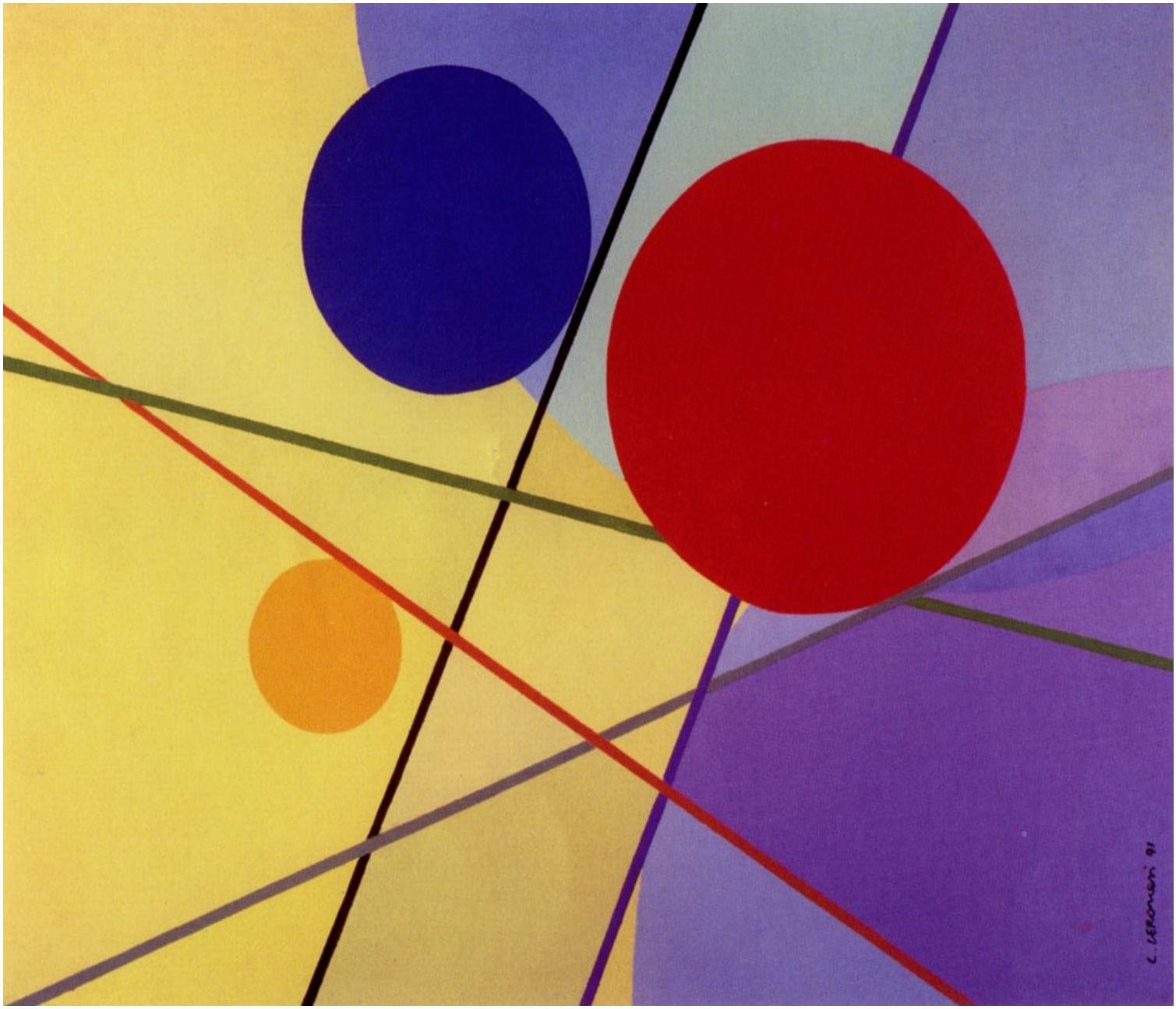
Issue N. 25 - 2024

ARGO

New Frontiers in Practical Risk Management



iason
ESSENTIAL SERVICES FOR
FINANCIAL INSTITUTIONS

iason

Argo magazine

Year 2024 - Issue Number 25

Published in April 2024
First published in October 2013

Last published issues are available online:
http://www.iasonltd.com/research

Front Cover: **Luigi Veronesi**, *Costruzione JH3*, 1991.

Milan Headquarter:
Corso Europa, 15
20122 Milan
Italy

London Headquarter:
3rd Floor, 120 Baker Street
W1U 6TU London
United Kingdom

Madrid Headquarter:
Calle Miguel Ángel, 16
28010 Madrid
Spain

Contact Information:
info@iasonltd.eu
www.iasonltd.com

Articles submission guidelines
Argo welcomes the submission of articles on topical subjects related to the risk management. The articles can be indicatively, but not exhaustively, related to models and methodologies for market, credit, liquidity risk management, valuation of derivatives, asset management, trading strategies, statistical analysis of market data and technology in the financial industry. All articles should contain references to previous literature. The primary criteria for publishing a paper are its quality and importance to the field of finance, without undue regard to its technical difficulty. Argo is a single blind refereed magazine: articles are sent with author details to the Scientific Committee for peer review. The first editorial decision is rendered at the latest within 60 days after receipt of the submission. The author(s) may be requested to revise the article. The editors decide to reject or accept the submitted article. Submissions should be sent to the technical team (**info@iasonltd.eu**). LaTeX or Word are the preferred format, but PDFs are accepted if submitted with LaTeX code or a Word file of the text. There is no maximum limit, but recommended length is about 4,000 words. If needed, for editing considerations, the technical team may ask the author(s) to cut the article.

Table of Contents

Asset Tokenization: Potential Applications

V. Ciminelli and G. Morisani

Dear Readers,

We are glad to present you the latest issue of Argo Magazine.

For this spring publication, we wish to propose you an interesting offer of new contents, with several in-depth and exciting discussions which look at various topics of the banking landscape.

The issue opens, traditionally, with the section dedicated to iason Just in Time, where you can read up on the main news of the financial industry of the last months. Among these, the results of the Supervisory Review and Evaluation Process (SREP) and the SSM Supervisory Priorities for 2024-2026.

The first article we propose, ***"EBA Report on the Role of Environmental and Social Risks in the Prudential Framework"****, illustrates how risks arising from environmental and social (E&S) issues are changing the risk framework for the financial sector.*
Through their effect on traditional categories of financial risks, such as credit, market and operational risks, environmental and social factors are expected to contribute to risks more significantly both towards individual institutions and financial stability. This highlights the need to enhance the prudential framework to better account for environmental and social risks. To this end the EBA report proposes targeted enhancements to the current Pillar 1 framework, which can be implemented in the short term and in the medium-long term, while preserving its integrity and purpose.

The Technology section follows with the interesting paper ***"Artificial Intelligence: Risks and Opportunities for the Banking System"*** *by M. Carminati, V. Frasca and L. Bandini where the authors seek to highlight the dual nature of AI adoption, emphasizing its benefits for the banks, alongside the imperative of addressing associated risks and challenges.*
Indeed, in recent years, there has been a significant diffusion of Artificial Intelligence (AI) solutions across the financial sector, in particularly in customer interactions and risk management, leveraging data-driven insights for informed decision-making. Despite the clear advantages, the widespread integration of AI brings inherent risks and challenges that regulatory authorities worldwide are responding to with varying degrees of urgency and rigor.
The paper conducts a careful analysis and underlines the importance of ethical considerations and regulatory compliance in harnessing AI's potential for safe and responsible use, ensuring the respect of fundamental rights and ethical principles.

The Research Papers section closes with ***"Asset Tokenization: Potential Applications"*** *by V. Ciminelli and G. Morisani. This paper aims to uncover the disruptive potential embedded in asset tokenization within the current evolving landscape.*
The authors start by explaining the features of both operative environment and regulatory landscape before moving on to analyze two key markets where asset tokenization could boost the growth and bring transformative shifts.

We conclude suggesting you visit our online Research page and subscribe to our newsletter service with a monthly update on the most relevant topics about practical Risk Management.

We wish you a happy reading!

Antonio Castagna
Luca Olivo
Giulia Perfetti

Just in Time

iason Notes

ECB - Aggregated Results of SREP 2023

The 2023 Supervisory Review and Evaluation Process (SREP) for banks supervised by the ECB confirm that the banking sector continues to show strength.

It has maintained robust capital and liquidity positions against the backdrop of an uncertain economic environment, Russia's war against Ukraine, high inflation leading to fast-paced interest rate hikes, and market turmoil following the bank failures in the United States and Switzerland.

read more

Date January 2024

ECB - SSM Supervisory Priorities 2024-2026

The SSM supervisory priorities reflect ECB Banking Supervision's medium-term strategy for the next three years and rest on a comprehensive assessment of the main risks and vulnerabilities for supervised institutions.

They take into account the outcome of the Supervisory Review and Evaluation Process (SREP) and progress made on the priorities from previous years

Supervised institutions have navigated the adverse macro-financial and geopolitical shocks of recent years well.

read more

Date January 2024

BCBS Consultative Document: Recalibration of Shocks for Interest Rate Risk in the Banking Book

In this paper, published in December 2023, the Basel Committee (BSBC) aims to propose a new methodology for calculating interest rate shocks in the Interest Rate Risk in Banking Book (IRRBB) framework.

In the first part of the paper, a small overview of the current methodology for calculating interest rate shocks is proposed.

read more

Date January 2024

EBA Consultation Paper Draft Guidelines on the Management of ESG Risks

ESG risks, in particular environmental risks through transition and physical risk drivers, pose challenges to the safety and soundness of financial institutions and may affect all traditional categories of financial risks to which they are exposed.

In this context, the European Banking Authority has issued in January 2024 a Consultation Paper on Guidelines on the management of ESG risks, with the aim to ensure the resilience of the business model and risk profile of institutions in the short, medium and long term, by setting dedicated requirements for the internal processes and ESG risks management arrangements that institutions should have in place.

read more

Date March 2024

ECB Report on Risks from Misalignment of Banks' Financing with the EU Climate Objectives

Risks stemming from the transition towards a decarbonised economy can have a significant effect on the credit portfolio of a financial institution. These transition risks are drivers of credit, market, operational and liquidity risk. If the transition towards a decarbonised economy becomes disorderly, there will be a growing need to quantify the transition risks in banks' credit portfolios.

On 23 January 2024, the European Central Bank published a report focusing on the transition risks stemming from banks' portfolio.

read more

Date March 2024

BIS - Progress in Adopting the Principles for Effective Risk Data Aggregation and Risk Reporting

The Basel Committee on Banking Supervision published a progress report on banks' implementation of the BCBS 239 Principles for effective risk data aggregation and reporting.

Nearly ten years after the initial publication of the BCBS 239 principles and seven years after the expected date of compliance, banks are at different stages in terms of aligning with the Principles.

The global pandemic and recent stress events provided a stark reminder that banks' ability to manage risk-related data is essential for sound decision making.

read more

Date Janaury 2024

iason Weekly Insights

Regulatory/Supervisory Pills

Among iason's various publications we also find the iason Pills.

With these daily Pills, iason aims to offer a summary on information, mostly, of the main regulatory and supervisory news in the banking and finance sector on both Pillar I and Pillar II risks of the Basel framework. The main purpose of these publications is to give the reader an effective, timely and brief overview of the main topics of the moment.

The authors of the Iason Pills are Dario Esposito and Cecchin Matteo.
read more

Market View

Among iason's weekly insight you can also find the iason Market View, a weekly update on financial market by Sergio Grasso.

The author, with almost three decades of investment experience, presents an accurate analysis of market fluctuations of the week, giving a critical view of observed phenomenos and suggesting interesting correlations with the main world events.
read more

GOVERNANCE. METHODOLOGY. TECHNOLOGY.

iason is a company specialised in advanced solutions for the **Risk Management** of **Financial Institutions.**

We provide highly qualified **consulting services** in the **methodological** and **technological** fields, together with targeted support for **Data** and **Model Governance** projects in risk frameworks.

We strongly believe in **Research** because we want to guarantee our clients services and solutions that are always at the forefront of **Regulatory** and **Modelling** requirements.

ARGO MAGAZINE

Quarterly magazine on the new frontiers of Risk Management

RESEARCH PAPER SERIES

Research articles on innovative and advanced methodologies in the financial sector

JUST IN TIME

Real-time updates on regulatory changes

FOLLOW US!

iason ESSENTIAL SERVICES FOR FINANCIAL INSTITUTIONS

EBA Report on the Role of Environmental and Social Risks in the Prudential Framework

About the Authors

Dario Esposito:
Chief Risk Regulatory Officer
Experienced professional with a demonstrated history of working in the financial services industry. Skilled in Enterprise Risk Management, Basel III and IV and AML. Strong finance professional postgraduated from University of London and IMD in Lausanne (International Institute for Management Development).

Matteo Bazzucchi:
Business Analyst
He holds a BS in Economics. Currently, he is an undergraduate student in the MSc in Quantitative Finance at University of Perugia. He joined Iason in 2023, mainly working on the developing of a model for monitoring and managing prepayment on loans.

Pierpaolo Carrozzino:
Business Analyst
He holds a master's degree in Intermediaries, International Finance, and Risk Management from Sapienza University of Rome. He worked in the Banking Regulation sector for a year and then moved to the risk management field. Currently, he has been working on the Risk Data Aggregation and Risk Reporting (RDARR) project in one of the major Italian banks.

Lorena Corna:
Manager
She holds a master degree in Economics and Finance from University of Milano-Bicocca. She worked within the Risk IT dedicated team of a big pan European on the back-testing model for Counterparty Credit Risk. Currently, as functional leader, she supports several Market Risk projects. In addition, she is responsible for the AML/CFT research division of iason.

Alessandro Prati:
Business Analyst
He holds a MSc in Economic and Finance obtained at the University of Milano-Bicocca. He joined iason in 2021 working on projects mainly focused on Market Risk. He supported with a dedicated team of a major European bank the integration of ESG factors into market risk. He is currently working on several regulatory projects.

This document was prepared in collaboration with Matteo Cecchin and Vicenzo Frasca, who at the time were working for Iason Consulting.

EBA Report on the Role of Environmental and Social Risks in the Prudential Framework

Dario Esposito Matteo Bazzucchi Pierpaolo Carrozzino Matteo Cecchin
Lorena Corna Vincenzo Frasca Alessandro Prati

Risks stemming from environmental and social (E&S) issues are changing the risk picture for the financial sector[1]. Through their effect on traditional categories of financial risks, such as credit, market and operational risks, environmental and social factors are expected to contribute to risks more significantly to both individual institutions and financial stability. This highlights the need to enhance the prudential framework to better account for environmental and social risks.
On May 2nd, 2022, the EBA published a Discussion Paper[3], which initiated the discussion on the appropriateness of the current Pillar 1 framework to address those new risks and on October 12th, 2023 the EBA published the final report[7]. The final version initiates a series of reports expected to be delivered over the upcoming years in accordance with Capital Requirement Regulation (CRR3) and complements past and ongoing EBA initiatives aiming to incorporate environmental risks across all pillars of the regulatory framework in line with the EBA's Roadmap on Sustainable Finance.
The report proposes targeted enhancements to the current Pillar 1 framework, which can be implemented in the short term and in the medium-long term, while preserving its integrity and purpose.

Economies and societies are increasingly facing the complex and severe consequences of climate change. This could lead to an increase in risks to individual banks as well as financial stability. The specific characteristics of these risks, particularly their multidimensional, non-linear, uncertain and forward-looking nature, could lead to their underestimation, at a time where the materialisation of these risks is likely to accelerate. This highlights the need to enhance the prudential framework to better account for environmental and social risks.
On May 2nd, 2022, the *EBA released a Discussion Paper* (DP) on the role of environmental risks in the prudential framework[3]. This DP included an initial analysis of the framework and identified areas for further study. Its aimed was to initiate a discussion and collect various opinions and inputs for a comprehensive examination of these complex issues. The feedback received on this DP, together with the findings of the Commission High-Level Expert Group on Sustainable Finance as well as the European Systemic Risk Board's (ESRB) work on this area have been used as inputs to the final report. The final report[7] published on October 12th, 2023 explores the appropriateness and feasibility of possible clarifications and targeted enhancements to better reflect the importance of environmental and social risk drivers in the prudential framework, focusing on those elements of the framework which are most likely to be affected by environmental risk drivers and hence where the analysis is most relevant. The report proposes targeted enhancements to the current Pillar 1 framework, which can be implemented in the short term and in the medium-long term.

The EBA considers, at this stage, that the most consistent way forward from a prudential risk-based perspective is to address environmental risks through effective use of and targeted amendments to the existing prudential regime (i.e. introducing specific risk-weighted adjustment factors) rather than through dedicated treatments such as supporting or penalising factors. More comprehensive changes to the Pillar 1 framework are warranted only where a clear link between E&S factors and traditional categories of financial risks can be established. EBA will monitor, as part of its continuous dialogue with competent authorities, the extent to which and how institutions incorporate environment-related forward-looking information into their risk and financial models.
Finally, the report identifies regulatory reporting as one of those areas where further work is needed to enable the collection of relevant and reliable information on environmental risks and their impact on financial losses of institutions. In this context, the EBA will propose amendments to its supervisory reporting and disclosures framework, including the progressive development of environment-related concentration risk metrics.
The report acknowledges that various components of the sustainable finance regulatory framework are still in the early stages of implementation. As the sustainable finance framework develops, future work on prudential treatments may need to incorporate new policy tools and options. The EBA will continue strengthening the integration of E&S risks across all pillars of the regulatory framework, hence contributing to supporting the transition towards a more sustainable economy, while ensuring that the banking sector

[1]The EBA report proposes targeted enhancements to the current Pillar 1 framework only on environmental and social (E&S) risks, not on governance (G) risks. In fact, EBA is of the view that it is a bit too early to consider exposures with governance objective and impact into the prudential framework, given the current limited evidence related to the impacts of such aspects on pillar 1 risks.

remains resilient.
Moreover, on January 18th, 2024, EBA launched a public consultation on *draft Guidelines on the management of Environmental, Social and Governance (ESG) risks*[2]. The draft Guidelines set out requirements for institutions for the identification, measurement, management and monitoring of ESG risks, including through plans aimed at addressing the risks arising from the transition towards an EU climate-neutral economy. The consultation is scheduled until April 18th2024; it is planned that the guidelines will be finalised by end-2024 and apply depending on CRD6 application date.

Principles and Challenges

Principles and Premises

EBA is following a risk-based approach to ensure that prudential requirements reflect underlying risks and ultimately support institutions' resilience to all risks. This includes, from a microprudential perspective, making sure that prudential requirements reflect the underlying risk profiles of exposures associated with environmental objectives and/or social objectives/subject to environmental and/or social impacts, hence supporting the safety and soundness of individual financial institutions. From a macroprudential perspective, this would mean safeguarding financial stability, by ensuring the robustness of the banking sectors, with a view to mitigating potential systemic vulnerabilities of the financial sector, stemming from environmental risks.
The analysis is not aimed at using prudential regulation to increase demand for environmentally and socially sustainable assets or penalise environmentally and socially harmful assets, the EBA is of the view that a dedicated prudential treatment which would explicitly aim to redirect ending could have undesirable or unintended consequences, which could have an impact on financial stability.
A risk-sensitive prudential framework can contribute to facilitating the recognition of the impacts of environmental and social risks on financial risks, hence ensuring that these risks are adequately capitalised and are better reflected in pricing. In the considerations reported in this report, an important concept to take into consideration is that of dual materiality: institutions can be impacted by or have an impact on environmental and social risks at the company level. A risk-sensitive prudential frameworks should thus take both dimensions into account to the extent that they affect the different prudential risk categories.
Regarding the risk categories, environmental and social risks should not be understood as entirely new categories of risks, but rather as risks that drive the traditional categories of financial risks through a variety of transmission channels. The main risk drivers of environmental risks are physical and transition risks, whereas social risks can be driven by environmental risks, changes in social policy and changes in market sentiment on social factors.

Challenges

Data Availability and Measurement Challenges

The existence of data gaps and other challenges in the context of identifying and measuring ESG risks makes it difficult to properly discriminate exposures subject to higher ESG risks. The list below provides a non-exhaustive list of frequently observed challenges:

- **Availability of relevant, high-quality, and granular data:** the various existing and forthcoming sustainability disclosure initiatives are expected to increase both the availability and quality of environmental data.
- **Lack of a common, standardised and complete classification system:** definitions of what can be considered environmentally and socially sustainable remain fragmented across exposure types and jurisdictions. Furthermore, these definitions tend to be binary, which is not ideal for distinguishing between different levels of environmental and social sustainability and their associated risks, as there can be various degrees of sustainability.
- **Challenges in linking non-financial forward-looking ESG information to prudential parameters:** estimating the probability of materialisation of physical risks poses significant challenges. Making a clear and robust link between the forward-looking dimension of these risks and the prudential parameters used in the regulatory framework remains a challenge.
- **Challenges in the use of ESG ratings or scores:** these can suffer from poor quality, a limited and varying scope, and lack of transparency on underlying methodologies used.
- **Complexity of analysis:** the granularity of classifications for what can be considered environmentally and socially sustainable may vary across different exposure classes. Complexity is further increased by the difficulties around defining common forward-looking indicators.

