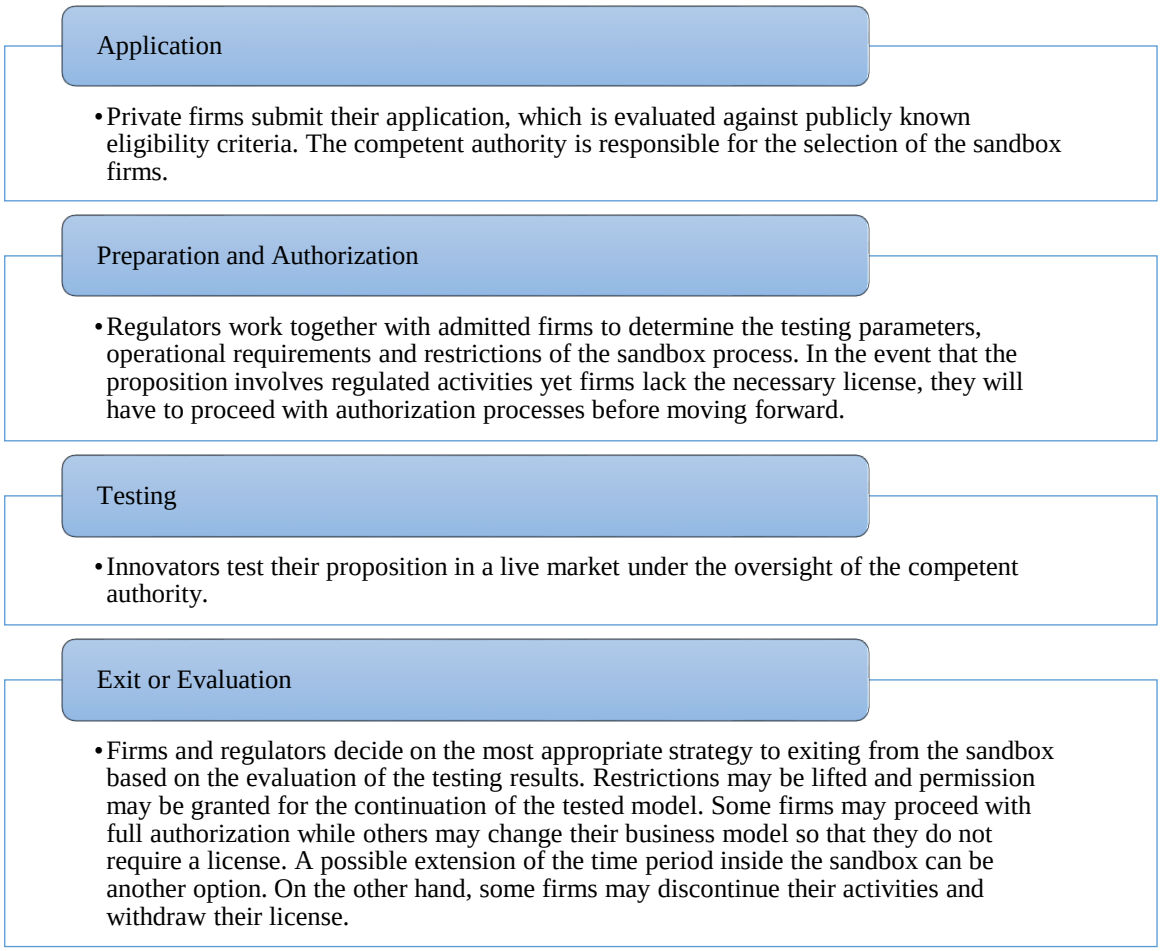
Other risks include the liability issues that come along with such a degree of involvement. Regulators should be aware of the reputational risk they face in case that they underestimate the potential risks of products participating in the sandbox or in the event that there are no clear results following the completion of the project. Due to their extensive involvement, they are bound to be held accountable by the public for any harm caused by innovations they helped get in the market or even face liability claims. This can damage their image and cause consumers and market participants to lose their trust in the financial system and the public authorities, a trust that is imperative for financial stability.

Lastly, an important challenge in practice is the limited number of participants that sandboxes can accept each time in contrast with the large amount of new entrants in the market. At the same time, sandbox evaluation processes ultimately depend on human judgment, which may influence their success and transparency.

[179] RegTechLab, (2018)

13.1.2 Regulatory Sandbox Process

There is no blueprint for regulatory sandboxes yet most initiatives follow four phases[180]:



13.2 Innovation hubs and other related initiatives

Innovation Hubs

Innovation hubs are schemes that allow the exchange of information and the provision of non-binding guidance on FinTech-related matters. They provide a contact point for regulated and unregulated firms to inquire about the applicable regulatory framework to innovative financial products, services and business models. Competent authorities are available to advise and guide firms to understand regulatory and supervisory expectations about new technologies. For instance, they can assist innovative firms in applying

[180]ESAs (2018). *Fintech: Regulatory Sandboxes and Innovation Hubs.* Joint Report.

for authorization and licensing, complying with regulatory standards and registering to the necessary bodies. The provided guidance is usually informal, and seeks to enable an open dialogue and information exchange between supervisors and innovators[181].