Challenges in the Estimation of Losses due to Environmental and Social Risks

The prudential framework is calibrated based on historical data, including market prices and expert judgement complementing the empirical results. Historical data, as well as current market prices, are unlikely to fully reflect environmental and social risks, which are more forward-looking in nature.
While there is generally a level of conservativeness embedded in the Pillar 1 framework, environmental risk drivers are expected to become more prominent going forward, and the data stemming from stressed or downturn periods in financial markets already observed during the past macroeconomic or financial crises may not be appropriate to capture environmental risks. Compared to environmental risks, the estimation of financial impacts stemming from social risks presents additional challenges in terms of data availability and how social risks may affect the price of financial assets. Therefore, the capture of social risks under the Pillar 1 framework would appear at this stage to be premature.
Nevertheless, while institutions operate in ever-changing conditions, the prudential framework remains stable over time in a way that it allows for these changes to be mechanically captured. The adaptive nature of the prudential framework to some extent allows these changes to be captured through the inputs to the prescribed calculation of own funds requirements. Therefore, this highlights the need to clarify which aspects of the Pillar 1 framework will capture changes driven by environmental risks over time, as risks materialise and data evolve, and what further amendments may be needed to maintain a prudent calibration. It is also necessary to assess the already existing tools making for capturing the forward-looking perspective in the Pillar 1 and in other parts of the prudential framework.

Time Horizon Considerations

Environmental risks present challenges to the effectiveness and relevance of the Pillar 1 framework. One key issue is the potential mismatch between the framework's time horizon and the long-term nature of environmental risks. Pillar 1 is designed for short-term economic fluctuations, while environmental risks manifest over the long term with uncertainty in their exact impact. In addition, environmental risks are also characterised by the uncertainty on their exact manifestation and magnitude, with a potential to create structural shifts (non-linearity) and to cause losses over an extended period of time. Therefore, it is unclear if the business cycle concepts and assumptions that are used in estimating risk weights and capital requirements are sufficient to capture the emergence of these risks. It could therefore imply that the existing Pillar 1 framework may not be able or well-founded to capture the full loss potential stemming from environmental risks, especially over long-time horizons. In this context, conceptual issues should also be considered regarding the relevant time horizon which should be reflected in the prudential framework. For this purpose, the role of the Pillar 1 own funds requirements should be recalled, considering that other parts of the regulatory and prudential framework can also contribute to address the forward-looking and long-term aspects of environmental risks.
In the remainder of this paper, it is possible to find the **focus on the main risks impacted by environmental and social risks** (credit risk, market risk, operational risk, liquidity risk and concentration risk) where the different elements of the prudential framework and the way in which they interact are treated with environmental and social risks. Within each chapter it is also possible to find a box with the **EBA Policy Recommendations** for each type of risk covered. Finally, given the potential concerns for systemic risk arising from environmental and social risk factors, how the **capital buffer and the macroprudential framework** interact with such risk factors is addressed in an ad hoc chapter.

Credit Risk

In general, existing literature about credit risk shows that there is a potential link between credit risk and environmental and social factors. This is more prominent for what concerns environmental aspects, both in the form of transition and physical risks, which have been shown to have potential adverse impact on the level of credit risk of a counterparty. At the same time, the literature shows the presence of inherent challenges and difficulties related to the quantification of the effects of environmental risks on credit risk exposures. This is primarily due to the difficulties related to the modelling of environmental phenomena themselves, as well as to the determination of the probability at which a given environmental risk can materialise. Nevertheless, it is without doubt that not considering environmental risk in relation to credit risk would lead to an underestimation of the latter.
Against this background, EBA has analysed how E&S risks could be integrated into the existing Pillar 1 credit risk framework which, under the Basel framework, foresees two different approaches for the calculation of own funds requirements against credit risk: the Standardised Approach and the IRB (Internal Ratings-Based) Approach. The interaction of each of these approaches with E&S risks is treated more in detail in the following.

Standardised Approach

The **Standardised Approach** (SA) for credit risk, which is the simplest of the Pillar 1 approaches for this risk, is based on a simple weighting of the institution's exposures (net of credit risk adjustment) using a set of supervisory determined risk weights, which depend on the exposure class and, in some cases, may be determined through external credit assessments.
In this context, there are several areas of interaction of the framework with E&S factors:

- **External Credit Assessment**;
- **Due diligence**;
- **Credit Risk Mitigation techniques**;
- **Prescribed risk weights for corporate and retail exposures**.

External Credit Assessment

So far environmental and social factors seem to be captured unevenly across credit rating agencies (CRAs) and sectors. EBA believes it important to consider the inclusion of such factors as a driver of credit risk in the external credit assessment performed by CRAs, and to provide transparent disclosure to the public on the methodologies used so as to allow comparability across different rating agencies and to evaluate the robustness of the different methodologies used. On the other side, EBA deems it premature to foresee explicit adjustments to the factors used for calibrating the mapping of External Credit Assessment Institutions (ECAIs) ratings with the prudential scale of credit quality steps[10], also to avoid potential risks of double counting which could materialise once environmental risks are better captured into external credit risk assessments.

Due Diligence

The prudential framework provides due diligence requirements for institutions on the adequacy of external ratings if they are used for the calculation of own funds requirements. EBA believes that such due diligence requirements should be broadened to explicitly integrate environmental aspects within the prudential framework, also in line with the BCBS clarifications issued in December 2022[1]. However, EBA notices that this requirement for adequate due diligence should not replace the ECAIs' role in the appropriate consideration of such aspects within the external credit assessment.

Credit Risk Mitigation Techniques

The SA allows for the recognition of Credit Risk Mitigation (CRM) techniques, making a distinction between funded (FCP) and unfunded credit protection (UFCP).
The framework for FCP refers to financial collateral, whose value may deteriorate over time also because of environmental risks. For prudential purposes, the FCP can be managed with two different approaches: the simple approach, under which an institution replaces the risk weight of the counterparty with the risk weight it would assign if it had direct exposure to the market value of the collateral instrument for the secured part of the exposure, and the comprehensive approach, which allows the exposure amount to a counterparty to be reduced by the market value of any eligible collateral, subject to haircuts to take into account potential value fluctuations due to market movements. For the simple approach, the environmental due diligence considerations presented in the previous section should apply to the resulting risk weights, while for the comprehensive approach

institutions should check for concentration risks to collateral with significant exposures to environmental risks as part as the current concentration risks requirements.
On the other side, by using UFCP the institution relies on a payment from the protection provider upon default of the obligor; in this case, the CRM may be recognized when calculating capital requirements by applying a substitution approach, where institutions replace the risk weight of the counterparty with the risk weight of the guarantor or the protection provider for the protected portion of the exposure, while the unprotected portion remains with the risk weight of the counterparty. For this type of CRM, environmental due diligence considerations presented in the previous section should apply to the resulting risk weights.
Finally, for exposures secured by physical collateral (where immovable property is the only type of physical collateral recognised under the SA), the current collateral re-evaluation requirements set out minimum frequencies at which collateral should be monitored, allowing to incorporate the evolving nature of environmental risks over time as market values are expected to increasingly embed environmental risks.
Considering what described above, regarding CRM techniques EBA deems not necessary to foresee specific interventions, as E&S factors may be embedded in the current CRM framework through market prices used for valuation and re-evaluation of financial collateral, while regarding UFCP and FCP, as described above, due diligence considerations should be applied on the risk weights resulting from the application of CRM techniques.

Prescribed Risk Weights for Corporate and Retail Exposure

For what concerns corporate exposures, which may be risk-weighted based on an external credit assessment issued by a nominated ECAI, EBA believes that risk sensitivity to E&S factors can be increased implicitly as the external ratings tend to better incorporate such factors.
Regarding retail exposures, at this stage EBA deems a review of prescribed risk weights complex and challenging, since differently from corporate exposures it is far less clear to determine which of the retail exposures could be considered green or environmentally harmful, and the related additional information in this regard is much more limited. Therefore, any intervention regarding risk weights for retail exposures will be reassessed by EBA over time.

IRB Approach

In contrast to the standardised approach, under the **IRB approach** institutions calculate own funds requirements by determining four regulatory parameters: the Probability of Default (PD), the Loss Given Default (LGD), the Credit Conversion Factor (CCF) and the Maturity (M).
Regarding the IRB approach, EBA has analysed its potential interaction with E&S risks taking into consideration the different steps which constitute the estimation process and the determination of own funds requirements according to this approach:

- **Definition of the Reference Data Set (RDS):** this step refers to the collection of all necessary data to be used for the model development;
- **Risk differentiation of the rating system:** in this step, the model is estimated with the objective of allowing for a meaningful discriminatory power and to ensure the grouping of sufficiently homogeneous obligors/facilities into the same grade or pool;
- **Risk quantification of the rating system:** in this step, institutions estimate PD, LGD or CCF by grade or pool coherently with the long-run average realisations of such parameters;
- **Application of the rating system to the current portfolio:** in this step, the risk estimates obtained through the previous steps are assigned to each exposure in the application portfolio of the institution;
- **Calculation of own funds requirements:** in this last step, the estimated risk parameters are plugged into the applicable Risk-Weight (RW) formula and the related own funds requirements are calculated.

Reference Data Set (RDS)

E&S risks may appear not to be directly linked with the mere identification of the defaults nor with the actual calculation of realized LGDs and CCFs; however, E&S risks could be considered as additional indications of unlikeliness to pay. In this regard, EBA believes that institutions shall have a process to obtain and update relevant and material E&S-related information on the borrowers' financial condition, as part of due diligence during the onboarding process and ongoing monitoring of the borrower's risk profile. At the same time, EBA acknowledges that the identification of materially relevant E&S risk drivers is not trivial and may pose challenge for institutions in ensuring the comprehensiveness of the RDS. In this context, the EBA will further investigate and assess whether relevant E&S risk drivers across different types of exposures shall be added to the corresponding lists of risk drivers referred in the EBA GL on PD and LGD estimation[6].
Regarding LGD estimation, one specific element of the RDS refers to the valuation of collateral. The current framework already requires institutions to establish internal requirements for collateral management, legal certainty and risk management; however, the EBA believes that additional requirements related to E&S risks could be specified in the *Commission Delegated Regulation (EU) 2022/439 on Assessment Methodology*[11] and in the *EBA GL on CRM*[4] .

Risk Differentiation of the Rating System (Model Development)

In the model development phase, institutions should consider all relevant information when assigning obligors or facilities to grades or pools, leveraging on information which should be current and enable the institution to forecast the future performance of exposures. In this context, E&S risks may already be factored in, to the extent that they are part of the RDS and have led to a materialisation of defaults, realised losses or drawdowns. In addition, it should be recalled that the design of the model leaves room for some human judgment, including the possibility to have subjective input data via expert judgment, which could be used to capture E&S risks in the rating system even if they could not be translated into observable metrics.
Regarding the incorporation of E&S risk drivers, these should only be incorporated to the extent that they are expected to translate into credit risk in a relatively short term. For missing relevant E&S risk drivers, as soon as the related defaults and losses start to materialise, the deterioration of the model performance would be assessed in an early phase through the existing mechanism of annual review of estimates, with the potential for a redesign of the rating system.
In consideration of the above, EBA believes that, at this stage, E&S risks should only be taken into account in the risk differentiation step via additional risk drivers under

the existing requirements and under the condition that sufficient information is available without materially decreasing the overall performance of the model. It is also important to note that any model assumption, particularly expert judgement, should be regularly assessed and challenged as per existing requirements.

Risk Quantification of the Rating System (Model Calibration)

To reflect E&S risks in the parameter estimates, considering that the estimation is performed at aggregate level (rather than at borrower/facility level), a possible way would be to introduce some calibration segments, where the risk quantification would be performed separately between exposures impacted or not by E&S-related financial risks. This approach would come with the difficulty of identifying risk drivers able to discriminate between positions exposed and not exposed to E&S risks.
With reference to the situation where an institution maps its internal grades to the scale used by an ECAI or similar organisation and then attributes the default rate observed for the external organisation's grades to the institution's grades, it should consider whether the scale used by the external institution reflects material climate-related financial risks.
Regarding the downturn requirements for LGD and CCF estimates, EBA does not consider that the nature of the economic downturn should be amended to incorporated dedicated E&S references in the form of specific additional E&S indicators to be considered for the identification of the downturn period.
For what concerns finally the application of MoCs to risk estimates to address deficiencies and uncertainties in the data or modelling methodologies, EBA believes that MoC of types A&B may be introduced related to E&S risks only if they are based on observed data and appropriate methods and are reviewed regularly by institutions.

Application of the Rating System

With respect to the application of the model, considering the challenges of setting up a comprehensive E&S risk-related overrides policy (i.e., difficulty in selecting relevant E&S risk drivers and E&S information in general, as well as in the possibility to integrate forward-looking drivers that will not materialise in the short term), the EBA believes that specific overrides could be used to address some specific, individual cases, where only a limited and well-justified number of the exposures within the range of application of the rating system is affected by E&S risks, until the relevant drivers are incorporated into the model.

Calculation of Own Funds Requirements

With respect to the calculation of own funds requirements, while the risk weight (RW) formula does not explicitly refer to E&S risks, it includes elements which to some extent may indirectly capture certain E&S aspects.
In this context, the EBA started the reflection on whether further differentiation could be introduced in the RW formula based on E&S risks, and in particular on the relationship between the capital requirements and the systemic risk. Theoretically, such differentiation could be justified if the status of the economy impacts E&S harmful assets or assets subject to E&S impacts to a different degree from other exposures, i.e., if the risks faced by such assets are less idiosyncratic and more systematic in nature. For example, exposures subject to transition risk are likely to be all affected by sudden public policy changes. This would, however, come with difficulties like the ones previously mentioned in the development and application of the model:

- It would be difficult at this stage to find common and objective differentiating factors (for instance, exposures subject to transition risk may not be equally affected by policy changes depending on their transition plans);
- It would also be difficult to determine appropriate levels of any adjustment, given the lack of evidence supporting the calibration;
- This regulatory adjustment could potentially take various forms and hence the exact functional form of the adjustment would have to be carefully considered to ensure the overall consistency and robustness of the framework;
- Double counting should be avoided between the potential adjustment and the estimates used as inputs to the formula (in particular, the downturn estimates).

Against this backdrop, the EBA does not consider that further differentiation in the RW supervisory formula based on E&S risks is a feasible option at this stage.

Slotting Approach

The **Slotting Approach** is a simplified approach to calculate RWAs for specialised lending exposures that can be used by institutions where they are not able to estimate PDs. It makes extensive use of human judgement in the form of subjective input data. Environmental risk drivers are not directly mentioned in the set of sub-factors to be considered according to the current rules, but they are indirectly captured by some of the sub-factors (e.g., "insurance against damage", "political and legal environment", etc.) and can be added as additional sub-factor components.
In this regard, EBA considers that it is relevant to bring the clarifications provided by BCBS in FAQ 8[1] into the *Commission Delegate Regulation (EU) 2021/598 on Slotting Approach*[9]; this FAQ provides that, when performing the assessment of the category of the sub-factor components, banks should analyse how climate-related financial risks could negatively impact the assignment into a category, also taking into consideration whether climate-related financial risks have been adequately mitigated (e.g., via insurance coverage against physical climate risks).
At the same time, EBA believes that changes to the RW calibration are not a feasible option at this stage.

Foundation-IRB (F-IRB) Approach

Under the **Foundation-IRB (F-IRB) Approach**, which is available for all non-retail exposures, institutions must use regulatory values for the LGD and CCF parameters. The EBA notices that, in this case, the drivers used for the differentiation approach indirectly and partially already capture E&S risks. As a matter of fact, leaving aside the CCF, for which the impact of E&S risks would be expected to be generally more limited, for LGD it is worth noting that the drivers used for the differentiation in this approach indirectly and partially capture E&S risks. This is because, apart from the seniority of the exposures and their exposure class, the LGD values depend on the credit risk mitigation associated with each exposure, which factors in E&S risks indirectly (e.g., via the value and haircuts used for funded credit protection, and via the credit risk of the guarantor for unfunded credit protection).

List of Policy Recommendations	
CR-SA-1	As a short-term action, EBA recommends that external credit assessments integrate E&S factors as drivers of credit risk whenever relevant.
CR-SA-2	As a short-term action, EBA recommends that cas verify that due diligence requirements explicitly integrate environ- mental aspects.
CR-SA-3	A medium- to long-term action, EBA will monitor that financial collateral valuations increasingly reflect environmental factors.
CR-SA-4	As a medium- to long-term action, EBA will assess whether high-quality specialised lending corporate exposures introduced in CRR3 could be subject to similar environmental provisions as under the infrastructure supporting factor.
CR-SA-5	As a medium- to long-term action, EBA will reassess whether environmental risks should be considered in evaluating the appropriateness of risk weights assigned to real estate exposures.
CR-SA-6	As a medium- to long-term action, EBA will reassess how E&S risks can be reflected in prescribed risk weights in the SA.

TABLE 1: *Policy Recommendation on Credit Risk - Standardised Approach*

At the same time, EBA notices that the general calibration of risk parameters could be reassessed considering future E&S risks, but not at this stage, given the lack of evidence on risk differentials and the respective levels of losses.

General Considerations on Stress Tests

According to Article 177 of the CRR, institutions using an IRB approach to determine their own funds requirements for credit risk are required to have in place sound stress testing processes and regularly perform a **credit risk stress test** to assess the effect of certain specific conditions on their total capital requirements for credit risk.
The exact design of the stress test is currently left to the institution, though subject to a supervisory assessment. In any case, the test should be meaningful and consider the effects of severe, but plausible, recession scenarios. While there is no impediment under the current framework to incorporating E&S components in their stress test scenarios, the new CRR3 is expected to explicitly require institutions to include ESG risks, in particular physical and transition risks stemming from climate change, in their stress test scenarios, when considering severe but plausible recession scenarios. This would be also in line with FAQ 11 provided by the BCBS[1], which foresees that banks should iteratively and progressively consider climate-related financial risks that affect the range of possible future economic conditions in their stress testing processes.
In consideration of what described above, EBA provides some policy recommendations on the interaction of credit risk and E&S risks, which are summarised in *"Table 1"* and *"Table 2"*.

Collateral Valuation

EBA highlights how recent studies show evidence of the incorporation of environmental aspects in **immovable property collateral valuation**. In particular, it is highlighted the presence of a market premium for green buildings, and similarly, that buildings that are not classified as green/sustainable are subject to a reduction in rent and prices compared to green/sustainable buildings. This shows that adding green or sustainability features to buildings might lead to a shift in asset values.
These statistics suggest that market practices and valuation standards are increasingly accounting for environmental aspects in the valuation of immovable property collateral.
The prudential framework also accounts for some environmental aspects in the valuation of immovable property collateral. Indeed, the CRR requires institutions to monitor the value of immovable property collateral also considering environmental factors, as well as to hold insurance against the risk of damage to buildings. In addition, regarding the monitoring and revaluation of the immovable property collateral, CRR3 is expected to explicitly require institutions to consider modifications made to the property that unequivocally increase its value, such as improvements in energy efficiency or to the resilience, protection and adaptation to physical risks of the property, as well as to consider the possibility that the current market price of the collateral be significantly above the value that would be sustainable over the life of the loan. In doing so, institutions are expected to consider the future impact of environmental factors and adjust the valuation accordingly.
To conclude, it is worth noticing that also the EBA GL on Loan Origination and Monitoring[5] require that, when applicable, institutions should consider ESG factors affecting the value of the collateral.
In consideration of the above, EBA suggests some policy recommendations related to the interaction of collateral valuation and E&S risks, summarised in *"Table 3"*.

Environmental Adjustment Factors

The current credit risk prudential framework foresees two **non-risk based supporting factors** which aim to support lending to certain sectors, namely **Small and Medium Enterprises** (SMEs) and **infrastructure projects** (ISF).
In general, EBA believes it not appropriate to rely on supporting factors to address environmental risks; however, similar adjustment factors to be applied for environmental purposes have been suggested by stakeholders to increase

List of Policy Recommendations	
CR-IRB-1	As a short-term action, the EBA recommends that E&S risks be taken into account in the risk differentiation, the risk quantification and in the application phase and recommends incorporating BCBS faqs 8 to 15 into the existing regulatory framework.
CR-IRB-2	As a medium- to long-term action, the EBA will further investigate whether E&S drivers should be added to the corresponding lists of risk drivers referred in the EBA GL on PD and LGD estimation.
CR-IRB-3	As a medium- to long-term action, as the impact of E&S risks on defaults and loss rates become available, the EBA recommends that institutions reflect E&S risks in PD and LGD estimates respectively.
CR-IRB-4	The EBA considers it, at this stage, premature to consider further differentiation in the RW supervisory formula, the risk weights applied under the slotting approach and the F-IRB parameters, while recommending bringing the clarifications provided by BCBS FAQ 8 directly in the CDR on Slotting approach.
CR-IRB-5	As a medium- to long-term action, the EBA will reassess the appropriateness of revising the RW supervisory formula, the risk weights applied to the specialised lending under the slotting approach and the F-IRB parameters.
CR-IRB-6	As a short-term action, the EBA recommends institutions to consider E&S risk as part of their stress testing programs.

TABLE 2: *Policy Recommendation on Credit Risk - IRB Approach*

List of Policy Recommendations	
CR-COL-1	As a short-term action, the EBA recommends that institutions account for relevant environmental factors in the prudent valuation of immovable property collateral, and they should make adjustments when the current market value does not adequately address relevant risks associated with environmental factors. This includes climate-related transition risk and physical risk, as well as other environmental risks, and should cover valuation at origination, re-valuation and monitoring.
CR-COL-2	As a short-term action, the EBA will continue monitoring how environmental factors and broader ESG factors are reflected in the value of collateral, with due consideration of national specificities that may exacerbate environmental risks.