Innovation hubs bring together regulators and supervisors with market participants and high-tech firms so that they can jointly address regulatory uncertainty and discuss their concerns about the implications of innovative technologies. In this aspect, innovation hubs allow regulators and supervisors to monitor market trends and emerging technologies while at the same time gain valuable insights that help them identify potential regulatory and supervisory implications related to innovation. They enable them to spot emerging opportunities and risks of the financial system and help them shape an appropriate regulatory or supervisory response.

Accelerators and Incubators

Accelerators and Incubators are both programs that seek to induce the growth of promising startups by funding, training and mentoring them. Their main difference lies on the time they enter the startup. Accelerators accept existing startups with a minimum viable product, whereas incubators can apply to earlier stages of product development and help mold disruptive ideas into sustainable business models.

Accelerators are fixed-term programs and as the name suggests, they enable startups to reach a level of business growth in a much shorter time interval than they could achieve on their own. They may help, for instance, startups to commercialize their product or receive funding in a small amount of time. On the other hand, incubators do not usually have a predefined deadline and can assist startups on a longer term with resources and guidance until they become self-sufficient. Lastly, accelerators usually collaborate with investors and choose startups on the basis of investor interest and requirements so that they can later connect these two, while incubators do not often entail such connections.

On the context of SupTech, accelerator programs can be developed by supervisors and central banks to select private firms that offer innovative solutions and explore how they could be used to address existing problems and improve efficiency and effectiveness of supervisory processes[182]. Accelerators can be additionally used as the link between FinTech and RegTech private firms with regulatory and supervisory

[181]ESAs, (2018) & BCBS, (2018)

[182] Gilhuly-Mandel A. (2018). *Understanding the Differences between Accelerators, Incubators, and Innovation Labs.* & BCBS, (2018)

agencies. The R2A accelerator, for example, helped the Philippines Central Bank (BSP) deal with its problematic reporting system by finding a partner for the creation of a solution. They issued a competition from which they selected Compliance Risk Technology (CRT) to develop their API prototype for the central bank[183].

[183] Castri, S. & Kulenkampff, A. (2018). *R2A API Solution Creates a Faster, Direct Data Delivery Channel between Philippine Banks and the Central Bank.*

14 Conclusion

RegTech and SupTech could revolutionize the regulatory and supervisory framework. In an ever-changing regulatory and financial landscape, uncertainty is the only stable variable. The greatest advantage of innovative solutions is the flexibility and adaptability they offer towards new norms and needs. Self-learning and self- executable programs, agile applications and platforms as well as real-time monitoring systems and alerts could support financial entities and supervisors in keeping up with complex and emerging regulatory implications caused by the digitalization of the economy and the evolution of financial innovation. Powerful processing, predictive and visualization tools could increase the depth and complexity of analyses to extract valuable insights from richer and diversified datasets that may have been previously unattainable. Automation and digitalization could bring about significant efficiencies in several aspects of regulatory and supervisory processes.

An improved regulatory regime could not only handle the upcoming legal implications of innovative technology but could also foster the growth of the overall economy. On one hand, it could increase the efficiency and accuracy of reporting and monitoring, enabling superior supervisory action and coordination between regulatory authorities, supervisors, and financial entities. Cost-efficient solutions regarding regulation could be provided to financial entities and improved data generation and management facilities could assist supervisors in their duties. On the other hand, emerging technologies such as AI and blockchain could develop efficient alternatives to traditional financial processes. There are several opportunities in the application of these technologies but currently, one main limitation to their adoption is regulatory uncertainty and possible legal implications. RegTech and SupTech could address these issues by exercising significantly more efficient control over cyberspace, which could in turn provide the necessary environment for the development of innovative business models and products. Most importantly, RegTech/SupTech solutions could promote financial inclusion and reduce entry barriers, assist policy objectives and increase competition and growth in the market.

However, there are always two sides of the same coin. Technology is a double-edged sword that if not controlled sufficiently, it could lead to severe implications for the financial sector. Poorly made algorithms, technical errors, and translation problems in the development of RegTech and SupTech solutions could lead to erroneous decisions and ill-suited systems. The digitalization of regulatory processes could further lead to the emergence of a new systemic risk based on innovative IT systems and technology providers. Operational risks and cyber-attacks are additionally an important consideration, especially in light of the

evolution of cyberattack practices and frequency. Lastly, the distribution and management of sensitive personal data over the internet raise serious legal concerns regarding data privacy rules.

Nevertheless, financial institutions and supervisors should explore the possibilities of utilizing innovative solutions in carrying out their regulatory and supervisory duties. As technology enters all aspects of economic activity, the ability to adapt to new digitalized standards and practices will differentiate winners from losers. Technological evolution cannot be stopped but should be handled carefully. The experimentation with regulatory "sandboxes" and other similar initiatives should be pursued in order to foster innovation in a controlled environment under supervisors' oversight. Innovation hubs and shared utilities on data and intelligence could facilitate the information exchange and collaboration on innovative technologies in order to jointly address potential regulatory implications and ensure market stability and consumer protection.

Concluding, regulation should face a paradigm shift from reactive and backward-looking towards a more proactive approach to market developments. Keeping up with fast-paced technological advances can be a challenging task but a long-term strategic approach to adopting innovation may be unavoidable. Technological innovations could bring powerful changes that are difficult to be undone. The only way is going forward. Regulation should do the same.

15 References

Main References

- Broeders D. & Prenio J. (2018). *Innovative technology in financial supervision (suptech): The experience of early users.* FSI Insights, No 9.
- Coelho R., De Simoni M. & Prenio J. (2019). *Suptech applications for anti-money laundering.* FSI Insights. No 18.
- di Castri S., Grasser M.& Kulenkampff A. (2018). *Financial Authorities in the Era of Data Abundance: Regtech for Regulators and Suptech Solutions*. R2A Whitepaper.
- Dias, D. & Staschen S. (2017). *Data Collection by Supervisors of Digital Financial Services*. Working Paper. CGAP.
- Institute of International Finance (2016). *RegTech in Financial Services: Technology Solutions for Compliance and Reporting*.
- Toronto Centre (2017). *FinTech, RegTech and SupTech: What they mean for financial supervision.* TC Notes. Retrieved from:
- Toronto Centre (2018). *SupTech: Leveraging technology for better supervision*. TC Notes.

Additional readings

- Accornero, M. & Moscatelli, M. (2018). *Listening to the buzz: social media sentiment and retail depositors' trust.* Bank of Italy. Working Paper No.1165. Retrieved from: https://www.bancaditalia.it/pubblicazioni/temi-discussione/2018/2018-1165/en_tema_1165.pdf
- Adl, M. & Haworth W.C. (2018). *How a Know-Your-Customer Utility Could Increase Access to Financial Services in Emerging Markets*. World Bank Group. EMCompass No. 59. Retrieved from: http://documents.worldbank.org/curated/en/133091547846776274/How-a-Know-Your-Customer-Utility-Could-Increase-Access-to-Financial-Services-in-Emerging-Markets
- Albinson, N., Thomas, C., Rohrig, M. & Chu, Y. (2019**).** *Managing the black box of artificial intelligence (AI): Future of risk in the digital era.* Deloitte Report. Retrieved from: https://www2.deloitte.com/us/en/pages/advisory/articles/black-box-artificial-intelligence.html
- Andini, M., Ciani, E., Blasio, G.D., D'Ignazio, A., & Salvestrini, V. (2018). *Targeting with machine learning: An application to a tax rebate program in Italy*. Journal of Economic

Behavior and Organization, 156, 86-102. Retrieved from: https://www.aiel.it/cms/cms-files/submission/all20170613173907.pdf

- Angelico, C., Marcucci, J., Miccoli, M. & Quarta, F. (2018) *Can We Measure Inflation Expectations Using Twitter?* Retrieved from: https://www.bancaditalia.it/pubblicazioni/altri-atti-convegni/2018-bigdata/Miccoli_Presentazione_Twitter_Workshop.pdf
- Arner D. W., Barberis J. & Buckley R. P. (2017). *FinTech, RegTech, and the Reconceptualization of Financial Regulation*. 37 Nw. J. Int'l L. & Bus. 371. Retrieved from: http://scholarlycommons.law.northwestern.edu/njilb/vol37/iss3/2
- Arner D., Barberis J. & Buckley R. The CFA Institute Research Foundation (2017). *FinTech and RegTech in a Nutshell, and the Future in a Sandbox*. SSRN Electronic Journal. DOI:10.2139/ssrn.3088303.
- Ashby, S. (2010). *The 2007–2009 Financial Crisis: Learning the Risk Management Lessons.* University of Nottingham: Financial Services Research Forum. Retrieved from: https://www.nottingham.ac.uk/business/businesscentres/gcbfi/documents/researchreports/paper65.pdf
- ASIC (2013). *ASIC's next generation market surveillance system commences.* Retrieved from: https://asic.gov.au/about-asic/news-centre/find-a-media-release/2013-releases/13-316mr-asics-next-generation-market-surveillance-system-commences/
- Bank for International Settlements (BIS). *History of the Basel Committee*. Retrieved from: https://www.bis.org/bcbs/history.htm
- Basel Committee on Banking Supervision (2013). *Principles for effective risk data aggregation and risk reporting.* Retrieved from: https://www.bis.org/publ/bcbs239.pdf
- Basel Committee on Banking Supervision (2018). *Sound Practices: implications of fintech developments for banks and bank supervisors.* Retrieved from: https://www.bis.org/bcbs/publ/d431.pdf
- Bauguess S.W. (2017).*The Role of Big Data, Machine Learning, and AI in Assessing Risks: a Regulatory Perspective.* Speech. Retrieved from: https://www.sec.gov/news/speech/bauguess-big-data-ai
- Ben Wolford (2020)**.** *What is GDPR, the EU's new data protection law?* Retrieved from: https://gdpr.eu/what-is-gdpr/