TABLE 3: *Policy Recommendation on Credit Risk - Collateral Valuation*

capital requirements for environmentally harmful exposures (*"brown penalizing"* factors) and to decrease them for environmentally sustainable exposures (*"green supporting"* factors). The EBA has analysed them from a prudential perspective[2], highlighting the related pros and cons, which are shown in the *"Table 4"*.
In consideration of the balance of arguments presented above, and given the conceptual and operational challenges related to environmental adjustment factors, as well as the lack of evidence, data and methodologies for identifying and quantifying environmental risk drivers at this stage, the EBA does not recommend introducing environment-related adjustment factors so far. It indeed believes that some prerequisites should be met before such adjustment factors could be justified. These include:

- Acquiring clear evidence that certain assets display distinct risk profiles due to environmental risk drivers;
- Establishing that the framework cannot capture these risk drivers;
- Overcoming classification challenges which currently hamper the identification of exposures to which adjustment factors could apply;
- Benefitting from a high-enough degree of comfort on impacts and potential unintended effects.

Regarding the introduction of specific environmental adjustment factors, the EBA suggests the policy recommendations reported in *"Table 5"*.

[2]EBA has analysed pros and cons of environmental-related adjustment factors also from a public policy perspective, which is however not the approach taken and supported by the EBA to determine prudential requirements. Therefore, for the sake of simplicity, the results of the public policy assessment are not represented in this paper, which focuses on the prudential perspective.

Market Risk

The CRR and related technical standards and guidelines set out the fundamentals on market risk treatment, well known as **Fundamental Review of Trading Book (FRTB)** that will be effective in 2025. The Trading Book could be impacted by the environmental risk via multiple channels: in the next paragraphs, the impact of transition and physical risks on equity, credit spread as well as commodity risk will be exanimated.
As outlined by EBA, the liquidity horizon, environmental risk factors represent the common risk environmental elements between **Standardized Approach** (SA) and **Internal Model Approach** (IMA). Concerning the liquidity horizon we can distinguish between the physical risk (that it materializes instantaneously) and the transition risk (that is a gradual process through time): the first one, due to its features, can be included also in a short liquidity horizon; instead, the last one is market risk relevant as in the credit risk. Furthermore, in the literature has been analysed the possible impact of ESG risks on market risk of financial instrument: the studies highlighted that ESG ratings or scores enhance the traditional market risk figures (e.g. VaR), i.e. the issuers with high ESG standings are usually linked to lower observed historical volatility or market risk. Regarding the risk factors, the latter are a well-defined object and the environmental risk does not add a new risk factor per se, i.e. the environmental risk could increase the risk factor volatility, as confirmed by empirical evidences. However, for a specific financial instrument like ESG-linked products, the environmental risk can be recognized with dedicated risk factors.

FRTB Standard Approach

Within the **Standardized Approach** (SA), the regulation defines that the risk weights that are calibrated on appropriate historical data (i.e. on a stress window that covers the global financial crisis). Therefore, a possible solution to recognize the environmental risk is represented by the inclusion of forward-looking climate scenarios but it could reduce the risk sensitivity of SA. An alternative is represented by a new environmental risk class where the equity and credit-spread risk factors exposed to environmental risk are inserted: with this solution, that the existing FRTB SA risk classes should not be impacted, the market risk requirements related to environmental risk could be readily recognized in regulatory reporting and diversification among the environmental risk factors could be possible. Both options require the issuers assignment to buckets based on their environmental riskiness, i.e. via defined risk factor set and a flat penalty factor damages the SA risk sensitivity. In case of ESG financial instruments, i.e. trades with new ESG factors that are used in the pricing function, could be managed via **Residual risk add-on** (RRAO) charge otherwise the new risk class creation could be considered.

FRTB Internal Model Approach

The **Internal Models Approach** (IMA) should be able to implicitly capture the environmental risk when it is material, nevertheless it is possible when banks are able to identify the environmental risk factors in the pricing. On the risk factor calibration, it is performed on a stress window and, usually, it is the period covering the 2007-2008 global financial crisis, but it is periodically updated and therefore it could be different to the mentioned one. However, current data could not properly take into account the environmental risk therefore financial institution could be held to adjust their historical data set with the consequent risk of possible double counting effects. The *"ECB guide to internal models"*[8] design a dedicated market risk framework, i.e. **Risk Not In the Model Engine** (RNIME), that supports financial institution to find out the risks excluded in the model engine due, for example, to inadequate historical data: these additional components have been monitored via RNIME and they could generate a RNIME addon. This methodology could be used also for environmental risk to enhance the market risk with several advantages:

- No market data adjustment;
- Financial institution could leverage on existing practices;
- Dedicated environmental add-on;
- Preserve the structure of internal model.

Moreover, the financial institution could be requested to add a validation requirement for modelling environmental risk: this is also quoted in EBA RTS draft that propose the assessment of stress testing programs under the IMA - that should include the environmental risk - of banks starting from January 1st, 2025.
As argued previously, it emerges that environmental risk will tend to increase in the coming years with significant impacts on the risk level of the trading book of financial institutions, both at the physical and transition risk level. Possible solutions to quantify this exposure have been developed for both approaches envisaged in the FRTB. In order to ensure that this evidence is well taken into consideration in the risk management of financial institutions, EBA proposes a series of recommendations actions both short-term and medium- to long-term horizon, summarized in *"Table 6"*.

Pros and Cons	
Pros	1. Adjustment factors could anticipate the risk differential associated with the sustainable transition and correct overreliance on historical data 2. Adjustment factors could represent a readily available option to address environmental risks in the prudential framework and would allow a homogeneous application throughout the EU 3. Adjustment factors penalising environmentally harmful activities would reflect the implicit risk of these assets in a forward-looking manner and strengthen the resilience of institutions 4. A "transition-supporting factor" would support and incentivise counterparties to develop transition-resilient business models and activities 5. Such factors would improve analytical capabilities of institutions, developing methodologies to distinguish "green", "transitioning", "sustainability-linked" or "environmentally harmful"
Cons	1. Adjustment factors lack risk sensitivity, leading to potentially miscalibrated capital requirements and may be a too rigid instrument, failing to take into account the transition developments of industries and companies 2. Adjustment factors might lead to double counting of environmental risks if they are already factored into risk weights (e.g., in internal or external ratings) 3. Activating such a tool to override the outcome of prudentially calibrated RWAs may appear premature in the absence of conclusive evidence on risk differentials 4. Adjustment factors applied in the EU would deviate from international standards and offer opportunities for regulatory arbitrage 5. Adjustment factors present operational and conceptual challenges (e.g., in the definition of the scope of eligible exposures) 6. Adjustment factors could lead to reduced lending scrutiny and, in the case of supporting factors, disproportionate risk taking

TABLE 4: Pros and Cons regarding the Environmental Adjustment Factors

List of Policy Recommendations	
CR-ADJ-1	At this stage, the EBA does not recommend introducing environment-related adjustment factors.
CR-ADJ-2	As a medium- to long-term action, EBA will reassess if and how environment-related adjustment factors could be taken into account as part of a prudentially sound and risk-based prudential treatment of individual exposures.

TABLE 5: Policy Recommendation on Credit Risk - Adjustment Factors

Operational Risk

Operational risk is defined as the risk of loss resulting from inadequate or failed internal processes, people and systems or from external events, including legal risk but excluding strategic and reputational risks. Calculating capital requirements for operational risk under the new Basel framework (Basel III) requires the use of the Standardized Approach (BCBS SA), which includes various components such as:

- **The Business Indicator** (BI), which is an indicator based on an institution's current business volume indicator by amending some of its components;
- **The Business Indicator Component** (BIC) which is obtained by applying fixed marginal coefficients to the BI based on an institution's business volume;
- **The Loss Component** (LC) which includes an institution's average annual historical losses over the preceding 10 years;
- **The Internal Loss Multiplier** (ILM), which is calculated as a smoothing function of the ratio between LC and BIC.

The formula for operational risk capital requirements is: **Operational Risk Capital** = BIC x ILM.
Operational risk could have an impact because of the environmental and social risks (E&S factor).
In this context it is noted that operational risk is inside in all banking activities and can be triggered by various categories of losses resulting from E&S factors. These factors can lead to damage to physical assets, service interruptions, legal risks, and conduct risks. Furthermore, cases of litigation against institutions, such as those related to *"greenwashing"*, could increase in the future and there may be an increase in cases where institutions are held responsible for environmental damage.
Regarding the EBA Taxonomy, the current loss event types do not map the triggers for the losses. Thus, while the loss event type taxonomy remains valid for operational risk management and measurement, institutions could also be asked to label losses to allow them and supervisory authorities to

track the causes, especially those related to environmental risk factors as drivers of the loss type categories.
From the perspective of incorporating the losses related to environmental risks, the methodology captures historical losses via the ILM component. However, due to the discretion of ILM equal to one being exercised in the EU, such information will only be considered in the services component in the BIC, which includes some built-in sensitivity to operational risk losses, including those triggered by environmental factors.
In addition, capital requirements for operational risk are partly based on losses of the past 10 years. However, environmental risks may increasingly materialise in the coming decades with effect in medium-long term. Hence, relying on historical data only might not be sufficient if one wanted to capture a risk materialising in the future. Ways for incorporating forward-looking information in the operational risk framework could therefore be considered, bearing in mind that the new BCBS SA for operational risk measurement currently does not include forward-looking elements.
In conclusion, a key challenge in adapting the operational risk framework is the lack of data to understand how environmental and social factors can negatively impact inherent operational risk. Monitoring events related to physical risk, operational disruptions, or legal and compliance risks due to these factors is currently difficult. Therefore, it is advisable to request financial institutions to identify environmental and social factors as potential triggers for operational risk losses, in addition to considering the existing risk categories.
The BCBS SA methodology currently relies on historical data using the BI and/or ILM, and any potential integration of forward-looking elements would require a revision of the methodology.

Liquidity Risk

EBA highlights the presence of a close relationship between liquidity risk and credit risk. Thus, the effectiveness with which the liquidity framework captures environmental risks depends on the ability of the credit framework to do so. Furthermore, changes in the credit risk framework will have an indirect influence on liquidity requirements.
Liquidity Risks are managed through **Liquidity Coverage Ratio** (LCR) and **Net Stable Funding Ratio** (NSFR).

Liquidity Coverage Ratio (LCR)

This metric was introduced by the Basel Committee in 2013 and implemented in the EU in October 2015 with the Commission Delegated Regulation. The objective of the LCR is to ensure that an institution has a liquidity buffer that allows it to survive in a 30-calendar day severe market-wide or idiosyncratic liquidity stress scenario. Liquidity Coverage Ratio can be expressed as follows:

$$LCR = \frac{Liquidity\ buffer}{net\ liquidity\ outflows\ over\ 30\ days}.$$

Environmental risks could affect liquid assets. In particular, the marketability of environmentally harmful issuances could be negatively impacted in a significant manner. In fact, customers could shift their preferences towards more sustainable products or increasing default rates might be expected for underlying loans which would in turn reduce the market value of the secured bond. Overall, the LCR Delegated Regulation seems to have the necessary safeguards to properly capture this reduced marketability. First because in case of a loss of marketability (or a drastic reduction) the minimum necessary operational requirements for eligibility would not be met (Article 8(4)). Second because if an environmental risk negatively impacted the market value of a security, this would be reflected in its liquidity value.
Some relevant securities could also suffer from a downgrade in credit quality, if considered environmentally harmful and with higher exposure to credit risk. Again, the LCR Delegated Regulation properly captures the related environmental risk by requiring a minimum credit quality criterion below which a security would be excluded from the liquidity buffer.
Environmental risks not only affect liquid assets but also the inflows and outflows used to calculate the LCR. Again, the current framework seems to be suitable as some inflows would not be allowed for calculations while there will be additional outflows from contingent liabilities arising from environmental harmfully products that would be included.

Net Stable Funding Ratio (NSFR)

Introduced by the Basel Committee in October 2014, it aims to mitigate funding risk by ensuring that stable long-term assets are financed with stable funding. It requires that the weighted **available amount of stable funding** (ASF) is at least equal to the weighted **required amount of stable funding** (RSF) in a one-year time horizon.

$$NSFR = \frac{ASF}{RSF} \geq 100\%.$$

ASF is weighted according to the assumed stability of funding resources while the required amount of stable funding is weighted according to the asset's expected permanence in the institution.
Similarly to the LCR case, the environmental risks that might arise and potentially influence the adequateness and stability of the funding structure of a bank by requiring additional stable funding, are addressed by the own NSFR framework. For example, environmentally harmful loans, linked to higher exposure to credit risk, are captured. The higher the credit risk, the higher the required stable funds (for example, non-performing exposures will be subject to a 100% RSF).
Analogously, securities with underlying environmentally harmful exposures may see their marketability deteriorate. As explained before, those securities might miss their LCR eligibility conditions. This is also addressed in NSFR framework. In fact, RSF is linked to LCR conditions; an instrument not eligible for the LCR liquidity buffer will be subject to an increase in RSF.

List of Policy Recommendations	
MR-1	As a short-term action, the EBA recommends that all institutions be more explicitly required to consider environmental risks in relation to their trading book risk appetites, internal trading limits and in the context of the new product approval.
MR-2	As a short-term action, the EBA recommends that institutions employing an IMA for some of their desks be required to consider environmental risks as part of their stress testing programs.
MR-3	As a medium- to long-term action, the EBA recommends that competent authorities assess how ESG-linked products are treated in relation to the risk-residual add-on to ensure that there is harmonised treatment across institutions.
MR-4	As a medium- to long-term action, the EBA recommends that competent authorities assess how ESG-linked products are treated in the internal risk measurement model.
MR-5	As a medium- to long-term action, the EBA recommends that institutions specifically consider environmental or even broader ESG risks when monitoring their risks that are not included in the model.
MR-6	As a medium- to long-term action, taking into consideration the developments agreed to at the international level by the Basel Committee, the EBA will reassess the appropriateness of including under the Sensitivities-based Method (SbM) a dimension, in the equity and credit-spread risk classes, reflecting environmental or even broader ESG risks to establish the buckets into which a risk factor falls, or of including an environmental risk class. A necessary condition for this long-term fix is the meaningful assignment of issuers to buckets according to their riskiness in terms of environmental risk, based on a set of factors to be defined. The assignment of issuers and the corresponding risk weights should provide sufficient explanatory power for the observed market risk of the position.
MR-7	With the increasing materialisation of environmental risks, internal models are expected to automatically capture environmental risk drivers either implicitly, by means of time series of classical risk factors reflecting environmental risk drivers in full, or more explicitly. However, to ensure that this is the case, as a medium- to long-term action, the EBA will reassess the appropriateness of introducing regulatory provisions explicitly requiring institutions to capture material environmental risk drivers in their internal models.

TABLE 6: Policy Recommendation on Market Risk

Concentration Risk

Institutions' sectoral and geographical concentrations of assets may expose them to increased environmental risks. Concentration risk deserves specific consideration when looking at how environmental risks, as well as social risks, are or could be better captured by the prudential framework.
The credit risk framework in Pillar 1 is based on the assumption of portfolio invariance but does not take into account concentration risks arising from imperfect diversification across sectors or geographies. Instead, in the market risk framework, the **Default Risk Charge** (DRC) for trading book instruments necessitates the use of two types of systematic risk factors and a proper reflection of issuer concentrations and concentrations that may arise within and among product classes under stress conditions. The concentration risks are managed through the **Large Exposure** (LEX) regime in Pillar 1 and the requirements of Pillar 2. The LEX regime acts as a backstop measure to supplement minimum capital requirements and manage systemic risks. Pillar 2 involves specific requirements for institutions to manage sectoral and geographical concentration risks, along with potential additional capital requirements.

A definition for environment-related concentration risk could be developed around the following points:

- It should cover aggregated exposure to counterparties/issuers in both banking and trading book;
- It should consider second-round effects from supply-chain-related risk events that can amplify financial stress;
- To align with the current prudential framework, it could reference direct and indirect exposures as used in the LEX regime;
- Developing an internationally agreed definition by Basel Committee for environment-related concentration risk is intended to be a short-term action;
- The definition of environment-related concentration risk should only capture potential risks stemming from institutions' exposures to their counterparties/issuers (outside-in).

To address E&S-related concentration risks, different options can be designed with respect to different time horizons. Below is an overview and possible approaches to progressively develop measures of concentration risk linked to the environment.

List of Policy Recommendations	
OR-1	As a short-term action, the EBA recommends that institutions be required to identify whether environmental and social factors constitute triggers of operational risk losses in addition to the existing operational risk taxonomy. This could, for example, be performed as part of supervisory reporting.
OR-2	As a medium- to long-term action, the EBA will following evidence of environmental – and where relevant social – factors triggering operational risk losses in increased frequency and severity, reassess the appropriateness of revisions to the BCBS SA methodology, taking into consideration the developments agreed to at the international level by the Basel Committee.

TABLE 7: Policy Recommendation on Operational Risk

List of Policy Recommendations	
LR-1	At this stage, the EBA does not recommend changes to the LCR framework
LR-2	At this stage, the EBA does not recommend changes to the NSFR.

TABLE 8: Policy Recommendation on Liquidity Risk

Short-Term Policy Considerations

Short-term policy considerations should aim to enhance the assessment of banks' sensitivity to environmental risks and create exposure-based metrics for environment-related concentrations risk. Initially, these metrics may be basic but should evolve toward greater accuracy over the medium to long term. In the short term, these metrics will not mechanically affect Pillar 1 capital; instead, they will be part of the Pillar 2 framework under SREP and, where applicable, could complement existing Pillar 3 disclosure on ESG risks. The enhanced reporting and disclosure requirements would rely on the use of predefined exposure-based metrics (i.e. ratio of their exposures sensitive to a given environmental risk driver in a specific geographical area or in a specific industry sector over total exposures, total capital or RWA). It is expected that enhanced disclosure requirements will contribute to data availability and to the progressive development of more refined environment-related concentration metrics.
The EBA is working on integrating ESG risks into supervisory reporting and creating metrics for environment-related concentration risk. While Pillar 2 already allows supervisors to address institutions' resilience to potential future losses from geographical or sectoral concentration, embedding environment-related concentration risk metrics in SREP could harmonize the treatment of these risks across competent authorities.

Medium-to-Long-Term Policy Considerations

As data quality and availability increase and institutions progressively become able to produce more refined environment-related concentration risk metrics, enhanced metrics could be considered in the form of scenario-based metrics or metrics relying on sensitivity-based measures (i.e. ratio assessing the share of own funds requirements related to exposures to a given environmental risk driver over total own funds requirements).
As a medium- to long-term policy recommendation the possibility to amend the **"Sensitivities-based Method"** (SbM) to introduce an additional bucketing dimension reflecting physical and transition risks. However, the design of an environment-related concentration risk metric inspired by the SbM poses several issues that would first need to be addressed:

- The SbM framework is meant to capture market risks. The extent to which this approach can be used to capture environment-related concentrations stemming from non-trading book exposures should be assessed.
- The SbM relies on the use of sensitivities. Instead, other measures (such as, notional/exposure at default) could better serve for the objective of assessing the concentration toward a given environmental risk driver.
- In the absence of widely accepted standards across jurisdictions, it is crucial to properly characterise the environment-related bucketing dimension to allow for a common level playing field at the European and international level.
- The concentration risk metric should be based on reliable data properly reflecting the exposure of an institution towards environment-related risk drivers.

In the medium to long term, as environment-related concentration risk metrics improve, the EBA may consider using them to create a new framework for these risks under Pillar 1. This could involve setting concentration limits, thresholds, capital add-ons, or buffers, or a combination of these measures. Institutions exceeding these thresholds might face increased monitoring and supervisory actions to reduce their exposures in specific sectors or geographical areas.
Importantly, environment-related concentration risk policies should not hinder institutions' counterparties from receiving financing for transitioning to low-carbon activities or introducing mitigating measures against physical risks. To this purpose, limits or thresholds could be phased in over time by increasingly sharpened requirements.

List of Policy Recommendations	
CONC-1	As a short-term action, the EBA will work on the development of a definition of environment-related concentration risk, taking into consideration the developments agreed to at the international level by the Basel Committee.
CONC-2	The EBA recommends that the current large exposures regime continue serving its own specific purpose and should be kept unchanged.
CONC-3	As a short-term action, the EBA will work on the development of exposure-based metrics for the quantification of environment-related concentration risks. Those exposure-based metrics should be implemented as part of supervisory reporting and should be disclosed where relevant. The EBA will conduct benchmarking analyses based on reported values for these concentration risk metrics across EU institutions. Due to the inherent limitations of those new metrics in the short-term, the developed exposure-based metrics should be considered as part of Pillar 2 under SREP or as part of the Pillar 3 framework, possibly complementing the existing Pillar 3 disclosures on ESG risks. The EBA will amend its SREP Guidelines accordingly to provide guidance on how competent authorities should assess and treat environment-related concentration risks.
CONC-4	As a medium- to long-term action, as data quality and availability increase and institutions progressively become able to produce more refined environment-related concentration risk metrics, the EBA will consider the possible implementation of enhanced concentration risk metrics, taking into consideration the developments agreed to at the international level by the Basel Committee. The EBA considers as a good starting point for defining those metrics, the principles on which the SbM is built.
CONC-5	As a medium- to long-term action, based on the acquired experience and the results derived from the implementation of environment-related concentration risk metrics, the EBA will reassess the appropriateness of introducing environmental-related concentration risks under the Pillar 1 framework. The new framework would entail the design and calibration of possible limits and thresholds, add-ons or buffers, as well as the specification of possible consequences if there are breaches. The work should take into consideration the developments agreed to at the international level by the Basel Committee.

TABLE 9: Policy Recommendation on Concentration Risk

Capital Buffers and Macroprudential Framework

The capital buffer and macroprudential framework can have a significant role to appropriate address the systemic aspects of environmental risks.
The current capital buffers and macroprudential framework generally consists of two pillars: capital buffers and borrower-based measures. These measures have been analysed by EBA to assess to what extent they could be adapted to introduce considerations related to environmental factors.

Capital Buffers

Capital buffers considered by the EBA as part of this assessment include the **Capital Conservation Buffer** (CCoB), the **Countercyclical Capital Buffer** (CCyB), and **the Systemic Risk Buffer** (SyRB)[3] , and the results of this assessment are reported below:

- For the **Capital Conservation Buffer**, the EBA notices that it was calibrated without taking environmental risks into account, and that a recalibration would require substantial changes to the existing framework. Moreover, it is unclear whether adding such a component would make any significant difference to the overall resilience of the banking sector should there be a disruptive tail event related to environmental risks.
- Regarding the **Countercyclical Capital Buffer** the EBA recalls that the purpose of this buffer is to help counter procyclicality in institutions' lending. However, given the non-cyclical nature of environmental risks, such measure is inappropriate to address the resulting capital needs.
- The **Systemic Risk Buffer** can generally be used to tackle a wide range of systemic risks, and as such it appears more suitable to potentially address environmental risks. EBA has hypothesised three different options in relation to such risks:
    1. Use the existing general SyRB as a general tool against systemic aspects of environmental risks, not necessarily linked to the risk of individual institutions.
    2. Use the sectorial SyRB (sSyRB) to enhance the resilience of institutions against the material-

[3]As part of the assessment, the EBA has not considered the Global Systemically Important Institution (G-SIIs) buffer and the Other Systemically Important Institutions (O-SIIs) buffer, since these are less relevant from an environmental risk perspective as environmental risks are not specifically related to the systemic importance of individual institutions.

isation of environmental risks within sectors associated with environmentally harmful or risky activities.

3. Activating the SyRB based on a concentration measure, addressing concentration risks on exposures affected by the same physical and/or transition risks. For this option to be able to work in practice, environment-related concentration risk metrics that are appropriate for this purpose would need to be developed.

Borrower-Based Metrics (BBMs)

Borrower-Based Metrics (BBMs) are used by policy makers to limit borrowing relative to household incomes and/or property values and ensure minimum lending standards. They can be used in either a cyclical manner, when growing cyclical pressures emerge, or in a structural manner, ensuring minimum prudent lending standards are always maintained. The most used forms of BBMs are **Loan-to-Value** (LTV) and **Loan-to-Income** (LTI):

- **LTV** operates by imposing a minimum deposit requirement on borrowing households relative to the value of the property, increasing the resilience of the banking sector by making both borrower and lender less vulnerable in the event of property price declines (by lowering the LGD).
- **LTI** measures impose borrowing restrictions relative to income, to enhance the resilience of both borrowers and lenders (by lowering the PD).

EBA has therefore assessed whether BBMs could be used to address environmental considerations:

- On one side, the EBA believes that BBMs could be applied for mortgages to the extent that properties used as collateral are exposed to physical and transition risk. In addition, they could serve as a tool to ensure that environmental factors and risks are incorporated into the assessment of the repayment capacity of the borrower, preventing institution's excessive risk taking.
- On the other side, EBA acknowledges that the amending of BBMs could pose potential drawbacks, namely:

  1. They generally apply only to new loans, hence their effect on environmental risks building in the overall stock of loans may take time to materialise;
  2. They are implemented at national level and therefore would face a risk of disparate application across jurisdictions, specifically in the absence of a uniform definition of what constitutes properties that are exposed to physical and transition risks;
  3. Since BBMs currently only apply to households, it would be necessary to assess how BBMs could be applied also to other loans to ensure that environmental risks are addressed effectively and comprehensively.

In this regard, and considering the assessment of both capital buffers and macroprudential measures presented in the previous section, EBA suggests some policy recommendations related to the usage of such instruments in the tackling of E&S risks (see Table 10).

Conclusions

The specific characteristics of environmental and social risks, particularly their multidimensional, non-linear, uncertain and forward-looking nature, could lead to their underestimation, at a time where the materialisation of these risks is likely to accelerate. This highlights the need to enhance the prudential framework to better account for environmental and social risks.
The EBA report proposes targeted enhancements to the current Pillar 1 framework, which can be implemented in the short term and in the medium-long term. It also develops considerations on the potential use of macroprudential tools.
At this stage, EBA considers addressing environmental risks through effective use of and targeted amendments to the existing prudential regime rather than through dedicated treatments such as supporting or penalising factors. More comprehensive changes to the Pillar 1 framework are warranted only where a clear link between E&S factors and traditional categories of financial risks can be established.
With respect to the interaction between the Pillar 1 **credit risk** framework and E&S risk, and regarding the **Standardised Approach**, EBA believes that E&S risks should be better reflected in the framework, but avoiding excessive complexity, which would undermine the inherent intended simplicity of such approach. This objective could be achieved through the following tools:

- Verification by competent authorities that due diligence requirements explicitly integrate environmental aspects;
- Monitoring that financial collateral valuations increasingly reflect environmental factors;
- Assessment of whether high-quality specialised lending corporate exposures could be subject to some sort of environmental supporting factor;
- Reassessment of whether environmental risks should be considered in evaluating the appropriateness of risk weights assigned to real estate exposures;
- Reassessment of how E&S risks can be reflected in prescribed risk weights in the SA.

For what concerns instead the **IRB Approach**, this is by design more risk sensitive than the SA, and as such can better capture any new risk that could result in credit losses, if there is sufficient availability of adequate data. In this context, EBA has reached the following conclusions:

- In the short term, E&S risks should be taken into account in the rating assignment (i.e., risk differentiation step), the risk quantification (through for example margin of conservativism, downturn component, calibration segments) and in the application (e.g., via use of human judgement and overrides) in accordance with the existing requirements and under the condition that sufficient information is available to apply corresponding adjustments to the rating function without materially decreasing the overall performance of the model. EBA recognises the need for further guidance on data collection regarding potential E&S risk drivers to benefit institutions in designing their rating models. In the medium- to long term, the EBA will investigate and assess whether relevant E&S risk drivers should be added to the existing lists of risk drivers mentioned in the relevant EBA Guidelines.
- As the impact of E&S risks on defaults and loss rates becomes available, institutions should reflect these

List of Policy Recommendations	
MACRO-1	The syrb appears as the most relevant tool to address environmental risks within the current macroprudential framework. As a short-term action, the EBA will assess the need for changes to its guidelines on sectoral exposures to which a syrb may be applied.
MACRO-2	As a medium- to long-term action, the EBA will coordinate with other ongoing initiatives and assess the most appropriate adjustments to the wider macroprudential framework to be able to address environmental risks effectively.

TABLE 10: Policy Recommendation on Capital Buffers and Macroprudential Framework

risks in their PD and LGD estimates through a redevelopment or recalibration of their rating systems in the long term.

- At this stage, the EBA currently views it premature to make immediate changes to the RW formulas, risk weights for specialised lending and LGD/CCF values to address E&S risks in own funds requirements. Nonetheless, the EBA suggests incorporating BCBS clarifications into the Commission Delegated Regulation (CDR) 2021/598 on slotting approach. In the medium- to long term, the EBA will reassess the need for revisions considering evolving E&S risks, keeping in mind that revisions of such a magnitude would require international agreement at the BCBS level.
- The EBA suggests incorporating E&S risk considerations into banks' stress testing programmes as a short-term action.

Regarding **market risk**, E&S risks should have impacts significant impacts on the risk level of the trading book of financial institutions, both at the physical and transition risk level. Possible solutions to quantify this exposure have been developed for both approaches envisaged in the FRTB. To ensure that this evidence is well taken into consideration in the risk management of financial institutions, EBA proposes a series of recommendations short-term actions:

- Inclusion of the environmental risk in the trading book risk appetites framework, through the definitions of limits to operations, as well as in the context of the new product approval;
- Inclusion of the environmental risk in the stress test plan for FRTB- IMA desks.

Furthermore, EBA also proposes a series of recommendations medium- to long-term actions:

- The competent authorities should guarantee a harmonized management of ESG-linked products, among institutions, regarding their additional residual risk;
- The competent authorities should evaluate the handling of ESG-linked products in internal risk models;
- EBA strongly suggest using the RNIME framework as a starting point when the ESG Risks are not included in their model;
- Reevaluations of the possibility to include a new environmental risk dimension in SbM given the issuer assignment to the buckets based on their environmental risk level;
- Re-assessments to make explicit the inclusion of environmental risk drivers in internal models of institutions.

Regarding **operational risk**, the EBA recommends, as a short-term action, that institutions be required to identify whether environmental and social factors constitute triggers of operational risk losses in addition to the existing operational risk taxonomy. As a medium- to long-term action, the EBA will following evidence of environmental - and where relevant social - factors triggering operational risk losses in increased frequency and severity, reassess the appropriateness of revisions to the BCBS SA methodology, taking into consideration the developments agreed to at the international level by the Basel Committee.
Regarding **liquidity risk**, the LCR and NSFR seem to already have the necessary framework in place to capture the environmental risks affecting liquid assets, inflows or outflows. Therefore, EBA, at this stage, does not recommend changes to the LCR or NSFR frameworks.
Regarding **concentration risk**, EBA proposes a series of short-term actions:

- EBA will work on the development of a definition of environment-related concentration risk, taking into consideration the developments agreed to at the international level by the Basel Committee.
- EBA recommends that the current large exposures regime continue serving its own specific purpose and should be kept unchanged.
- EBA will work on the development of exposure-based metrics for the quantification of environment-related concentration risks, through benchmarking analyses. EBA will amend its SREP Guidelines accordingly to provide guidance on how competent authorities should assess and treat environment-related concentration risks.

Furthermore, EBA proposes also a series of medium- to long-term actions:

- EBA will consider the possible implementation of enhanced concentration risk metrics, taking into consideration the developments agreed to at the international level by the Basel Committee.
- EBA will reassess the appropriateness of introducing environmental-related concentration risks under the Pillar 1 framework.

Finally, **capital buffer and macroprudential framework** can have a significant role to appropriate address the systemic aspects of environmental risks. EBA notices that the deployment of macroprudential measures to address environmental risks requires a close dialogue between micro prudential and macroprudential authorities to ensure an effective and consistent set of policies to address those risks.

References

[1] **Basel Committee on Banking Supervision.** *Frequently asked questions on climate-related financial risk*. December 2022.

[2] **European Baking Authority.** *Consultation Paper: Draft Guidelines on the management of ESG risks*. January 2024.

[3] **European Baking Authority.** *Discussion Paper: The role of the Environment Risks in the Prudential Framework*. May 2022.

[4] **European Baking Authority.** *EBA Guidelines on Credit Risk Mitigation for institutions applying the IRB approach with own estimates of LGDs*. May 2020.

[5] **European Baking Authority.** *EBA Guidelines on Loan Origination and Monitoring*. May 2020.

[6] **European Baking Authority.** *EBA Guidelines on PD estimation, LGD estimation and treatment of defaulted assets*. January 2017.

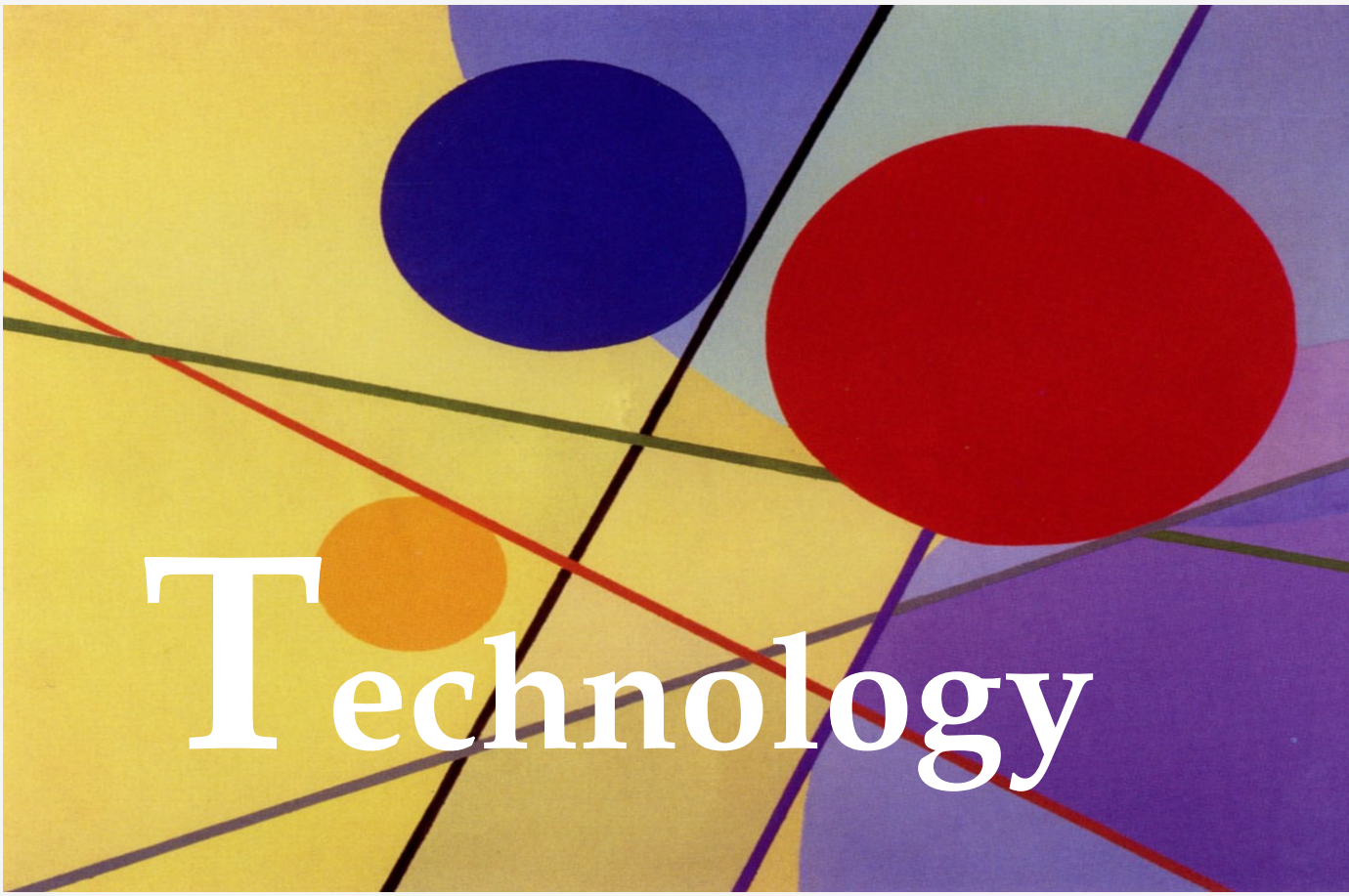
[7] **European Baking Authority.** *The Role on the Environment and Social Risks in the Prudential Framework*. October 2023.

[8] **European Central Bank.** *ECB guide to internal models*. February 2024.

[9] **European Comission.** *Commission Delegated Regulation (EU) 2021/598 supplementing Regulation (EU) No 575/2013 of the European Parliament and of the Council with regard to regulatory technical standards for assigning risk weights to specialised lending exposures*. December 2020.

[10] **European Comission.** *Commission Implementing Regulation (EU) 2016/1799: laying down implementing technical standards with regard to the mapping of credit assessments of external credit assessment institutions for credit risk in accordance with Articles 136(1) and 136(3) of Regulation (EU) No 575/2013 of the European Parliament and of the Council*. October 2016.

[11] **European Comission.** *Commission Delegated Regulation (EU) 2022/439 of 20 October 2021 supplementing Regulation (EU) No 575/2013 of the European Parliament and of the Council with regard to regulatory technical standards for the specification of the assessment methodology competent authorities are to follow when assessing the compliance of credit institutions and investment firms with the requirements to use the Internal Ratings Based Approach*. March 2022.



Artificial Intelligence: Risks and Opportunities for the Banking System

About the Authors

Marco Carminati:
Senior Manager
After taking a Bachelor in Finance and a Master of Science in Economics, he specialised in Credit Risk Management and Modelling through almost 10 years of experience in both banking and consultancy industry with special focus on the development and validation of models for Credit Risk for regulatory and managerial purposes. Currently in charge of several projects in the Credit Risk Management area and Head of the iason Credit Risk Competence Center.

Leonardo Bandini:
Junior Credit Risk Quant
He graduated with a Master's degree in Statistics from the Università di Bologna. Currently, he is involved in projects in the areas of credit risk model validation and Artificial Intelligence financial applications with some of the main Italian banks.

This document was prepared in collaboration with Vincenzo Frasca, who at the time was working for Iason Consulting.

Artificial Intelligence: Risks and Opportunities for the Banking System

Marco Carminati Leonardo Bandini Vincenzo Frasca

*In recent years, there has been a significant **diffusion of Artificial Intelligence (AI) solutions** across various sectors. AI, denoting **computer systems' capability to mimic human intelligence and decision-making processes**, has seen increasing adoption due to the **availability of vast data sets** and **enhanced computing power**. Businesses stand to gain substantially from AI implementation, with **opportunities for automation, improved productivity, and profitability**. Similarly, society benefits from more **efficient services, advanced healthcare solutions**, and **heightened public safety measures**. The **banking and financial sector** is not exempt from AI's transformative potential, particularly in **customer interactions and risk management**, leveraging data-driven insights for informed decision-making. Despite the **clear advantages**, the widespread integration of AI brings **inherent risks**. **Complex decision-making models** pose challenges to **transparency and interpretability**, while the **reliance on data** increases the likelihood of **biases and privacy concerns**. Additionally, **cybersecurity threats** make AI solutions vulnerable, necessitating robust protective measures. **Regulatory authorities** worldwide are responding to these challenges with varying degrees of urgency and stringency. The **European Union**, for instance, has proposed **comprehensive regulations to govern AI usage**, emphasising risk assessment and compliance with EU fundamental values. In contrast, the regulatory frameworks in the **United Kingdom** and the **United States** are **less developed**, while **China boasts advanced AI regulations** tailored to specific applications. This paper seeks to highlight the **dual nature of AI adoption**, emphasising its **benefits** for businesses, and particularly for the **banking sector**, alongside the imperative of **addressing associated risks and challenges**. The paper furthermore underlines the **importance of ethical considerations and regulatory compliance** in harnessing AI's potential for **safe and responsible use**, ensuring the respect of **fundamental rights and ethical principles.***

In recent years, there has been a growing **diffusion of solutions and tools based on Artificial Intelligence**. The term **Artificial Intelligence** (hereinafter usually referred as AI) generally refers to the **ability of computer systems to develop knowledge and make decisions that would typically require human intelligence**, but **without human intervention**, relying on the observation and analysis of available data.

The **increasing adoption of AI techniques** observed in recent years is facilitated, on one hand, by the **continuous increase in data availability**, and on the other hand, by **improvements in the computing power of computers**, enabling the processing of large amounts of data more quickly. The availability of **decision-making tools based on AI** represents an unprecedented **opportunity for businesses and society as a whole**. Companies can benefit from **intelligent tools** to support their **business processes**, allowing them to automate activities that would typically require human intervention, leading to **increased productivity and profitability**. From a broader perspective, individuals can benefit from the **availability of more efficient services**, **improved and more accurate healthcare solutions**, and a **higher level of public safety**.

The opportunities presented by AI for firms do not exclude the **banking and financial sector**. They are related, for instance, to the **streamlining of customer interactions** and of **risk mitigation activities**, relying more on **data-driven results and evidence**.

While the opportunities and potential benefits of the widespread adoption of AI are evident, there are also **risks that should not be underestimated** in the process of implementing such tools. The **increased complexity of AI decision-making models** poses **limits on the transparency and interpretability** of their results, which tend to be inherently more opaque. Additionally, there are challenges in verifying the **correctness** of and the **rationale** behind the decisions made by these systems. Furthermore, the **high dependence on underlying data** increases the **risk of amplifying potential distortions (bias)** present in the data, posing the risk of **distorted and potentially discriminatory results and decisions**. Moreover, the **analysis of vast amounts of data**, including information about individuals' activities and spending habits, poses **risks in terms of data privacy**. Finally, potential **cybersecurity risks** should not be neglected, as AI-based decision systems may be susceptible to **malicious attacks** aimed at **manipulating decisions** and producing possible discriminatory effects.

In light of the accelerated proliferation of AI-based solutions and in order to mitigate potential risks as listed above, **regulatory authorities** in major countries are taking **steps to regulate the adoption of AI** and promote its **safe and conscious use**. In the European Union (EU), the **European Commission** issued in 2021 a proposal for regulation (known as the "**Artificial Intelligence Act**") which, following a **risk-based approach**, includes a **ban on the use of certain forms of AI** deemed contrary to the values of the Union. It also introduces **specific requirements for the production and use of AI systems** considered to be of **higher risk**. The proposal has been recently subject to **agreement between the European Commission, Parliament and Council** in **De-**

cember 2023, and is currently awaiting for the publication of the official final text. In other countries, the state of regulatory maturity varies significantly. In the **United Kingdom**, the current regulatory intervention is focused on **identifying principles and guidelines without legally binding regulatory provisions**. In the **United States**, **regulatory intervention is still in its early stages**, with an absence of specific and general initiatives regarding AI legislation. In **China**, on the other hand, **AI regulation is at an advanced stage**, with specific rules for each identified application of the technology currently in place.
Against this background, the **objective of this document** is, on one hand, to describe the **main benefits resulting from the adoption of Artificial Intelligence tools**, emphasising in particular for firms operating in the **banking sector**. On the other hand, it aims to **illustrate the potential risks** associated with such tools, which must be **assessed and managed consciously** to harness their potential **safely** and **ensure respect for ethical principles and fundamental rights of individuals**. The document is organised as follows:

- Chapter "Artificial Intelligence: Definitions and Main Diffusion Drivers" provides an **overview of the diffusion and definitions of AI** and describes some of the **main forms of Artificial Intelligence** available on the market;
- Chapter "Possible Benefits from the Use of Artificial Intelligence" describes the potential **benefits that the adoption of AI can bring to society and businesses**;
- Chapter "Potential Risks Associated with the Use of Artificial Intelligence"an overview of the **potential risks associated** with the use of AI;
- Chapter "Main Applications of Artificial Intelligence in Banking Sector" highlights the main **opportunities that the banking system can seize with the use of AI-based tools**, describing some examples of application;
- Chapter "Regulation of Artificial Intelligence: an Overview" illustrates the **regulatory evolution of AI in the European Union** and possible **regulatory trends in other globally relevant countries**;
- Chapter "Conclusions" provides some **concluding remarks**.