- Berlind, D. (2015). *What Are APIs and How Do They Work?* Retrieved from: https://www.programmableweb.com/api-university/what-are-apis-and-how-do-they-work
- Bluwstein, K., Buckmann, M., Joseph, A., Kang, M., Kapadia, S. & Şimşek, O. (2020). *Credit growth, the yield curve and financial crisis prediction: evidence from a machine learning approach*. Bank of England. Staff Working Paper No.848. Retrieved from: https://www.bankofengland.co.uk/-/media/boe/files/working-paper/2020/credit-growth-the-yield-curve-and-financial-crisis-prediction-evidence-from-a-machine-learning.pdf?la=en&hash=F37E72F9D003C4D3FE66AA4F1A70CDC2EC4C3A0D
- Butler T., O'Brien L. (2019) *Understanding RegTech for Digital Regulatory Compliance*. In: Lynn T., Mooney J., Rosati P., Cummins M. (eds) Disrupting Finance. Palgrave Studies in Digital Business & Enabling Technologies. Palgrave Pivot, Cham.
- Carlo R.W. De Meijer (2020). *Remaining challenges of blockchain adoption and possible solutions.* Retrieved from: https://www.finextra.com/blogposting/18496/remaining-challenges-of-blockchain-adoption-and-possible-solutions
- Castri, S. & Kulenkampff, A. (2018). *R2A API Solution Creates a Faster, Direct Data Delivery Channel between Philippine Banks and the Central Bank.* Retrieved from: https://bfaglobal.com/r2a/insights/r2a-api-solutions-for-phillipine-and-central-banks-video/
- Cerchiello, P., Giudici, P. & Nicola, G. (2016). *Big data models of bank risk contagion.* University of Pavia. DEM Working Paper No.117. Retrieved from: http://economiaweb.unipv.it/wp-content/uploads/2017/06/DEMWP0117.pdf
- Colaert, V. (2018). *RegTech as a Response to Regulatory Expansion in the Financial Sector* Available at SSRN: https://ssrn.com/abstract=2677116 or http://dx.doi.org/10.2139/ssrn.2677116
- Confluence (2016). *RegTech: Bringing New Meaning to Compliance and Cloud Technology in Asset Management.* Retrieved from: https://www.confluence.com/uploads/regtech-whitepaper-formatted-final.pdf
- Corporate Finance Institute (CFI). *Value at Risk*. Retrieved from: https://corporatefinanceinstitute.com/resources/knowledge/trading-investing/value-at-risk-var/

- Crane, J., Meyer, M.L. & Fife A.E (2018).*Thinking Inside The Sandbox: An Analysis of Regulatory Efforts to Facilitate Financial Innovation.* RegTechLab. Retrieved from: https://www.regtechlab.io/report-thinking-inside-the-sandbox
- Deloitte (2016). *RegTech is the new FinTech: How agile regulatory technology is helping firms better understand and manage their risks.* Retrieved from: https://www2.deloitte.com/content/dam/Deloitte/ie/Documents/FinancialServices/IE_2016_FS_RegTech_is_the_new_FinTech.pdf
- Deloitte (2017). *The Future of Regulatory Productivity, powered by RegTech*. Retrieved from: https://www2.deloitte.com/content/dam/Deloitte/us/Documents/regulatory/us-regulatory-future-of-regulatory-productivity-powered-by-regtech.pdf
- Deloitte (2018). *The case for artificial intelligence in combating money laundering and terrorist financing.* Retrieved from: https://www2.deloitte.com/content/dam/Deloitte/tr/Documents/financial-advisory/sea-fas-deloitte-uob-whitepaper-digital.pdf
- Deloitte (2020). *RegTech Universe 2020: Take a closer look at who is orbiting in the RegTech space.* Retrieved from: https://www2.deloitte.com/lu/en/pages/technology/articles/regtech-companies-compliance.html
- Deloitte Centre for Regulatory Strategy (2018). *A journey through the FCA regulatory sandbox: The benefits, challenges, and next steps.* Retrieved from: https://www2.deloitte.com/content/dam/Deloitte/uk/Documents/financial-services/deloitte-uk-fca-regulatory-sandbox-project-innovate-finance-journey.pdf
- di Castri S., Grasser M. & Kulenkampff A. (2018). *An API-based Prudential Reporting System for the Bangko Sentral ng Pilipinas (BSP): R^{2}A Project Retrospective and Lessons Learned.* Retrieved from: https://bfaglobal.com/wp-content/uploads/2020/01/R2AAPICaseStudy-1.pdf
- Digital Transformation Monitor (2018). *Biometrics technologies: a key enabler for future digital services.* European Commission. Retrieved from: https://ec.europa.eu/growth/tools-databases/dem/monitor/sites/default/files/Biometrics%20technologies_v2.pdf
- Duke SciPol (2019). *Artificial Intelligence: An Overview.* Retrieved from: https://scipol.duke.edu/learn/science-library/artificial-intelligence-overview

- ECB (2019). *What is the BIRD?* Retrieved from: https://www.ecb.europa.eu/stats/ecb_statistics/co-operation_and_standards/reporting/html/bird_dedicated.en.html
- ECB (2020). *The ESCB's long-term approach to banks' data reporting*. Retrieved from: https://www.ecb.europa.eu/stats/ecb_statistics/co-operation_and_standards/reporting/html/index.en.html
- ESMA (2020). *MiFID II*. Retrieved from: https://www.esma.europa.eu/policy-rules/mifid-ii-and-mifir
- European Central Bank (ECB) (2018). *Report on the Thematic Review on effective risk data aggregation and risk reporting.* Retrieved from: https://www.bankingsupervision.europa.eu/ecb/pub/pdf/ssm.BCBS_239_report_201805.pdf
- European Supervisory Authorities (ESAs), (2018).*Fintech: Regulatory Sandboxes and Innovation Hubs.* Joint Report. Retrieved from: https://eba.europa.eu/sites/default/documents/files/documents/10180/2545547/154a7ccb-06de-4514-a1e3-0d063b5edb46/JC%202018%2074%20Joint%20Report%20on%20Regulatory%20Sandboxes%20and%20Innovation%20Hubs.pdf
- Expert Group on Regulatory Obstacles to Financial Innovation (ROFIEG) (2019). *30 Recommendations on Regulation, Innovation and Finance.* Final Report to the European Commission. Retrieved from: https://ec.europa.eu/info/sites/info/files/business_economy_euro/banking_and_finance/documents/191113-report-expert-group-regulatory-obstacles-financial-innovation_en.pdf
- EY (2019). *Regulatory technology (RegTech) brief*. Retrieved from: https://www.ey.com/en_us/financial-services/how-technology-can-be-used-to-manage-evolving-regulatory-environment
- FATF (2012-2019). *International Standards on Combating Money Laundering and the Financing of Terrorism & Proliferation*. Retrieved from www.fatf-gafi.org/recommendations.html

- FATF (2015). *Effective Supervision and Enforcement by AML/CFT Supervisors of the Financial Sector and Law*. Retrieved from: https://www.fatf-gafi.org/media/fatf/documents/reports/RBA-Effective-supervision-and-enforcement.pdf
- FCA (2016).*Call for input on supporting the development and adopters of RegTech*. Feedback Statement FS16/4. Retrieved from: https://www.fca.org.uk/publication/feedback/fs-16-04.pdf
- FCA (2017). *Regulatory sandbox lessons learned report*. Retrieved from: https://www.fca.org.uk/publication/research-and-data/regulatory-sandbox-lessons-learned-report.pdf
- FCA (2018). *Call for Input: Using technology to achieve smarter regulatory reporting.* Retrieved from: https://www.fca.org.uk/publication/call-for-input/call-for-input-smarter-regulatory-reporting.pdf
- FCA (2020). *Global Financial Innovation Network (GFIN)*. Retrieved from: https://www.fca.org.uk/firms/innovation/global-financial-innovation-network
- Fenergo (2020). *Another Fine Mess: A Global Research Report on Financial Institution Fines and Enforcement Actions.* Retrieved from: https://www.fenergo.com/resources/reports/another-fine-mess-global-research-report-financial-institution-fines.html
- Figliola P. M. (2020). *The Internet of Things (IoT): An Overview.* Congressional Research Service (CRS). Retrieved from: https://fas.org/sgp/crs/misc/IF11239.pdf
- Financial Conduct Authority (2015). *Call for Input: Supporting the development and adoption of RegTech*. Retrieved from: https://www.fca.org.uk/publication/call-for-input/regtech-call-for-input.pdf
- Financial Stability Board (FSB) (2017). *Artificial intelligence and machine learning in financial services.* Retrieved from: https://www.fsb.org/wp-content/uploads/P011117.pdf
- FinTech Global (2019). *The first half of 2019 marked the strongest start to a year in RegTech to date*. Retrieved from: https://fintech.global/the-first-half-of-2019-marked-the-strongest-start-to-a-year-in-regtech-to-date/
- Gasparri, G. (2019). *Risks and Opportunities of RegTech and SupTech Developments.* Frontiers in Artificial Intelligence. 2. 14. Doi:10.3389/frai.2019.00014. Retrieved from: https://www.researchgate.net/publication/334765414_Risks_and_Opportunities_of_RegTech_and_SupTech_Developments#pf3