Artificial Intelligence: Definitions and Main Diffusion Drivers

Definitions and Diffusion of Artificial Intelligence

The term "**Artificial Intelligence**" (hereinafter also **AI** for brevity) generally refers to a **set of methodologies and techniques** that enable the design of **computer solutions capable of replicating human intelligence to varying extents**. More specifically, the term refers to the **ability of computer programs** to **acquire knowledge and make decisions without human intervention**, through the **observation and analysis of available data**. Artificial intelligence systems are characterised by their **ability to perform tasks that would typically require human intelligence**, such as understanding text, creating an image, or making a decision.
In recent years, thanks to the **continuous technological development** and the **increasing availability of data**, there has been a growing proliferation of techniques and solutions based on AI. In fact, AI as a field of computer research has **existed for decades** (for example, as early as 1950, the British mathematician Alan Turing formulated the so-called *Turing Test*, a criterion to determine if a machine could exhibit intelligent[4]). However, it is only in more recent years that solutions based on such techniques have accelerated their diffusion, mainly due to a series of **enabling factors**, such as:

- The **increasing availability of data**, of different nature and originating from various sources, is primarily linked to the **continuous growth in internet usage**, allowing for the increase in digital data production and availability. For instance, in a 2019 study, Deutsche Bank Research[12] highlighted how, in the last 10 years alone, the **amount of data generated globally has increased by a remarkable 17 times**, with estimates indicating a further fivefold growth by 2025. This evolution provides a **vast amount of information** (commonly referred to as "***big data***"), which serves as the **primary informational source** to enable the use and maximisation of the potential of Artificial Intelligence solutions. In general, the term ***big data*** refers to data characterised by **specific features**, identified by the so-called **"3 Vs"**[5]: 1) **volume**, meaning a substantial amount of data, 2) **variety**, encompassing various types of data, including **structured**, **semi-structured**, and **unstructured data**[6], and 3) **velocity**, indicating that data is produced at high rates.
- The significant **increase in computing power** enables algorithms to **process information quickly**, contributing to the **accuracy of the decision-making process**. In this regard, the widespread adoption of **cloud computing solutions** serves as an accelerator for the use of advanced analytics techniques. The cloud infrastructure provides more space for the storage and processing of vast amounts of data in an efficient manner.
- Other evolutionary factors are related, for example, to the **reduction of costs associated with data storage solutions**, advancements in **data extraction and processing processes** (so-called "***data mining***"), and the increasing availability in the labour market of **IT experts specialised in the analysis of large quantities of data** (so-called "***data scientists***").

These factors have provided businesses with the **opportunity to employ advanced techniques**, which are currently used for various purposes across different sectors. For

[4]See, for instance, "The Turing Test".

[5]In this regard, see also EBA[14]. In some cases, these "3Vs" are accompanied by other 2 ("5Vs" paradigm), including also the following characteristics: veracity, which relates to the need to ensure that such data represent as accurately as possible the underlying reality, and value, a characteristic related to the need to be able to transform the data into useful business information. In this regard, see also Banca d'Italia[2].

[6]Structured data refers to data presented in an ordered and organised format within standard structures (e.g. tables within a database); semi-structured data, on the other hand, refers to data that contain some "tags" but do not respond to the structure associated with typical relational databases (e.g., data related to email or XML); finally, unstructured data are types of data that are not ordered or organised according to a predefined format, consisting of a wide variety of information that is inherently complex to navigate and process (think, for example, of information contained in audio or video files, or derived from surveillance cameras or social media).

example, such solutions are already being applied in the **healthcare sector** (e.g., for the analysis of diagnostic images), in **marketing activities** (e.g., providing buyers with customised spending suggestions based on past purchasing experiences), and in the **financial sector** (see Chapter "Main Applications of Artificial Intelligence in Banking Sector" for detailed examples of possible AI applications in the banking sector).

Types of Artificial Intelligence

Despite being referred usually as Artificial Intelligence in a general way, AI encompasses a **broad set of techniques and methodologies**, each characterised by **specific features** that make them more suitable for application in certain areas of activity and for specific purposes. The **most commonly used forms of Artificial Intelligence** include, in a non exhaustive manner, the following:

- ***Machine Learning (ML)***;
- ***Natural Language Processing (NLP)***;
- ***Generative Artificial Intelligence (GAI)***.

These forms of AI are described in more detail in the following paragraphs.

Machine Learning

Machine Learning (ML, also known as "automatic learning") is a set of techniques that, based on a predefined set of rules (called ***hyperparameters***) and through a **learning process** (also called "learning" or "training"), allow for the identification of **relationships among data** and, based on these, formulate the best decisions and predictions. The learning process enables the generation of **predictive models** whose results can be used for various purposes (e.g., for classification problems, clustering, etc.). Thanks to these characteristics, Machine Learning techniques are often used for the **development of predictive analysis solutions**. Compared to traditional statistical analysis techniques (e.g., linear regressions), these algorithms are capable of **identifying non-linear relationships among data**, thereby **increasing the accuracy of predictions**.
In general, Machine Learning algorithms can be divided into sub-categories, differentiated based on the learning mode used.
Regardless of the specific approach described above, there are **several families of ML algorithms** that can be used in each of the cases mentioned above, among which the following are notable due to their widespread use:

- ***Ensemble Learning***: these techniques are based on the **use of a set of models**, whose **predictions are then aggregated to determine the final prediction** (which can be, for example, determined as the average of the predictions of the individual models). A widely used type of technique of this kind is represented by **decision trees**, which can be used for **simultaneous learning of independent models** (called "bagging") or through **sequences of models that progressively refine the learning process**, reducing the error of the previous models (called "boosting").
- ***Deep Learning***: this is a family of ML techniques whose **learning process is structured into layers** (each composed of interconnected units, called "neurons") inspired by the **functioning of the human brain** (and therefore also called "neural network"). At each level of the network corresponds a phase of learning with increasingly complex concepts. Neural networks can have **very complex structures**, with hundreds or even thousands of layers, making it difficult to understand the rationale behind the decisions made; for this reason, they are often referred to as "black boxes".

Natural Language Processing

Another widely used form of Artificial Intelligence is ***Natural Language Processing (NLP)***, a subcategory of AI based on algorithms capable of **processing**, **understanding**, and **interpreting human language**, effectively **enabling communication between humans and machines**. The application of such techniques allows, for example, the extraction of a subset of relevant information from a document, making content processing more efficient and reducing (or completely replacing) the need for human intervention. According to a **recent report** from the Alan Turing Institute[28], some of the most widely used NLP algorithms include:

- ***Sentiment Analysis***: algorithms that determine the emotional tone within a text by analysing textual data;
- ***Named Entity Recognition (NER)***: algorithms capable of identifying names (e.g., referring to people or places) within unstructured data;
- ***Machine Translation***: algorithms that translate text from one language to another while preserving the textual meaning of the processed sentences;
- ***Speech Recognition***: algorithms capable of listening to and understanding a text and transcribing it.

Generative AI

Another form of AI that has seen significant growth recently is ***Generative AI* (or *GAI*)**. It comprises a set of techniques and AI models that can **generate various types of digital content**, such as text, images, and music, after receiving specific instructions from a human. Generally, these models are based on ***Large Language Models (LLM)***, a form of **deep learning** that leverages techniques such as ***Recurrent Neural Networks (RNN)***, a type of neural network based on sequential data capable of **understanding and managing temporal sequences** in the context of **language translation** and **speech recognition.**[7]
One of the most prominent examples of Generative AI models is **ChatGPT**, a language model developed by the U.S.-based company OpenAI. It can **understand questions posed by humans** and **respond effectively** and almost **instantaneously**. Another example of GAI is represented by DALL-E 2, also developed by OpenAI, an AI model capable of **creating original and high-quality images** in response to a textual instruction[8].
While the potential **benefits** of such techniques are evident[9] (for example, enabling the rapid processing and analysis of a wide set of information and providing users with data-driven recommendations), the ability of these solutions to **create original and high-quality content** is **not without risks**. If used inappropriately, such technologies can pose **ethical risks**[10], allowing malicious actors to **create false and**

[7] See, for instance, IBM.
[8] For a detailed overview on Generative AI techniques, see Cao et al.[6].
[9] On the potential benefits of Generative AI, see [25].
[10] On the general risks posed by Generative AI, see [33], while for a more specific view related to the risks for the financial system, see [24].

Approach	Definition
Supervised Learning	In this context, the algorithm learns the **relationships between inputs and outputs through** a set of data that has been previously **labelled** by a human (referred to as a "**labelled dataset**"). For example, consider a dataset related to transactions for which, in addition to a series of descriptive features (such as transaction amount, business sector of the subject, etc.), there is also a label indicating whether a transaction was fraudulent or not. The algorithm identifies a **classification rule** for the outputs that can be used to predict the value of the label (in the previous example, identifying potentially fraudulent transactions) for new data.
Unsupervised Learning	In this case, the algorithm autonomously learns the model from the **available dataset** without the need for it to be preprocessed for label attribution. Here, the **algorithm identifies relationships between data by identifying groups ("clusters")** of similar observations, i.e., with **common characteristics.** These techniques can be used in various circumstances, such as for **clustering analysis** or the **detection of potentially anomalous observations** within a set of data.
Semi-supervised Learning	Semi-supervised learning represents an intermediate case between the two previous ones, where the **dataset available to the algorithm is only partially labeled.** These techniques are useful when only a **few labelled observations are available,** for example, in cases where **the label attribution process is particularly complex or costly.**
Reinforcement Learning	In this context, the algorithm doesn't **learn relationships** from observations in a dataset, but rather from its **interaction with the surrounding environment**. Specifically, it **takes an action and receives feedback on its correctness.** Based on this **feedback** (such as profit or loss in the case of a trading algorithm), the **algorithm improves its strategy to maximise positive feedback,** thereby **enhancing its accuracy**. An example of the application of these techniques could be trading or pricing. strategies.

TABLE 11: Types of Machine Learning Algorithms

misleading content to **manipulate the opinions and behaviors of individuals**. Additionally, from the perspective of **personal data protection**, there is a risk of u**nauthorised creation of "artificial" images or videos** depicting certain individuals without their consent. Furthermore, there is also the risk of **inappropriate diffusion of sensitive and non-disclosable data or information** uploaded or divulged by the user when using the system.

Other Forms of Artificial Intelligence

In addition to the forms of Artificial Intelligence described in the preceding paragraphs, other possible AI solutions of particular utility and prevalence in business activities include ***Expert Systems*** and ***Robotic Process Automation (RPA)*** tools. According to The Alan Turing Institute[28]:

- An **Expert System** is an Artificial Intelligence system that **replicates the decision-making capabilities of a human expert** in a specific field of application, using a **predefined set of rules and an inference engine** to solve problems that typically require human judgement. In the financial sector, such tools can be used for various applications, such as portfolio management or financial forecasting. These tools can be particularly useful in situations where a high level of knowledge is required and difficult to obtain or where there is limited availability of human experts in the field of analysis in question.
- **Robotics Process Automation (RPA)** is a branch of Artificial Intelligence that enables the **automation of a set of repetitive actions and tasks** typically performed by human agents. Such solutions can be used in the financial sector to carry out a variety of routine activities, such as account opening and closure, complaint management, fraud detection, customer service activities, and reporting.

Possible Benefits From the Use of Artificial Intelligence

General Benefits

The adoption of solutions based on Artificial Intelligence can without doubt produce **benefits for society**. In particular, potential **advantages** related to the **diffusion of AI-based solutions** are linked, for example, to the **improvement of healthcare services** (think of potential improvements in diagnosis accuracy), the increase in the **accuracy of decision-making processes** (which can more effectively exploit the information contained in data), or the increase in precision in various stages of **agricultural cultivation** (which can allow for reduced land use and therefore mitigate the impacts of agriculture on climate change).
In its **White Paper** on Artificial Intelligence, the **European Commission**[17] identifies the **set of potential benefits** deriving from the adoption of Artificial Intelligence techniques, differentiating them according to the perspective of analysis:

- From the **citizens' perspective**, they can benefit, for example, from the availability of **better healthcare solutions, more efficient transportation, improved public services**, and greater efficiency of tools used in daily activities (e.g., smarter appliances);
- From an **economic development standpoint**, there is the potential for the diffusion of a **new generation of key products** and services in sectors where European Union countries excel, such as machinery,

transportation, cybersecurity, as well as the agricultural sector and the **green and circular economy**, healthcare, and high-value-added sectors such as fashion and tourism;

- From the **perspective of public services**, AI-based solutions can **reduce costs related to the provision of key services** such as transportation, education, energy, and security, **improving the sustainability** of these products and services and equipping public safety authorities with appropriate and cutting-edge technologies to ensure **citizens' safety**.

In addition, Artificial Intelligence technologies can be a key tool for addressing some of the **greatest challenges of our era**, such as those related to **environmental protection and sustainability goals**. In this regard, the European Commission believes that the use of such systems can play an important role in achieving sustainability goals **linked to the United Nations' Sustainable Development Goals**, as well as in supporting democratic processes and respecting **human rights**.

Benefits for Businesses

The adoption of Artificial Intelligence techniques undoubtedly offers **benefits to businesses**. In particular, the application of these techniques can allow:

- **To reduce operating costs by automating activities** previously entirely reliant on human intervention;
- To **increase profitability**, for example, by retaining customers through personalised offerings, as close as possible to their purchasing preferences.

The table 12 provides a more detailed overview of the **main potential benefits** arising from the use of Artificial Intelligence techniques.

Benefit	Description
Reduction of operational costs	This is allowed by the automation of business processes, both routine ones (such as opening a bank account, massive pre-processing of documents for customers), and more specific ones (such as financial advisory services), also thanks to the so-called robo-advisors, digital assistants available at any time of the day. The use of these solutions allows companies to free up labor that can be dedicated to other activities with higher intellectual intensity.
Reduction of costs caused by fraud	The ability of Artificial Intelligence techniques to process, even instantly, large volumes of data from multiple sources, allows for more effective and faster detection of suspicious transactions, fraud schemes, signs of money laundering, and anomalous financial behaviors in general, reducing associated costs.
Improvement of sales strategies	The adoption of AI tools that track consumer purchasing preferences and provide personalized spending suggestions based on observed buying behavior can allow companies to better intercept the needs of potential buyers through targeted offerings.
Streamlining decision-making	This is enabled by the automated and almost instantaneous support that advanced technologies can offer in contexts where significant amounts of data (big data) are present, such as credit assessment and decisions regarding loans and investments.
Improvement in the accuracy of predictions generated by predictive models	This improvement is due to the ability of AI-based tools to identify connections between variables, even those that are less evident and highly complex, compared to what is possible through the use of traditional techniques. Additionally, AI techniques are significantly more efficient in handling larger volumes of data and factors that may seem less relevant at first glance to the specific context of financial risk assessment. Consequently, they enable the production of more accurate predictions.

TABLE 12: AI Benefits for Businesses

Potential Risks Associated with the Use of AI

In contrast to the benefits derived from the proliferation and use of AI-based solutions, **they are also accompanied by a series of disadvantages and potential risks that**, if not managed and mitigated properly, can **compromise the proper application of AI and**, in some cases, cause harm to its users and beyond. In particular, according to the White Paper on Artificial Intelligence published by the European Commission in 2020, **the risks associated with AI can be both material** (related, for example, to risks to the health and safety of individuals) **and immaterial** (related, for example, to limitations on data privacy or freedom of expression), depending on the actual use of such tools.
Here is a more detailed overview of the **main potential risks** arising from the use of Artificial Intelligence techniques:

- **Transparency and Explainability**;
- **Distorsions (Bias) and Fairness**;
- **Accountability and Reliability**;
- **Data Privacy**;
- **Cybersecurity**.

Transparency and Explainability

As described in Chapter "Possible Benefits from the Use of Artificial Intelligence" regarding the potential benefits of AI solutions, **they are capable of accurately modeling phenomena for which they are used**, often leveraging complex relationships among data that are **not identified by traditional models** and techniques. While this characteristic improves the accuracy of predictive models and the decisions based on them, **it also complicates the interpretation of the relationships** on which these decisions are based, making them opaque and difficult to explain. This phenomenon is particularly relevant with higher levels of complexity in AI techniques, such as **deep learning based on complex neural networks**, which essentially act as **black boxes**. This usually results in a **trade-off between the performance** (accuracy) of AI systems on one hand and **transparency** on the other, necessitating developers to strike an appropriate balance between the two dimensions. When analysing problems related to the complexity or even the impossibility of understanding how a particular AI system operates and the **rationales behind its decisions**, the concepts of **explainability** or **interpretability** typically arise. According to EBA[14], **an AI model is considered "explainable" when its internal dynamics can be directly understood by humans** (interpretability) or when explanations can be provided regarding the main factors that have led to its results.

The **lack of transparency** in AI systems not only **negatively impacts the explanation of the results they produce** but also **affects the ability to identify potential malfunctions** or areas for improvement. In general, issues related to the transparency and explainability of AI systems are more relevant when their results and decisions **impact humans**. For example, in the case of adopting an AI model to determine loan approval for a credit applicant, **it is crucial for the bank to identify the rationales that led the model to deny the approval**. In this regard, the **European Regulation on the protection and processing of personal data (GDPR)**[20] stipulates, in **Article 13**, the right of data subjects (and thus customers) to receive information about "the **existence of automated decision-making** [...] and the **logic used**, as well as the significance and the envisaged consequences of such processing for the data subject." According to Banca d'Italia[2], the request for "meaningful information on the logic used "***implies an obligation for intermediaries to provide so-called "local" explanations*** *to applicants, inclusive of the details of the main variables that contributed to a specific outcome regarding the loan approval or denial*". The risks associated with the **lack of explainability** of AI systems are further **accentuated** in the case of **solutions purchased by**

companies from third parties. In such cases, the EBA recommends that the purchasing institution have **adequate tools** available to **explain** and **validate** the results produced by the purchased system without being heavily dependent on the third-party provider.
In light of the above, it is evident that for those using such solutions for **decision-making purposes** that **impact individuals** (e.g., credit scoring, fraud detection, etc.), such as financial institutions, there is a need to **balance the trade-off** between model performance and explainability, **accepting lower accuracy for greater transparency**. A contribution in this regard is linked to the increasing **availability** of explainability tools (so-called "**Explainable Artificial Intelligence**," or **XAI**) that can be adopted to **reduce the opacity level** of AI models. Academic research on XAI is continuously evolving and already provides developers with **explainability libraries** for the most common programming languages used in AI[11].

Distorsions (Bias) and Fairness

A **widely discussed topic** in the realm of AI-based decision-making applications with impact on individual persons is the **potential presence of biases in the data** used for model training. If **not adequately addressed** during the development and/or application of the AI model, such biases can lead to **discrimination against individuals or groups of individuals** (e.g., discrimination based on age, disability, gender, sexual orientation, political, religious affiliations, etc.).
In general, as reported by Castelnovo et al.[9], the concept of bias can be **distinguished** into:

- **Statistical or representation bias**: this form of **data distortion** occurs when the data is **not representative** of the **true population** it refers to. It can be generated by forms of **selection bias**, where the individuals represented in the available data **do not belong to a random selection of the true population**. For example, consider the case of data related to **loan repayment capacity**, which is **observed** and **available** only for individuals who have actually been granted **credit in the past**, and therefore **not representative** of individuals who have applied for credit but have been denied it.
- **Historical or societal bias**: even if the data is not affected by statistical bias, there may be a **form of distortion** in the data that reflects distorted **behaviors or decisions in the past**. This can typically be attributed to a **bias in label assignment**, where there is a phenomenon of **systematically favorable/unfavorable treatment towards certain groups of individuals** when the target variable on which the AI system is trained is created (for example, consider the case where a credit scoring model is developed based on credit decisions made by managers in the past).

Regardless of their nature, **biases in data** can lead a model developed on such data to produce results, and **ultimately decisions**, that may be **discriminatory** towards certain individuals or homogeneous groups of individuals. This phenomenon, which generally represents a risk even in the case of traditional statistical models, **is exacerbated in the case of AI models**, as they **tend to replicate or even amplify any biases** present in the data, for example through **non-linear connections** between different data sources[12].
The **principle of non-discrimination** is generally referred to as the principle of **fairness**. The topic of fairness represents a deeply explored and **debated element** in the literature concerning the **ethical implications** arising from the **application of AI** techniques. One of the **main issues** to address when analysing the **fairness of a model** relates to **defining the characteristics** for which the model under consideration is **deemed fair**. Indeed, there are **various definitions** and **interpretations** of fairness, primarily based on the distinction between **individual fairness** and **group fairness**. Before proceeding with the definitions, however, it is important to define the concept of **protected** or **sensitive attributes**, typically used in articulating possible definitions of fairness. Protected or sensitive attributes are defined as those **personal characteristics of individuals** (or groups of them) **on which the absence of discrimination is to be verified**, such as gender, ethnicity, age, sexual orientation, political or religious affiliation, etc. Consequently**, it is possible to define the concepts of individual and group fairness** (for a broader and more detailed examination of possible definitions and articulations of fairness metrics, refer to Castelnovo et al. (2021)[8], Castelnovo et al. (2022)[9] , and Rubicondo and Rosato[27]):

- *Individual fairness*: this principle focuses on **comparing individual persons** and posits that similar individuals (i.e., those differing only with respect to their characterisation of sensitive attributes) should receive **equal** or at least similar treatment.
- *Group fairness*: this principle of fairness focuses on **comparing groups** of individuals and requires that these groups receive similar treatment **regardless of their sensitive characteristics**. The principle of group fairness is typically expressed by demanding **equality** of certain **statistical metrics** across different groups. In the literature, three possible notions of group fairness are proposed, as follows:
  - *Independence*: according to this criterion, the model's outcomes should be **independent** of the characterisation of **sensitive attributes** across different groups analysed. Taking the decision regarding the approval of a loan for individuals of different genders (male and female) as an example, this principle implies that the **probability of a positive decision** (credit approval) should be **equal** between males and females.
  - *Separation*: this criterion entails that the model's outcomes are, as above, **independent of the characterisation** of sensitive attributes, but **conditioned** on the value of the **target variable** considered. In the previous example regarding credit approval, this means that any **differences** in the probability of a positive decision between males and females are entirely justified by **differences in observed riskiness** between the two groups (for example, the historically observed default frequency).
  - *Sufficiency*: this criterion **reverses** what is expected by the **concept of separation** and requires that, among subjects belonging to **different sensitive groups** and receiving the **same decision** from the model, the **probability of having the same realisation** of the true target variable considered is **equal**. Continuing with the previous example regarding credit approval, this implies that, for two subjects of different genders who have received the same decision from the model (for example, loan

[11] For an overview regarding the most popular XAI techniques currently available, see [26].
[12] European Banking Authority, *Report on Big Data and Advanced Analytics*, January 2020, see [14].

denial), **the actual riskiness** (risk of default) **is equal or at least similar**.

Beyond the precise **definition of fairness** among those listed above, a model can generally be deemed **fair** if it **does not produce discrimination in outcomes** based on the values of protected or **sensitive attributes** as defined above. **Biases in data** and potential risks of discrimination in outcomes can be **mitigated** by addressing specific aspects in the **model development** process, such as **removing information** on sensitive attributes from the **training dataset** (so-called "Fairness Through Unawareness"), or intervening in the dataset composition using **oversampling techniques** to mitigate issues of poor representativeness towards certain groups.
The **ethical implications** related to fairness represent one of the **main concerns** highlighted by the **European Commission** in its Ethics Guidelines for Trustworthy AI[18] and its White Paper on Artificial Intelligence, which are reflected in its proposed regulation on Artificial Intelligence (described in more detail in Chapter "Regulation of Artificial Intelligence: an Overview", to which reference is made).

Accountability and Reliability

An additional **element of complexity** associated with AI systems lies in their **accountability**, namely the ability to **trace back** to the origin of a particular decision made by the system and ultimately define **responsibility** in case of erroneous or **harmful decisions**. The concept of **accountability** is therefore **closely linked** to that of transparency and explainability discussed in the preceding paragraphs, and the related issues are of **increasing importance** as the volume of decisions delegated to such systems grows, which must therefore be as **transparent** and **justifiable** as possible. The need to ensure a **sufficient level** of accountability for the results of AI systems is among the principles of the **Ethics Guidelines for Trustworthy AI** issued by the European Commission, which require **suppliers and/or users** of such solutions to establish **adequate mechanisms** to ensure the accountability of AI systems and their results, both during **development** and **in their use**. To achieve this, AI systems must be **auditable**, for example by providing traceability and **logging mechanisms** to ensure that their operation can be **independently audited**. Another **potential risk** associated with AI techniques and connected to accountability is that of the **reliability of the results** produced. According to Rubicondo and Rosato [27], reliability refers to the **poor robustness** of **AI-based models** with respect to possible **variations in input data**, which, even if limited, can produce **significant variations** in the results of such models. Indeed, as these solutions rely on data as their **strength**, they are more **vulnerable** to possible **distributive shifts** in the underlying data and to potential variations in the **actual relationships** among them. Issues related to reliability are further exacerbated by the difficulty of **monitoring** and **investigating** the results produced by AI models, confirming the **need to ensure transparency and auditability** in their operation.

Data Privacy

AI-based models **benefit** enormously from the **abundance of data** at their disposal, which allows them to model phenomena under analysis **more accurately** and precisely. However, the **ability** of these tools to analyse data from **diverse sources**, such as internet browsing data, social media data, online purchasing experiences, or through payment cards, poses potential **risks** regarding the **protection of customers' personal data**. Therefore, it is important for those who develop and use such tools to **ensure compliance** with **principles** related to the protection of personal data, ensuring that categories of **protected data are not actually used** by the analysis models. This principle generally applies to **analytics solutions** based on **traditional techniques** as well; however, it becomes more relevant in the context of using **AI techniques** because they, by exploiting **correlation relationships** between data, may be able to **reconstruct** protected information (such as sensitive attributes exemplified in the section dedicated to fairness) even if they are **previously removed** from the training dataset.
In this regard, EBA[14] recommends that **financial institutions** ensure **compliance with the data protection principles** established by the **GDPR** in **all stages** of the life cycle of big data and advanced analytics-based models (both in development and production phases). Among these **data protection principles**, the EBA emphasises the need for **customer consent** to the processing of personal data and the **obligation to inform** the customer about any form of data processing carried out on such data. Regarding data used for **credit assessment** purposes, it is also worth noting the **European Commission's proposal** for a new **directive on Consumer Credit**, which highlights the **prohibition** of using certain categories of personal data for **creditworthiness assessment** (CWA), including data derived from **social media** and data related to the **health conditions** of customers[13].
Lastly, concerning **data privacy issues**, it's worth noting that when using Generative AI solutions (like **ChatGPT**), there's a **risk of disclosing sensitive data** (personal data or internal company data) during system queries. There's indeed a risk that such data might be **acquired** by the system, potentially **violating** the principle of **confidentiality** and **protection**.

Cybersecurity

Another potential **risk** associated with the application of **AI-based tools** is related to **cybersecurity** issues. Given that these are **decision-making** systems, AI models are susceptible to potential **malicious data manipulation** aimed at **distorting** their results. For example, **Deutsche Bank Research**[12] highlights the risk of potential **hacker attacks** aimed at **altering the database** used by an AI system (for example, by **spreading false news**) in order to manipulate its results in a particular direction. Other examples of possible manipulation using AI include the alteration or even **creation of fake media content** (such as images or videos) designed to influence **individuals' opinions** on various aspects, such as political views or consumer preferences, through **false representation** of reality, with significant ethical and social repercussions[14].
According to the **European Banking Authority** (EBA) in its ***Report on Big Data and Advanced Analytics***, some of the **main types of attacks** to which **AI** solutions are susceptible include, for example:

- ***Model stealing***: a type of attack aimed at "**stealing**" the models by **replicating their functioning** (for ex-

[13] European Commission, *Proposal for a Directive of the European Parliament and of the Council on Consumer Credit*, 2021 [15]. It reports at paragraph 37: "[...] what categories of data may be used for the processing of personal data for creditworthiness purposes, which include evidence of income or other sources of repayment, information on financial assets and liabilities, or information on other financial commitments. Personal data, such as personal data found on social media platforms or health data, including cancer data, should not be used when conducting a creditworthiness assessment."

[14] Rubicondo,D., Rosato,L., *AI Fairness: Addressing Ethical and Reliability Concerns in AI Adoption, Iason Research Paper Series*, March 2022, see [27].

ample, requesting a model to **provide predictions** on a wide variety of different inputs and using these predictions to develop a new model, which will effectively tend to **replicate** the first one).

- ***Poisoning attacks***: attacks in which attempts are made to **influence and manipulate the training data** in order to **distort the results** and decisions made by the model.
- ***Adversarial attacks***: in these cases, the attack consists of providing the model with a **slightly perturbed** input data sample in order to **alter its predictive power**. These attacks are typically aimed at inducing the model to **avoid detecting** a particular element (so-called "evasion attack").

In light of the above, it is of **paramount importance** for businesses employing AI tools to **equip** themselves with adequate **cybersecurity** measures, maintaining a level of protection and **technical surveillance** that is sufficiently robust, and **continuously monitoring** potential cybersecurity attacks and the corresponding defensive techniques available.

Main Applications of Artificial Intelligence in Banking Sector

Opportunities for the Banking Sector

As anticipated in Chapter "Possible Benefits from the Use of Artificial Intelligence", the adoption of **AI solutions** can bring **undeniable benefits** to businesses, assisting them in their **digital transformation** processes and increasing **profitability**. This also applies to companies in the **banking** and **financial** sector, which have been actively employing AI techniques in various areas of their operations for several years. In fact, **AI-based tools** are already used for different purposes and **multiple applications** by **banking intermediaries**. A survey conducted by The Economist Intelligence Unit in 2022, targeting the **major global banks** on the **use of AI** in the banking context, highlighted that **almost all financial institutions** resort to Artificial Intelligence to some extent. Specifically, **more than half** of the participants in the study reported using **AI technologies**, for example, for fraud detection, optimisation of IT operations, and digital marketing (in terms of purchase suggestions and recommendations based on purchase history). Other areas where these technologies are **widely applied** include risk assessment and credit scoring, customisation of customer experience (including marketing and sales aspects), product design optimisation, and personalised investment strategies. In the **United Kingdom**, a survey conducted by the **Bank of England**[5] in 2022 on a sample of national banks illustrated that about **two-thirds of the responding institutions** already use **Machine Learning** techniques for various purposes, with **customer engagement** and areas of **risk management** and compliance predominating.

In particular, based on various studies and reports (including the aforementioned survey by the **Bank of England**, as well as reports published by the **Financial Stability Board**[21] and the European Banking Authority[14][15]) the following is an **overview of the main areas of application of AI in the banking sector**.

While the above provides an overview of the potential applications of AI-based tools by banks, it's important to note that, from a **supervisory perspective**, regulatory authorities have also embraced the adoption of such techniques. In this regard, the emergence of so-called "***SupTech***," the adoption process by financial sector supervisors of technological and digital tools, including AI[16], is noteworthy. According to The Alan Turing Institute's aforementioned study, AI tools are already being used by some **regulatory authorities**, for instance, to identify the **risk of illicit conduct by financial advisors** or to independently **verify the appropriateness of risk models** of supervised intermediaries. The Financial Stability Board[21], for example, highlights the launch by the Bank of Italy of a **textual sentiment analysis model** to monitor depositors' confidence levels by analysing Twitter posts, for challenging the funding models of supervised banks. In a recent blog post[17], the **European Central Bank (ECB)** provided some details regarding certain areas of activity where it is already **applying AI tools** (both in its role as a monetary policy authority and as a banking sector supervisory authority). To cite a few examples, albeit not exhaustively, the ECB states, for instance, that it uses **Machine Learning techniques** for classifying data used for **statistical and decision-making purposes** across various reference sectors. It also employs **Natural Language Processing techniques** to analyse vast amounts of documents and extract relevant information (for example, applying entity recognition tools to identify information associated with a specific bank among news articles or newspapers).

Potential Challenges for the Banking Sector

In addition to the opportunities that Artificial Intelligence offers to the banking system, there are also notable **potential challenges and difficulties** that a conscious adoption of AI entails. Among the possible challenges for the banking system, the following points of concern are highlighted.

Regulation of Artificial Intelligence: an Overview

As described in previous chapters, the phenomenon of AI has seen increasing diffusion and application only in recent years. Its use and adherence to existing regulatory frameworks are therefore not yet fully defined, nor are they fully covered (except partially) by current regulations. In fact, the risks described in previous chapters make some form of **regulation necessary**, partly new, to **ensure the security, reliability, and fair dissemination of AI techniques**. This regulation should ensure both a correct and functional use by companies and guarantee that customers and society as a whole can benefit from **fair and transparent technology**.

The Regulation in the European Context

Regarding the European Union, the European Commission has initiated a regulatory process on the application of Artificial Intelligence a few years ago, ensuring its **safe and reliable development**. Below is a brief chronology based on **key regulatory milestones**:

1. The publication of the ***GDPR (General Data Protection Regulation)* in 2018**, although not directly

[15] Further insights into the main applications of AI tools in banking and finance can be found in the aforementioned reports by The Alan Turing Institute[28] and Deutsche Bank Research[12].

[16] Regarding the applications of AI for central bank, see [4].

[17] See The ECB Blog.

Type of Application	Examples
Front-office and Customer Interaction	AI tools can be used for automating customer service and assistance activities, which can be managed through the use of chatbots (virtual assistants capable of generating personalised responses based on available data) and the application of Robotic Process Automation (RPA) techniques for providing automated and customised recommendations to clients regarding investment choices (robo-advice) or for delivering basic services (e.g., guiding a new client in opening a bank account).
Know Your Customer	Another area of application for AI solutions concerns streamlining Know Your Customer (KYC) processes, reducing the time associated with document verification by leveraging a broader spectrum of data to verify the reliability of the information provided and the background of customers. AI techniques can be used, for example, to verify the authenticity of images contained in customer documents (performing cross-checks with other documents pertaining to the same subject) and identifying and flagging any potentially anomalous cases requiring human review.
Credit Risk Scoring	One of the most significant applications of AI in the banking sector concerning risk management activities relates to credit risk scoring of customers, which can be executed using predictive models based on AI to support lending decisions. Banks can benefit from an increasing amount of additional data, including data on current account movements or web interactions, for assessing creditworthiness[13]. The ability to leverage additional data allows for a quicker and more informed assessment of the potential borrower's creditworthiness, while also ensuring better access to financing for creditworthy counterparts whose historical data may not be extensive enough to be included in traditional statistical models. For an investigation into the adoption of AI techniques in credit assessment models in the Italian banking sector, reference is made to a recent study conducted by the Bank of Italy in 2022[2].
Anti-money Laundering and Fraud Detection	Another area of significant application of AI solutions for risk mitigation purposes is related to fraud detection and anti-money laundering activities. AI techniques can be used to analyse (even in real-time) vast volumes of customer transaction data, identifying any anomalies and flagging potentially suspicious transactions for further scrutiny. Furthermore, AI techniques can be employed to analyse corporate financial data and intercept any financial irregularities.
Mitigation of the Risk of Illicit Conduct	AI tools can also be used to identify potential insider trading situations. In particular, through clustering algorithms, it is possible to analyse the trading activities of a specific actor, identifying any discontinuities in their behavior, and detecting the presence of groups of investors acting similarly even in the absence of price-sensitive public information, thus highlighting potential illicit conduct.
Model Validation	AI techniques can be used by the Internal Validation Functions of financial institutions to develop challenger models to test the robustness of models developed within the bank.
Algorithmic Trading	AI systems can be used to develop algorithmic trading tools to identify anomalies and/or predict market dynamics. Some examples include AI tools used to analyse investor sentiment or investigate the impact of social media on the performance of financial instruments.
Calculation of Capital Requirements	The same techniques used for credit scoring purposes can be employed to estimate credit risk parameters for calculating capital requirements through Internal-Ratings Based (IRB) models. In this regard, the Follow-up Report on the use of Machine Learning for IRB Models published by the EBA in August 2023[14] illustrates the state-of-the-art practices among European banks regarding the usage of Artificial Intelligence for IRB models. Specifically, the report highlights that, despite some challenges faced by banks, such as issues related to the interpretability of such models or the lack of adequate skills for their development and validation, models based on AI techniques are already widespread. They are predominantly used in specific phases of the IRB approach, including the core development of modeling, validation activities using "challenger" models, and collateral assessment activities.
Regulatory Compliance	Among these, the possibility of streamlining regulatory reporting activities is highlighted. AI tools can be used to support the management of the increasing volumes of data to be reported within the regulatory reporting requirements of financial institutions. For example, such tools can be used to expedite data processing and verify its quality, thus identifying any errors and other data quality issues and anomalies to be reported to data analysts.

TABLE 13: Examples of AI applications in the banking sector

related to AI regulation, is considered a foundational starting point for the development and application of these technologies. As seen, AI relies heavily on data usage, and it's impossible to separate the fundamental issues of its correct and fair use from those related to the treatment and protection of sensitive data.

2. The release of the ***Ethics Guidelines for Trustworthy AI***[18] in 2019 and the ***Assessment List for Trustworthy Artificial Intelligence*** (ALTAI)[19] in 2020 was carried out by the Independent High-Level Expert Group (HLEG) on Artificial Intelligence appointed by the European Commission. Both publications focus on additional **fundamental aspects** necessary for creating a conducive environment for the development and application of AI techniques that are safe and reliable. Specifically, they suggest conditions useful for **implementing a reliable and ethical framework** that takes into account all possible aspects of respecting individuals' **fundamental rights, preventing potential harms, ensuring fairness, and enhancing transparency and interpretability** (as already mentioned among the potential risks in Chapter "Potential Risks Associated with the Use of Artificial Intelligence"), with particular attention to impacts on minorities and vulnerable groups. Additionally, within the ALTAI, a **checklist** is proposed for the first time, which is useful for evaluating, through **self-assessment** by each entity that - regardless of the development stage - uses AI, the **level of compliance** with the mentioned requirements. The outlined requirements generally mirror those listed within the proposed AI Act, namely:

   - *Human Agency and Oversight*: requirements aimed at ensuring that the **decision-making process of AI systems is supervised by humans** to ensure that the resulting decisions

Type of Application	Examples
Availability and Quality of Input Data	Banks face the following challenges related to input data: • Availability of a sufficiently large volume of data: training AI models requires vast amounts of data, enabling them to identify relationships that may not be evident in smaller datasets and contribute to increasing the accuracy of the estimates provided. The use of large datasets is also essential for reducing the risks of overfitting, where a model fits too closely to the known data during training and fails to generalize its predictive ability to new data. The growth in the quantity of available data, driven by the increasing digitisation of the financial sector, should over time help mitigate limitations due to this obstacle; • Availability of high-quality data: in addition to the volume of data required to produce reliable AI solutions, the data itself must be of good quality. If the data used is incomplete, inaccurate, distorted, or inconsistent, the model's predictions can be imprecise or distorted, exacerbating the potential risks of bias and discrimination described in Chapter 3; • Compliance with data privacy requirements, which can nullify the potential effect of data availability and quality (as well as expose the bank to legal liabilities). In this regard, Art. 5 of the aforementioned European regulation on the protection of personal data (GDPR) requires banks to demonstrate compliance with the principles of personal data protection. This requirement becomes even more relevant in the use of AI techniques, as they are capable of reconstructing "protected" information from their relationship with other variables in the dataset, even in the absence of sensitive information among the data available. It is therefore evident that banks need to adopt appropriate measures for responsible data management in compliance with regulatory requirements, ensuring that models do not leverage sensitive personal data where its use is not permitted[16]. The relevance of these requirements is greater when the decisions based on such data have consequences for individuals' access to fundamental rights, such as access to credit or the possibility of obtaining a certain job[17]. This need is also reflected in one of the four pillars outlined by EBA [13] for the use of big data and advanced analytics, which involves banks identifying and categorising the data protection constraints used and anticipating the definition and implementation of technical and organizational measures aimed at ensuring data security.
Interpretability and Explainability	As mentioned in Chapter 3, the complexity of relationships modeled by AI solutions can make it challenging to interpret the results. Banks must therefore balance the trade-off between model performance and interpretability. Additionally, they need to equip themselves with appropriate interpretability techniques to increase the transparency of these models and explain the relationships between inputs and outputs that have produced a particular result.
IT Infrastructure	Banks need to adapt their IT infrastructure, which, if outdated, can hinder the introduction of modern artificial intelligence techniques, with negative effects on their diffusion. Particularly, the hardware and software systems currently in use by banks may lack the computational power and storage capacity needed to effectively develop and manage next-generation models, which heavily rely on these resources. One of the initial responses adopted by banks to address the challenges of potential technical obsolescence, which are difficult to resolve quickly and in line with market competitiveness, is the adoption of cloud systems. This involves purchasing remote servers to outsource computationally intensive processes and hardware requirements. The adequacy of IT infrastructure is also one of the pillars outlined by EBA for the use of big data and advanced analytics, envisioning a technological structure based on three components: infrastructure, data platform, and processing component. The infrastructure includes network resources for data transmission, computing resources, and storage resources. The data platform manages all the data used by the analytics system, allowing access to them, while the processing component supports the software required for analysis processing, in line with their volume and speed[18].
Availability of Adequately Skilled Personnel	The use of Artificial Intelligence-based tools poses a challenge in terms of skills, as many of these systems require advanced mathematical-statistical knowledge as well as specific programming and data analysis skills. Without these competencies, company resources may not fully leverage the potential of such systems, encountering difficulties in understanding and interpreting the results provided by the models, or failing to identify and manage aspects of model correctness or bias and distortions in the results appropriately. Additionally, ensuring an adequate level of understanding of the results produced by these systems at all levels of the organisation, starting from top management, is necessary. Therefore, it is essential for banks to anticipate and plan for these changes and provide their structures with the necessary support and training to adapt to technological advancements effectively.
Uncertain and Evolving Regulatory Landscape	Given the novelty factor and considering the paradigm shift brought about by Artificial Intelligence techniques, the level of regulation on these issues in the near future remains uncertain. Currently, what emerges is an evolving and partially heterogeneous regulatory forecast across different jurisdictions. The evolving regulatory landscape thus poses a challenge for financial institutions looking to embark on their AI adoption journey, as they must strive to anticipate regulatory developments in the sector to avoid being caught unprepared for potential future regulatory scenarios. A dedicated overview of AI regulation is provided in the next chapter, which offers an insight into the current state of regulation and potential future developments in this area, with a predominant focus on the European context before briefly analysing regulatory trends at the international level.
Regulatory Body Recommendations	With regard to all the challenges described above, Banca d'Italia [3] recommends ensuring the centrality of governance to adequately manage the risks associated with AI, strengthening data governance measures, and ensuring continuity and integrity of information systems. Furthermore, Banca d'Italia recommends keeping human responsibility as the ultimate decision-maker, with AI serving as a supportive tool rather than a guiding force in decision-making processes. Additionally, concerning the possibility for banks to use AI techniques for calculating capital requirements in credit risk (IRB), the recommendations provided by the EBA [14] are highlighted, reaffirming the challenges and critical issues mentioned in earlier chapters of this document.
Algorithmic Trading	AI systems can be used to develop algorithmic trading tools to identify anomalies and/or predict market dynamics. Some examples include AI tools used to analyse investor sentiment or investigate the impact of social media on the performance of financial instruments.