- Gilhuly-Mandel A. (2018). *Understanding the Differences between Accelerators, Incubators, and Innovation Labs.* Retrieved from: https://hartfordinsurtechhub.com/understanding-differences-accelerators-incubators-innovation-labs/
- Gogineni C. (2019).*How Automation of Data Validation Works?* Retrieved from: https://www.comtecinfo.com/rpa/automation-data-validation/
- Grand View Research (2019). *RegTech Market Size, Share & Trends Analysis Report by Organization Size, by Application (Risk & Compliance Management, Identity Management), by Region, and Segment Forecasts, 2019 – 2025.* Report ID: GVR-2-68038-960-9. Retrieved from: https://www.grandviewresearch.com/industry-analysis/regulatory-technology-market
- Grasshoff G., Mogul Z., Pfuhler T., Gittfried N., Wiegand C., Bohn A. & Vonhoff V. The Boston Consulting Group (2017). *Global Risk 2017: Staying the course in Banking.* Retrieved from: https://image-src.bcg.com/BCG_COM/BCG-Staying-the-Course-in-Banking-Mar-2017_tcm9-146794.pdf
- Hamilton, A. (2020). *Central Bank of Egypt pilots eKYC solution for financial inclusion.* Retrieved from: https://www.fintechfutures.com/2020/01/central-bank-of-egypt-pilots-ekyc-solution-for-financial-inclusion/
- Hammond S. & Cowan M. (2020). *Cost of Compliance Survey 2020: New Decade, New Challenges.* Retrieved from: https://www.jdsupra.com/legalnews/cost-of-compliance-2020-new-decade-new-31844/
- Hammond S. (2019). *Cost of Compliance Survey 2019: Nothing is certain except regulatory change.* Retrieved from: https://blogs.thomsonreuters.com/answerson/cost-of-compliance-survey-2019/
- Heuver R. & Triepels R. (2019). *Liquidity Stress Detection in the European Banking Sector.* DNB Working Paper. No. 642. Retrieved from: https://www.dnb.nl/binaries/Working%20paper%20No.%20642_tcm46-384672.pdf
- Hugé F.K., Duprel C., & Pescatore G. (2017). *The Promise of RegTech.* Retrieved from: https://www2.deloitte.com/content/dam/Deloitte/lu/Documents/technology/lu-the-promise-regtech-27032017.pdf
- Institute of International Finance (2017). *Deploying Regtech against Financial Crime*. Retrieved from: https://www.iif.com/portals/0/Files/private/32370132_aml_final_id.pdf

- Irving Fisher Committee on Central Bank Statistics (IFC) Survey (2015). *Central banks' use of and interest in "big data"*. Retrieved from: https://www.bis.org/ifc/publ/ifc-report-bigdata.pdf
- ISDA (2017). *Smart Contracts and Distributed Ledger – A Legal Perspective*. Retrieved from: https://www.isda.org/a/6EKDE/smart-contracts-and-distributed-ledger-a-legal-perspective.pdf
- Jenik, I. & Lauer, K. (2017). *Regulatory Sandboxes and Financial Inclusion*. Working Paper CGAP. Retrieved from: https://www.cgap.org/sites/default/files/Working-Paper-Regulatory-Sandboxes-Oct-2017.pdf
- Katara A. (2018). *RPA as a Compliance Enabler – Exciting Times Ahead.* Retrieved from: https://www.tcs.com/content/dam/tcs/pdf/Industries/Banking%20and%20Financial%20Services/RPA-Compliance-Enabler.pdf
- Kathleen Weiss Hanley, K. W. & Hoberg, G. (2016). *Dynamic Interpretation of Emerging Systemic Risks*. Working Paper. Retrieved from: http://gcfp.mit.edu/wp-content/uploads/2016/09/Hanley-Hoberg.pdf
- KPMG (2018). *There's a revolution coming: Embracing the challenge of RegTech 3.0*. Retrieved from: https://assets.kpmg/content/dam/kpmg/uk/pdf/2018/09/regtech-revolution-coming.pdf?source=post_page----------
- Kraft O. (2018) *Financial RegTech: Opportunities and Obstacles.* CapTech consulting. Retrieved from: https://www.captechconsulting.com/uploads/whitepapers/financial-regtech-ebook-opportunities-and-obstacles-final-compressed.pdf
- Lee, S.J., Chen, M., Deininger, M. & Sicilian, M. (2019). *Identifying Financial Crises Using Machine Learning on Textual Data*. Federal Reserve Board. First Draft.
- Loberto, M., Luciani, A. & Pangallo, M. (2018).*The potential of big housing data: an application to the Italian real-estate market*. Bank of Italy. Working Paper No.1171. Retrieved from: https://www.bancaditalia.it/pubblicazioni/temi-discussione/2018/2018-1171/en_tema_1171.pdf?language_id=1
- Lootsma Y. (2017). *Blockchain as the Newest Regtech Application—the Opportunity to Reduce the Burden of KYC for Financial Institutions.* Banking and Financial Services Policy Report 36.8. Retrieved from:https://static1.squarespace.com/static/567bb0614bf118911ff0bedb/t/59ca5fc4017db2da07e

c290c/1506435012176/Article+-+Blockchain+as+the+Newes+Regtech+Application+-+Yvonne+Lootsma+%281%29.pdf