TABLE 14: *Challenges in AI Adoption by Banks*

respect individuals' fundamental rights;

- ***Technical Robustness and Safety***: this requirement is aimed at ensuring the **technical safety and reliability of AI systems** and minimising any unexpected and unintentional damages;
- ***Privacy and Data Governance***: data governance requirements aimed at **ensuring the quality and integrity of the data used** and compliance with the principles of protecting sensitive personal data;
- ***Transparency***: this requirement aims to **ensure the transparency and explainability** of the results produced by AI systems and full communication of their potential limitations;
- ***Diversity, Non-discrimination and Fairness***: these requirements aim to ensure the **absence of biases** in the data supporting AI systems and the **absence of discrimination** in the decisions resulting from them, also ensuring the **fair and non-discriminatory accessibility of AI solutions**;
- ***Societal and Environmental Well-being***: these requirements aim to **ensure that AI systems are compatible with sustainability principles**, both environmentally and socially;
- ***Accountability***: this final requirement aims to **trace back the causes of any potential negative effects** resulting from the application of AI systems.

3. The ***White Paper on Artificial Intelligence***[17] published in 2020 by the European Commission, continues the aim of outlining a **competitive and reliable framework for the development and application of Artificial Intelligence** within the European Union. The document defines the objective of creating both an "ecosystem of excellence, "which encourages the adoption of AI-based solutions, and an "ecosystem of trust," which ensures compliance with regulations by institutions and guarantees citizens the necessary level of trust for the widespread adoption of such technologies".
4. The ***Artificial Intelligence (AI) Act***[16], whose proposal dates back to April 2021 and was agreed upon in December 2023 following discussions between the Commission, Parliament, and the European Council.[18] , is aimed at the entire spectrum of businesses and activities that use or intend to use AI methodologies for their purposes. This regulation applies to all AI tools[19] used within the **European Union**, even if produced by providers from third countries. The AI Act follows a **risk-based approach**, distinguishing various levels of inherent risk associated with potential AI tools based on their nature and use. It identifies different requirements and obligations accordingly:
    - AI systems characterised by an **unacceptable risk**, and therefore **prohibited** (so-called "**prohibited practices**"). This category includes all systems whose use is deemed **unacceptable as it contradicts the values of the Union**, namely those that **violate fundamental rights**. These are practices that could potentially **manipulate individuals** through subliminal techniques without their awareness or methods used to exploit the vulnerabilities of specific individuals to materially distort their behavior in ways that could cause personal harm to themselves or others. Prohibited practices include those related to the **attribution of a social score** generated by AI for general purposes by public authorities and the use of real-time remote **biometric identification systems** in public spaces for surveillance purposes.
    - **High-risk AI systems**, meaning those AI systems that pose a **high-risk to health and safety or to the fundamental rights of natural persons**. In line with the risk-based approach, such systems are **allowed on the European market only if they meet certain mandatory requirements** and pass a conformity assessment. The classification of an AI system as high risk is based on its intended purpose, following current product safety legislation. Consequently, the classification as high risk depends not only on the function performed by the AI system but also on its **specific purpose and how it is used**. Annex III of the regulation identifies the list of AI systems classified as high risk, including, for example, systems used to determine **access to essential services** (including access to credit), systems used for **recruitment and human resources** management purposes (e.g., determining termination of employment), and systems used for **critical infrastructure management** purposes (including traffic management and the provision of water, gas, and electricity).

      According to the regulation, the European Commission will **maintain a list of high-risk AI systems**, containing a limited number of these systems whose risks have already materialised or may materialise in the near future. Following the **risk-based approach**, the Commission may **expand the list of high-risk systems** by applying a series of criteria and a risk assessment methodology. Regarding the specific requirements for systems classified as high risk, the regulation broadly follows what has been outlined in the ALTAI document (previously described), with requirements namely for:

        - ***Data and data governance***: requirements aimed at ensuring that the data used for model development and training meet **quality standards**, particularly regarding **model design choices, data collection and preparation processes,** assumptions about the data, a prior assessment of data availability, suitability, and deficiencies, as well as an assessment of potential biases;

[18] See Artificial Intelligence (AI) Act.

[19] According to Annex 1 of the proposal of *AI Act*, the following AI techniques and approaches fall within the scope of regulation: "Machine learning approaches, including supervised learning, unsupervised learning, and reinforcement learning, with use of a wide range of methods, including deep learning; b) logic-based and knowledge-based approaches, including knowledge representation, inductive (logic) programming, knowledge bases, inferential and deductive engines, (symbolic) reasoning, and expert systems; c) statistical approaches, Bayesian estimation, search methods, and optimisation".

  - ***Technical documentation***: this requirement aims to ensure that each high-risk AI system intended for commercial use is accompanied by **accurate and up-to-date informational documentation**, enabling authorities to verify the system's compliance with regulatory requirements;
  - ***Record keeping***: this requirement ensures that all AI systems in use maintain a **continuous and systematic record of events and operations performed**;
  - ***Transparency and Provision of information to users***: according to these requirements, AI systems must be structured to ensure that users can **interpret and use their outputs correctly**, if necessary by providing concise and clear instructions to users;
  - ***Human oversight***: this requirement aims to ensure that high-risk AI systems are designed to **allow human supervision** through measures such as incorporating controls into the system. Such supervision aims to prevent risks to health, safety, and fundamental rights during the use of AI, assigning these oversight activities to individuals fully capable of understanding the system's operation and intervening as necessary;
  - ***Robustness, Accuracy and Security***: these requirements aim to ensure that high-risk AI systems are **accurate, robust, and computationally secure** throughout their entire lifecycle. At the same time, models on the market must be resilient to biases, data inconsistencies, and interferences with other systems.

- **Low-risk AI systems**, for which **compliance with minimum transparency standards** is required, for example, concerning the need to **inform users that they are interacting with an AI system** and, in the case of content generated by AI tools that may be misconstrued as authentic, to **disclose that the content has been manipulated or generated using AI tools**.

Worldwide AI Regulatory Trends

In its proposal for the AI Act, the European Commission states that the requirements established for high-risk AI systems are broadly **consistent with other international recommendations and principles**, ensuring that the European regulatory framework for AI is compatible with those adopted by the international partners of the European Union. Below is a brief overview of the **trends and possible regulatory developments on Artificial Intelligence** in the other main countries of the world, namely the **United Kingdom**, the **United States of America**, and **China**.
In the United Kingdom, the **policy paper** published by the Department for Science, Innovation, and Technology promotes an approach to AI regulation aimed at fostering an **environment of innovation and achieving specific goals** to make the country a scientific and technological "superpower"[20]. In terms of **AI governance approach**, the main difference from the rule-based approach of the European Union lies in the proposal of a "sectoral regulatory framework", anchored to its existing and widespread network of regulators and laws, which is therefore **less centralised**. The UK's approach is based on **two main elements**: the **AI principles** that existing regulators will be tasked with implementing, and a series of **new "central functions"** to support this implementation activity. In particular, the **principles** underlying the framework to guide responsible AI use are as follows:

- ***Safety, security and robustness***: AI systems must function robustly and securely throughout their lifecycle, and their risks must be identified, monitored, and managed continuously;
- ***Appropriate transparency and explainability***: AI systems must provide adequate levels of transparency, meaning sufficient information to the parties involved in using an AI system, and explainability, allowing the involved parties to access, interpret, and understand the decision-making process of the system;
- ***Fairness***: AI systems must not limit the rights of individuals or organisations, and must not create unjustified discrimination against certain individuals;
- ***Accountability and governance***: adequate governance measures must be provided to ensure an appropriate level of supervision over the provision and use of AI systems, with clear lines of responsibility established throughout the lifecycle of such systems;
- ***Contestability and redress***: where appropriate, users or affected third parties must be able to contest a decision or result produced by an AI system where it causes harm or there is a material risk of harm.

While these requirements may appear in line with those outlined in European regulation, a substantial **difference** lies in the fact that, for the UK, their implementation will not be initially based on legislation but rather **progressively implemented** by existing authorities. This approach aims to prevent new rigid legislative requirements from stifling innovation and reducing the ability to respond quickly and proportionately to future technological advancements.
Regarding regulatory trends in the United States, a **lighter approach** to AI regulation is observed, which is less extensive and impactful compared to what has been seen in the EU and the UK. Despite the expressed intent to introduce federal legislation to regulate AI specifics, the country's regulatory framework largely relies on **voluntary guidelines** at present. For instance, the ***AI Risk Management framework*** [31] published in early 2023 by the *US National Institute of Standards and Technology* (NIST) or **industry self-regulation**, mainly targeted at major tech companies pioneering this field. In this context, noteworthy is the publication of the ***Blueprint for an AI Bill of Rights****[30]*, by the **Office of Science and Technology Policy (OSTP) of the White House**. This white paper aims to outline a **minimum set of guiding principles** for the development and conscious adoption of AI techniques. While these principles are non-binding, they are intended as **guidelines**, and they include:

- ***Safe and Effective Systems***: AI systems must be developed and used safely and effectively, with independent evaluation confirming compliance with these characteristics.
- ***Algorithmic Discrimination Protections***: AI systems must be developed with adequate safeguards to prevent discriminatory effects and violations of fairness principles.

[20] See in this regard Department for Science, Innovation and Technology, *A pro-innovation approach to AI regulation*, March 2023, see [11].

- ***Data Privacy***: AI systems must ensure data usage that is consistent with and compliant with the right to personal data protection, with data collection and usage only permitted with the consent of the individuals concerned.
- ***Notice and Explanation***: the use of an AI system for certain decision-making purposes must be disclosed to the individual beforehand, who has the right to information about the reasons behind a specific decision made by the system.
- ***Human Alternatives, Consideration, and Fallback***: where appropriate, there must be the option to replace judgment based on the AI system with a human assessment, as well as the need for human intervention in cases where automatic systems produce clear errors.

At the federal level, it is also worth considering the publication, in October 2022, of a series of guidelines on **consumer protection** in the use of AI. However, these guidelines serve as general indications and do not have legally binding value. In general, therefore, there is currently **no legislative process** aimed at introducing a set of **legally binding rules** on the development and application of AI, which must therefore rely on the principles and guidelines mentioned above.
In the opposite direction is the regulation of Artificial Intelligence in China, which has adopted **new proposals and laws**[21], in recent years, including a set of **rules on recommendation algorithms** that came into effect in 2022 (introducing requirements for regular assessment of these algorithms regarding their effectiveness, fairness, and security[22]), In 2022, **regulations on synthetically generated content** (deep synthesis) were also introduced, obliging clear disclosure if content was created using AI. Finally, in July 2023, a draft regulatory package on **Generative Artificial Intelligence** was formulated[23]. This package includes licensing requirements for providers of generative AI solutions and aligns with aspects already present in the European regulatory proposal, such as **safety, transparency, and non-discrimination**. It also includes specific requirements, such as adherence to socialist values and a prohibition on producing content that incites against the state[24]. Due to its tendency to foresee updates and further expansions of the regulatory framework in response to new technological developments, China's AI regulations are described as **iterative**. Compared to European AI regulations, China's approach can be considered more "vertical," focusing on individual applications of the technology and differing from the European regulation analysed earlier, which takes a more cross-cutting approach covering all possible applications of AI technologies.

Conclusions

In the previous pages, an overview has been provided regarding the **definition and diffusion of Artificial Intelligence**, along with the **potential benefits and related risks** that can arise from its increasing adoption.
As seen, AI solutions offer the potential for businesses to **enhance their efficiency and productivity** and to **guide them in the transformation processes** dictated by their digital strategies. At the same time, these benefits are accompanied by **risks and challenges**, which must be managed carefully and consciously in order to **maximise the long-term benefits** associated with the use of such new technologies. To do this, companies, including those in the banking sector, will be required to **invest in acquiring adequate skills and IT infrastructure** that allow them to make the most of AI in a secure manner while ensuring respect for **fundamental rights and principles of ethics and fairness**. Furthermore, the continuously **evolving regulatory landscape**, as well as being partially misaligned with the jurisdictions of the major global economic players, will require companies to remain vigilant about what the **future regulatory scenario** may entail, anticipating possible developments. Regarding this, considering the risks associated with AI as described within the document and beyond the regulatory requirements applicable to AI following the conclusion of the ongoing regulatory process, a set of **guiding principles** is outlined below to be evaluated preventively in the development and use of Artificial Intelligence solutions:

- **Accuracy and replicability**: ensure that the results produced by the AI system are reliable and that the system provides indications of the probability of errors. Also, ensure that the results of the AI system can be reproduced by third parties.
- **Communication**: clearly and proactively communicate the benefits and limitations of the AI system to all stakeholders. In the case of systems that interact autonomously with users, transparently communicate to users that they are interacting with an AI system.
- **Data privacy**: during the development of an AI system, ensure that the data used or collected by it is processed and stored consistently and in compliance with applicable data protection regulations. Additionally, ensure that any sensitive data collected by the system is not used to produce discriminatory decisions against users. During the use of an AI system, especially within the scope of using Generative AI solutions, ensure that sensitive and/or confidential data is not improperly disclosed to the system.
- **Data quality**: during the development of an AI system, ensure that the data used for training the system is of adequate quality and does not contain errors, inaccuracies, or distortions that could alter the decision-making process of the system.
- **Equity and non-discrimination**: ensure respect for human dignity, individual freedoms, and principles of fairness and equality in the development and use of an AI system. Minimise the risk of generating unjustified discrimination based on individuals' "sensitive" characteristics by adopting measures to ensure that the data used by the systems are accurate, unbiased, and representative of the context in which the system results are used. Pay particular attention to cases where the use of the system impacts vulnerable individuals or minority groups at risk of discrimination.
- **Technical skills**: promote training and awareness among stakeholders involved in the development or impacted by the use of the AI system, at all levels of the organisational structure, to ensure adequate understanding of the results produced by the system and management of associated risks.

[21] For an overview of these regulatory interventions, see [7].
[22] Friedrich Ebert Stiftung, *China's Regulations on Algorithms. Context, impact and comparisons with the EU*, see [23].
[23] Cyberspace Administration of China, *Interim Measures for the Management of Generative Artificial Intelligence Services*, see [10].
[24] Forbes, *How Does China's Approach To AI Regulation Differ From The US And EU?*, see [22].

- **Technical robustness and security**: adopt appropriate measures to ensure the technical robustness of the AI system through testing activities, continuous monitoring of stability and proper functioning over time, and verification of its compliance with expected behavior. Additionally, ensure the system's resilience to malicious attacks (cyberattacks) that could alter its operation through appropriate cybersecurity measures (e.g., data protection measures against unauthorised or illicit processing and monitoring processes during both training and post-release phases).
- **Human oversight**: provide a mechanism for human oversight during the development and use of an AI system through the presence of adequate controls and the possibility of manual intervention during the decision-making process and system operation. Clearly document the roles and responsibilities of individuals involved throughout the AI system's lifecycle.
- **Transparency, explainability, and traceability**: adopt appropriate measures to ensure the explainability of the results produced by the AI system to transparently communicate them to involved stakeholders (e.g., apply adequate Explainable AI techniques to elucidate the relationships between the system's inputs and outputs). Additionally, adopt measures to ensure the traceability of the system and any errors produced by it, clearly and comprehensively documenting the data used by the system and its development process.

References

[1] **AIFIRM, Position Paper No. 33.** *Artificial Intelligence and Credit Risk. Possible uses of alternative methodologies and data in internal rating systems*, January 2022.

[2] **Banca d'Italia.** *Intelligenza artificiale nel credit scoring. Analisi di alcune esperienze nel sistema finanziario italiano, Questioni di Economia e Finanza*, October 2022.

[3] **Banca d'Italia, Intervento di Giuseppe Siani, Capo del Dipartimento Vigilanza bancaria e finanziaria della Banca d'Italia, Boston Consulting Group.** *AI-driven bank: Opportunità e sfide strategiche per il sistema finanziario e la vigilanza*, October 2023.

[4] **Bank for International Settlements.** *Artificial Intelligence in Central Banking - Bulletin No. 84*, January 2024.

[5] **Bank of England.** *Machine Learning in UK financial services*, October 2022.

[6] **Cao,Y., Li,S., Liu,Y., Yan,Z., Dai,Y., Yu,P.S., Sun,L.** *A Comprehensive Survey of AI-Generated Content (AIGC): A History of Generative AI from GAN to ChatGPT*, August 2018.

[7] **Carnegie Endowment for International Peace.** *China's AI Regulations and How They Get Made*, July 2023.

[8] **Castelnovo, A., Crupi, R., Del Gamba, G., Greco, G. Naseer, A., Regoli, D.and San Miguel Gonzalez, B.** *Addressing Fairness in the Banking Sector*, February 2021.

[9] **Castelnovo, A., Crupi, R., Greco, G., Regoli, D., Penco, I.G. and Cosentini, A.C.** *A clarification of the nuances in the fairness metrics landscape, Scientific Reports Volume 12, No. 4209*, March 2022.

[10] **Cyberspace Administration of China.** *Interim Measures for the Management of Generative Artificial Intelligence Services*, July 2023.

[11] **Department for Science, Innovation and Technology.** *A pro-innovation approach to AI regulation*, March 2023.

[12] **Deutsche Bank Research.** *Artificial intelligence in banking. A lever for profitability with limited implementation to date*, June 2019.

[13] **European Banking Authority.** *Follow-up Report from the Consultation on the Discussion Paper on Machine Learning for IRB Models*, August 2023.

[14] **European Banking Authority.** *Report on Big Data and Advanced Analytics*, January 2020.

[15] **European Commission.** *Proposal for a Directive of the European Parliament and of the Council on Consumer Credit*, June 2021.

[16] **European Commission.** *Proposal for a Regulation of the European Parliament and of the Council laying down harmonised rules on Artificial Intelligence (Artificial Intelligence Act) and amending certain union legislative acts*, April 2021.

[17] **European Commission.** *White Paper on Artificial Intelligence - A European approach to excellence and trust*, February 2020.

[18] **European Commission - High Level Expert Group (HLEG) on Artificial Intelligence.** *Ethics Guidelines for Trustworthy AI*, April 2019.

[19] **European Commission - High Level Expert Group (HLEG) on Artificial Intelligence.** *The Assessment List for Trustworthy Artificial Intelligence (ALTAI) for self-assessment*, July 2020.

[20] **EU Regulation 2016/679.** *EU Regulation 2016/679 of the European Parliament and of the Council on the protection of natural persons with regard to the processing of personal data (General Data Protection Regulation)*, April 2016.

[21] **Financial Stability Board.** *Artificial intelligence and machine learning in financial services. Market developments and financial stability implications*, November 2017.

[22] **Forbes.** *How Does China's Approach To AI Regulation Differ From The US And EU?*, July 2023.

[23] **Friedrich Ebert Stiftung.** *China's Regulations on Algorithms. Context, impact and comparisons with the EU*, January 2023.

[24] **International Monetary Fund.** *Generative Artificial Intelligence in Finance: Risk Considerations*, August 2023.

[25] **Korzynski, P., Kozminski, A. and Baczynska, A.** *Navigating leadership challenges with technology: Uncovering the potential of ChatGPT, virtual reality, human capital management systems, robotic process automation, and social media*, May 2023.

[26] **Molnar, C.** *Interpretable Machine Learning. A Guide for Making Black Box Models Explainable*, August 2023.

[27] **Rubicondo, D. and Rosato, L.** *AI Fairness: Addressing Ethical and Reliability Concerns in AI Adoption, Iason Research Paper Series*, March 2022.

[28] **The Alan Turing Institute.** *The AI Revolution: Opportunities and Challenges for the Financial Sector,* August 2023.