- Matlab (2020). *What Is Machine Learning?* Retrieved from: https://www.mathworks.com/discovery/machine-learning.html
- McLaren, N. & Shanbhogue, R. (2011). *Using Internet Search Data as Economic Indicators*. Bank of England Quarterly Bulletin No. 2011 Q2. Retrieved from: SSRN: https://ssrn.com/abstract=1865276 or http://dx.doi.org/10.2139/ssrn.1865276
- Medeiros, M. C., Vasconcelos, G., Veiga, A. & Zilberman, E. (2019). *Forecasting Inflation in a Data-Rich Environment: The Benefits of Machine Learning Methods*. Retrieved from SSRN: https://ssrn.com/abstract=3155480 or http://dx.doi.org/10.2139/ssrn.3155480
- Mehrabi, N., Morstatter, F., Saxena, N., Lerman, K., & Galstyan, A. (2019). *A Survey on Bias and Fairness in Machine Learning.* ArXiv, abs/1908.09635.
- Mell P. & Grance T. (2011). *The NIST Definition of Cloud Computing*. Technical Report. National Institute of Standards and Technology (NIST). Retrieved from: https://nvlpubs.nist.gov/nistpubs/Legacy/SP/nistspecialpublication800-145.pdf
- Microsoft Azure (2020). *What Is Cloud Computing? A Beginner's Guide.* Retrieved from: https://azure.microsoft.com/en-us/overview/what-is-cloud-computing/
- Nakamoto, S. (2008). Bitcoin: A Peer-to-Peer Electronic Cash System. Retrieved from https://bitcoin.org/bitcoin.pdf
- Narita, F., & Yin, R. (2018). *In Search of Information: Use of Google Trends' Data to Narrow Information Gaps for Low-Income Developing Countries*. IMF Working Paper No. 18/286. Retrieved from: https://www.imf.org/en/Publications/WP/Issues/2018/12/14/In-Search-of-Information-Use-of-Google-Trends-Data-to-Narrow-Information-Gaps-for-Low-income-46475
- Natarajan, H., Krause S. K. & Gradstein H. L. World Bank Group. (2017). *Distributed Ledger Technology (DLT) and blockchain.* Doi: 10.1596/29053. Retrieved from: http://documents.worldbank.org/curated/en/177911513714062215/Distributed-Ledger-Technology-DLT-and-blockchain
- Nizan G. P. (2018) *Regtech, Compliance and Technology Judgement Rule*. 93 Chi.-Kent L. Rev. 193. Retrieved from: https://scholarship.kentlaw.iit.edu/cklawreview/vol93/iss1/7

- Nzuva S. (2019). *Smart Contracts Implementation, Applications, Benefits, and Limitations.* Journal of Information Engineering and Applications. 10.7176/JIEA/9-5-07. Retrieved from: https://www.researchgate.net/publication/336369143_Smart_Contracts_Implementation_Applications_Benefits_and_Limitations
- O'Halloran, S., Maskey, S., Mcallister, G., Park, D. & Chen, K. (2015). *Big Data and the Regulation of Financial Markets. Foundations and Applications of Big Data*. 2015 IEEE/ACM International Conference on Advances in Social Networks Analysis and Mining (ASONAM), Pages 1118-1124. Retrieved from: https://doi.org/10.1145/2808797.2808841
- Panisi, F., & Perrone, A. (2018). *'Systems So Perfect That No One Will Need to be Good'? RegTech and the 'Human Factor'*. Development of Innovation eJournal. Available at SSRN: https://ssrn.com/abstract=3284636
- Pearlman, S. (2016). *What are APIs and how do APIs work?* Retrieved from https://blogs.mulesoft.com/biz/tech-ramblings-biz/what-are-apis-how-do-apis-work/
- Piechocki M. & Dabringhausen T. (2015*). Reforming Regulatory Reporting From Templates to Cubes.* Bearing Point. Retrieved from: https://www.bis.org/ifc/publ/ifcb41o.pdf
- Piwowar M.S. (2018). *Remarks at the 2018 RegTech Data Summit - Old Fields, New Corn: Innovation in Technology and Law*. Speech. Retrieved from: https://www.sec.gov/news/speech/piwowar-old-fields-new-corn-innovation-technology-law
- Randis P. (2019). *KYC Utility: why should you consider it?* Retrieved from: https://www.capgemini.com/2019/07/kyc-utility-why-should-you-consider-it/
- Regulation (EU) No 596/2014 of the European Parliament and of the Council of 16 April 2014 on market abuse (market abuse regulation) and repealing Directive 2003/6/EC of the European Parliament and of the Council and Commission Directives 2003/124/EC, 2003/125/EC and 2004/72/EC Text with EEA relevance
- Ron Triepels R., Daniels H & Heijmans R. (2017). *Anomaly Detection in Real-Time Gross Settlement Systems.* Retrieved from: https://www.scitepress.org/Papers/2017/63330/63330.pdf
- Rönnqvist, S. & Sarlin, P. (2016). *Bank distress in the news: Describing events through deep learning.* Neurocomputing, 264, 2017.Retrieved from: https://arxiv.org/pdf/1603.05670.pdf
- Roy S., Heaney M. & Seibert H. Oliver Wyman (2018). *Regtech on the rise: Transforming compliance into competitive advantage.* Retrieved from:

https://www.oliverwyman.com/content/dam/oliver-wyman/v2/publications/2018/may/RegTech-on-the-Rise.pdf

- Russell, S. J., & Norvig, P. (2010). *Artificial intelligence: A modern approach*. 3rd edition. Prentice-Hall, Inc.
- Schizas E., McKain G., Zhang B., Ganbold. A, Kumar P., Hussain H., Garvey K. J., Huang E., Huang A., Wang S. & Yerolemou N. (2019). *The Global RegTech Industry Benchmark Report*. Cambridge Centre for Alternative Finance (CCAF). Retrieved from: https://www.jbs.cam.ac.uk/fileadmin/user_upload/research/centres/alternative-finance/downloads/2019-ccaf-global-regtech-benchmarking-report.pdf
- Stucke, M.E. and A.P. Grunes (2016). *Big Data and Competition Policy*. Oxford University Press, United Kingdom.
- Szabo N. (1994): *Smart Contracts*. Retrieved from:http://www.fon.hum.uva.nl/rob/Courses/InformationInSpeech/CDROM/Literature/LOTwinterschool2006/szabo.best.vwh.net/smart.contracts.html
- Tavana, M., Abtahi, A., Caprio, D.D., & Poortarigh M. (2018). *An Artificial Neural Network and Bayesian Network model for liquidity risk assessment in banking*. Neurocomputing, 275, 2525-2554. Retrieved from: http://tavana.us/publications/NEURO-BANK.pdf
- The World Bank (2018). *Financial Inclusion.* Retrieved from: https://www.worldbank.org/en/topic/financialinclusion/overview#1
- Thomson Reuters (2017). *Global KYC Surveys Attest to Even Greater Compliance Pain Points.* Retrieved from: https://www.thomsonreuters.com/en/press-releases/2017/october/thomson-reuters-2017-global-kyc-surveys-attest-to-even-greater-compliance-pain-points.html
- Tissot, B. (2019). *The Role of Big Data and Surveys in Measuring and Predicting Inflation.* Journal of Mathematics and Statistical Science. ISSN 2411-2518, Vol.6, 9-17. Retrieved from: http://www.ss-pub.org/wp-content/uploads/2020/01/JMSS19091001.pdf
- Turner J. (2016). *New Ways in Reporting for Austrian Banks.* European Institute of Financial Regulation (EIFR). Retrieved from: http://www.eifr.eu/uploads/eventdocs/57e246698c61b.pdf
- United Nations Secretary-General's Special Advocate for Inclusive Finance for Development (UNSGSA) (2018). *Briefing on Regulatory Sandboxes.* Retrieved from: https://www.unsgsa.org/files/1915/3141/8033/Sandbox.pdf

- Wibisono O., Ari H.D., Widjanarti A., Zulen A.A., & Tissot, B. (2019). *The use of big data analytics and artificial intelligence in central banking – An overview*. IFC Bulletins chapters, 50. Retrieved from: https://www.bis.org/ifc/publ/ifcb50_01.pdf
- World Government Summit & Accenture (2018). *RegTech for Regulators: Re-Architect the System for Better Regulation.* Retrieved from: https://www.worldgovernmentsummit.org/api/publications/document?id=5ccf8ac4-e97c-6578-b2f8-ff0000a7ddb6
- Zednik, C. (2019). *Solving the Black Box Problem: A Normative Framework for Explainable Artificial Intelligence.* arXiv: General Literature.
- Zetzsche D., Buckley R., Arner D. & Barberis J. (2017). *Regulating a Revolution: From Regulatory Sandboxes to Smart Regulation*. 23 Fordham Journal of Corporate and Financial Law 31-103 (2017); European Banking Institute Working Paper Series 2017 - No. 11; Retrieved from: SSRN: https://ssrn.com/abstract=3018534 or http://dx.doi.org/10.2139/ssrn.3018534
- Zulen, A.A., & Wibisono, O. (2018). *Measuring stakeholders' expectations for the central bank's policy rate.* IFC Bulletins chapters, 50. Retrieved from: https://pdfs.semanticscholar.org/da33/f42e2b44938e96089ab84ba45c17e8673c4e.pdf?_ga=2.47617639.133672769.1593716340-1911624474.1586445848