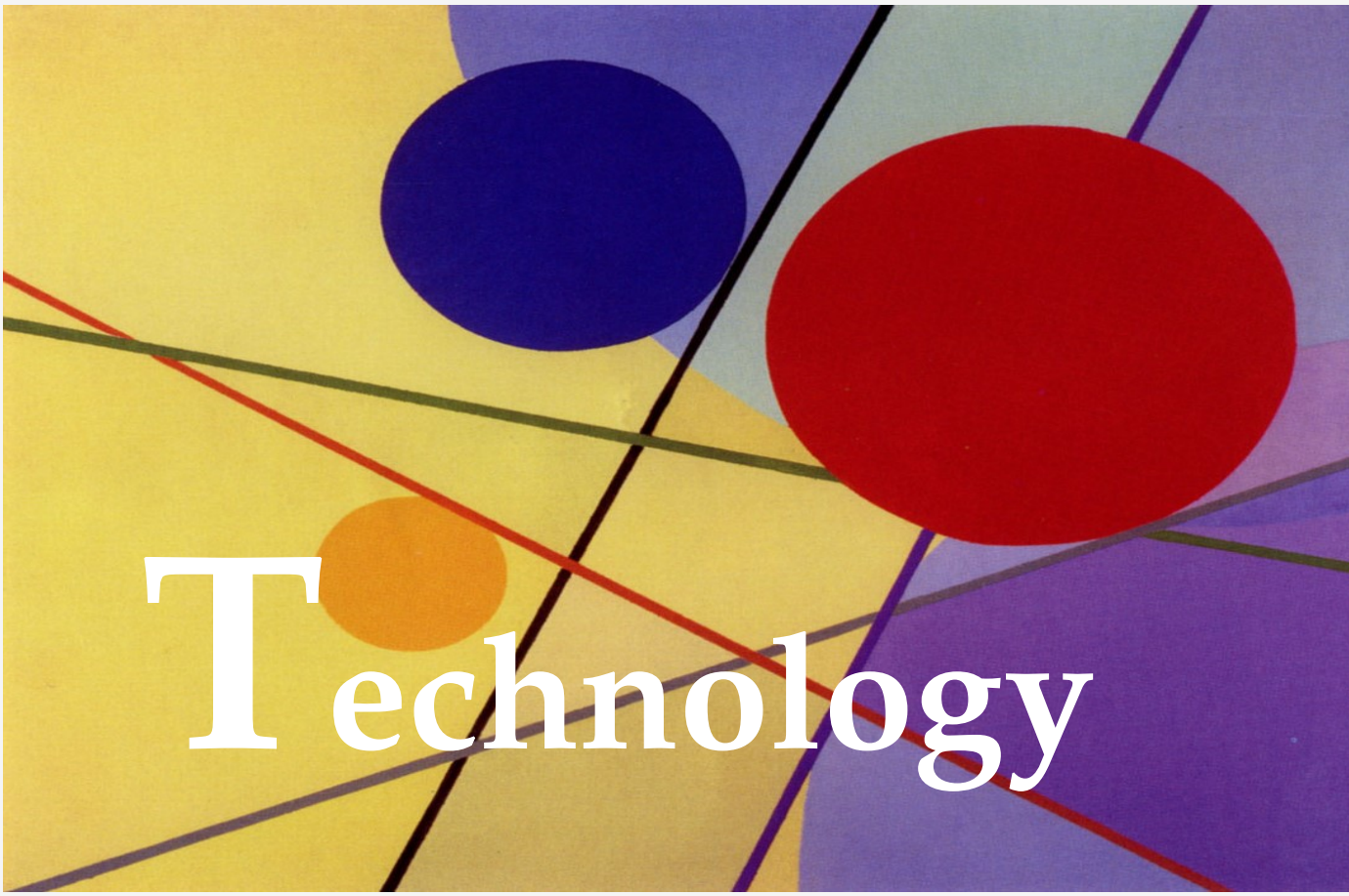
[29] **The Economist Intelligence Unit.** *Banking on a game-changer: AI Risk Management Framework*, 2022.

[30] **The White House - Office of Science and Technology Policy.** *Blueprint for an AI Bill of Rights*, October 2022.

[31] **US National Institute of Standards and Technology.** *AI Risk Management Framework*, January 2023.

[32] **US National Institute of Standards and Technology.** *Big Data Interoperability Framework*, June 2018.

[33] **Wach, K., Duong, C. D., Ejdys, J., Kazlauskaité, R., Korzynski, P., Mazurek, G., Paliszkiewicz, J.and Ziemba, E.** *The dark side of generative artificial intelligence: A critical analysis of controversies and risks of ChatGPT*, May 2023.



Asset Tokenization: Potential Applications

About the Authors

Valerio Ciminelli:
Business Analyst
He holds a MSc in Finance, Intermediaries and Markets from Alma Mater Studiorum University of Bologna. He has experience as Business Analyst and he is currently working on various implementation projects for one of the major European banks.

Giuseppe Morisani:
Senior Business Analyst
He holds a BSc in Economics&Management from the University of Pavia and a MSc in Finance& Investments from the University of Leeds Business School. He has been working as an analyst for the Morgan Stanley Market Risk Portfolio Team located in London, Budapest, Frankfurt, and New York; and supported other global consulting firms as well as wealth management funds in the following areas: risk management, research, asset management, IT solutions and project management. Currently, he is working on various strategic projects at a major Italian bank.

This document was prepared in collaboration with Nicola Mazzoni, who at the time was working for Iason Consulting.

Asset Tokenization: Potential Applications

Lending and Real Estate Markets

Valerio Ciminelli Nicola Mazzoni Giuseppe Morisani

The growing interconnections between markets and technologies are fostering radical changes in traditional business paradigms supporting potential groundbreaking shifts in various industries. This research aims to uncover the disruptive potential embedded in asset tokenization within this evolving landscape. Explaining first the features and the characteristics of both its operative environment and its regulatory landscape. The paper proceeds in the analysis of two key markets where asset tokenization could boost the growth and bring transformative shifts. In summary, the main object of the research is to provide both a technical and applicative vision of the evolution of the market on asset tokenization, providing a brief but solid knowledge of the potential of these technologies.

In the dynamic and fast-changing digital and financial landscape, the rise of asset tokenization stands out as one of the most impactful technology applications in markets which will probably reshape the traditional view of asset ownership and trading. The growing interest in this technology is strictly related to the widespread of the DeFi, a decentralized financial environment that relies on DLTs, within the markets and the potential changes that these could bring in the future economic landscape. The core focus of the research is firstly to uncover the technology foundations on which DeFi, and so asset tokenization, rely and proceed with an explanatory view of the main phases of the asset tokenization process unrevealing the most important benefits that this technology could bring across several markets. Secondly, the work focuses on the playing field where different market participants can apply this new technology in their respective business areas. To this end, the state of the art of the international regulatory framework is analyzed, considering the latest efforts by International Financial Authorities, as well as national and supranational regulations. Furthermore, the analysis will rely on two pivotal applications of asset tokenization, lending and real estate markets examining also some of the most relevant asset tokenization leveraged projects in these markets.

DeFi Key Concepts and Components

This first chapter aims to explain all the core concepts which will be crucial to understanding how the asset tokenization works. We will provide the reader with an overview of the main "new" Technologies that are cornerstones of the Digital Assets environment. A reader who is already comfortable with terms and concepts such as DLT, Blockchain, and tokens could consider reading the chapter as a "refresher". After that, we will describe the token anatomy, focusing on the main token typologies and their characteristics.

The Environment

The core of any introduction to tokenized environments has to be the explanation of the already famous Distributed Ledger Technologies. DLTs are the most important technologies that have made the expansion and growth of Digital Asset transactions possible. With DLT we are referring to a database distributed in identical copies among the nodes that compose the environments. The peculiarity of DLTs is that the ledgers among the nodes chain are simultaneously updated through a consensus mechanism. The node's network is in charge of the maintenance of the ledgers implying the continuous update of the information stored in the registries. However, the ledgers are not simultaneously updated at all the node levels implying a floating time to synchronize the information in all of them.

One of the most notable differences between a traditional centralized ledger and DLTs is the application of a consensus algorithm that requires accordance between every node of the network in order to proceed with the update of the ledgers. The most diffuse Consensus Mechanism is the well-known "Mining Process" that requires the network components to solve high-level computational problems to validate the information and update the ledgers. The high computational and energetical cost of the PoW (Proof of Work) "Mining mechanism" has opened the way to another kind of consensus algorithm among which one of the most famous is PoS (Proof of Stake) that requires participants to hold and prove the ownership of a certain amount of digital assets to validate transactions and secure the network. Another key role in ensuring transactions and information stored in the ledgers is played by cryptography algorithms that are used to authenticate the transaction's participants, guarantee the integrity of the messages and avoid breaches in the network by third parties. The most famous ones are asymmetric cryptography, which consists of the use of a public key to encrypt a message that can only be read by using a private key, and hash function, which consists of mathematical functions that map the input data into a fixed-size string of known hashes. The DLTs could be classified according to the access control profile in Permissioned and Permissionless. Permissioned DLTs are characterized by a restricted group of participants that could participate in the

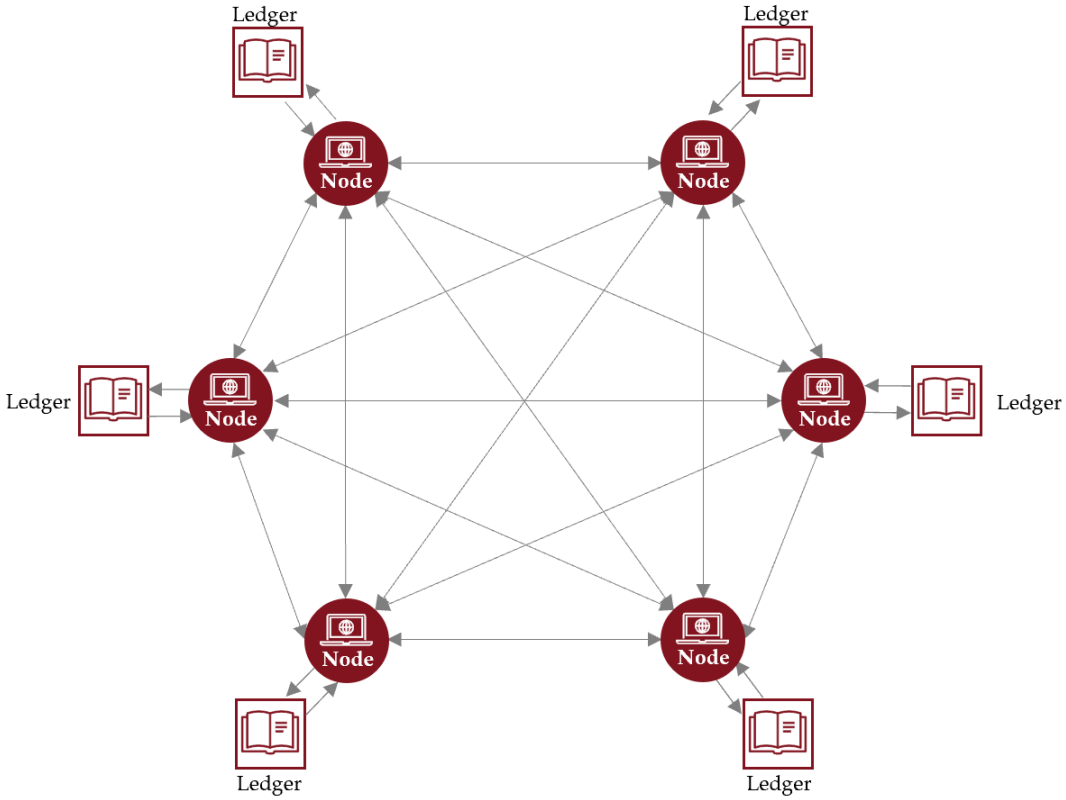


FIGURE 1: DLT Structure

consensus mechanism and act as trusted validators within the network. We could distinguish inside this type of DLT between Private Permissioned DLTs and Consortium Permissioned DLTs, the first is characterized by the presence of only one validator that is typically the owner of the network while the second presents a restricted predefined number of trusted validators.
Permissionless Public DLTs are the purest form of decentralized ledgers; without a centralized authority that manages the network, anyone can join it. These types of DLTs rely on consensus mechanisms to ensure the validation of the information stored in the ledgers. The absence of a Central Authority grants the complete transparency of the transactions that are performed within the network. Furthermore, some networks are experimenting a hybrid version of the upper configurations, these are known as hybrid DLTs that present, for instance, the open participation and transparency of public DLTs and let the validator role at a defined group of participants as the Private DLTs. We should punctuate that there is not a preferred configuration, the wider plethora of participants, and the absence of a central control of the public DLTs are counterbalanced by the loss in terms of speed and performance that a minor number of validators as of private DLTs could improve. It is indeed clear that DLTs could bring several advantages in a wide range of markets. First, this kind of network could boost both the transparency of the transactions, as all the network participants have access to the same ledger, and the security of the information, as the presence of a cryptographic algorithm ensures the system from data breaches. Secondly, one of the focal points of the DLTs is the reduction of intermediation, bypassing the needs of central authorities, improving efficiency, and reducing intermediation costs. On the other hand, DLTs still suffer difficulties in the scalability of transactions, struggling to handle a large number of transactions simultaneously without a speed reduction within the network. Moreover, there is still uncertainty surrounding the regulatory environment of DLTs that could obstacle and slow the adoption of these technologies in some markets.

Blockchain

Blockchain is a particular Permissionless Public DLT, the most famous and notable one, characterized by the usage of blocks of data. Specifically, the Blockchain network records transaction information and groups them inside "blocks" that contain a cryptographic hash of the previous block's header. Each block is then broadcasted to all the nodes of the network that, through a "Mining Process", validate or deny it. If it is validated the block is added to the previous ones forming the so-called "chain" and is distributed through the network. Once added, the blocks are immutable and the information stored inside is permanent.

Smart Contracts

Smart contracts are computer protocols with predeterminate conditions that ensure the automatic execution of an agreement, with no need for a central authority, where the conditions are met. smart contracts rely on DLTs, where their transactions are stored and registered, and are designed to facilitate and automate the exchange of digital assets, information, or services. Their function could be seen as a simple if/then condition directly imprinted, for instance, in a block of the chain. When the smart contract conditions are met and verified, a computer network will

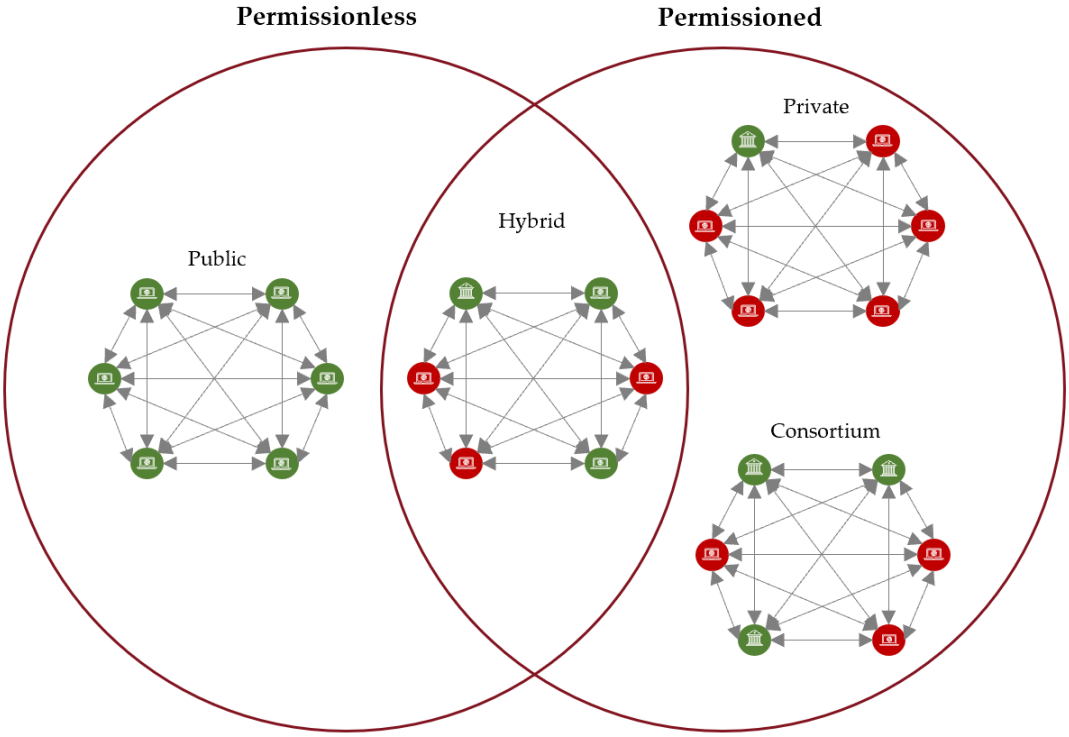


FIGURE 2: Types of DLTs

automatically execute the actions, such as issuing a ticket, moving funds between parties, or unlocking functionalities within the platform. In summary, smart contracts are the vault of the conditions that rule the interactions inside the platform, so network participants have to determine all the conditions and the possible outcomes that have to be programmed inside the smart contract in order to avoid any possible dispute. The Flight Delay assurance of Etherisc[25] could be an easy-to-understand example of the functioning of smart contracts. In this case, if the smart contracts are linked to several APIs that monitors the take-off and the landing time of the flight, and if the subscriber's flight is delayed or canceled the smart contract underlying the assurance will automatically pay the payout of the assurance.

The insurance market is not the only one that could benefit from the automatisms that smart contracts bring, in fact, generally financial markets could benefit probably more than other sectors from the innovation of smart contracts. For instance, the coupon payment schedule of a bond could be encoded into a smart contract that at every payment could quickly execute the settlement of the payment without the need of any intermediary. It is clear from these short examples that the potential usage of this technology could be advantageous to all business areas that may benefit from the improvement of the transaction speed and efficiency, in fact, once the conditions of the smart contract are met the algorithm embedded in it will immediately be executed avoiding any kind of payment delay or reconciliation error. The automatisms underlying the function of the smart contract will also reduce the transaction costs as no third party or intermediaries are needed to execute the transaction. Considering also that smart contracts run on the chain, they inherit other improvements in transparency as the transaction immutability within the network and the transaction visibility among the network participants.

Tokens

A central role within the DLT environments is played by tokens, which usually act as the exchange goods among network participants. Simplifying, tokens are native digital assets registered on top of decentralized ledgers that allow their exchange within the network while their creation, issuing, and management happen thanks to the support of smart contracts. The origin of a token could be anything from a real-world asset, such as a piece of art or a real estate asset, to a right to vote within the governance system of the network and they could serve for several purposes, for example, payment services. Despite the wide applications and services that a token could aim for, we can find five intrinsic characteristics that are common to every type of token: they are "valuable, representative, digital, distinct, and authentic"[20]. As described in the "Token Taxonomy" by Dan Tapscott, a token is valuable because we can always determine its value, for instance, we can express a token value into a fiat currency amount as USD. A token holder will always have the claims or the rights represented by the token. As we already said, tokens are native to DLTs so consequentially they are "digital" by definition. Considering the updating process that occurs among the ledgers of the network we can always know the discretional amount of tokens that are circulating within the network and distinguish one from another. A token's authenticity is also ensured by the intrinsic characteristic of DLTs that use a consensus mechanism to validate the transactions. Going a little deeper in the explanation, tokens incorporate two main "layers": a "Core Layer" that embeds the specific features of the token, such as ownership rights and proof of

[25] Etherisc is a Deutsche firm that offers decentralized insurance services.

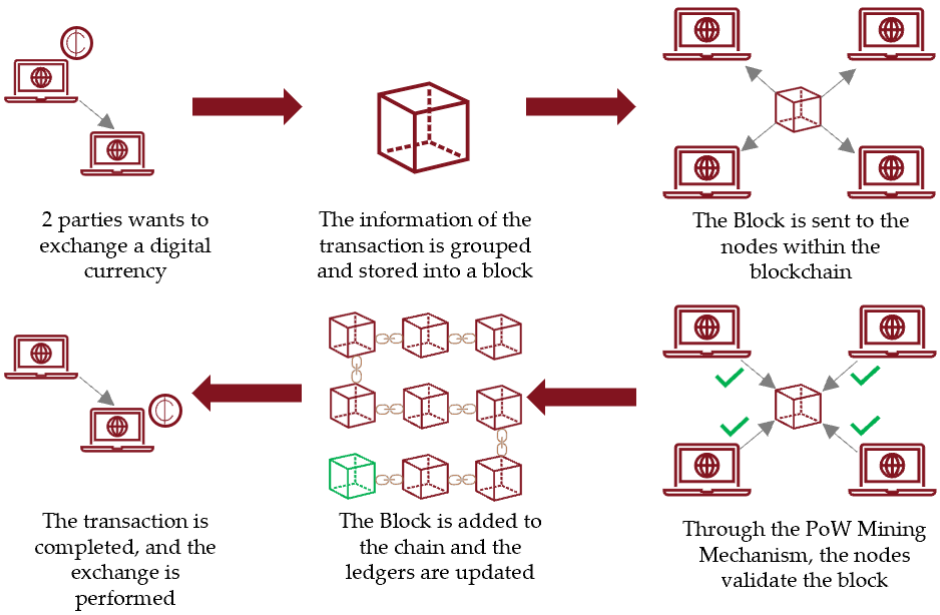


FIGURE 3: Blockchain process

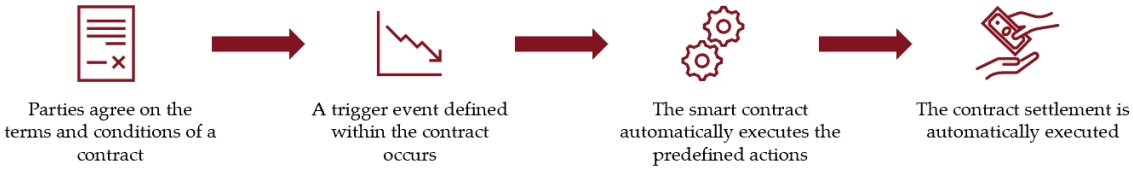


FIGURE 4: Smart Contract synthetical execution process

authenticity, and a "Service Layer" that specifies the logic underlying the token used within the Platform (e.g., the interoperability and Cross-Chain Functions or the token regulatory conditions).

Tokens, as stated before, serve various purposes depending on their specific design and reference Platform. For instance, DeFi Tokens are a specific type of tokens designed to provide functionality, governance, or economic incentives within the DeFi environment. Below are some examples of the most popular typologies of tokens[15]:

- Cryptocurrencies;
- Stable Coins;
- Security Tokens;
- Non-Fungible Tokens (NFT);
- Commodity Tokens;
- Utility Tokens;
- Collateral Tokens.

Cryptocurrencies are decentralized digital currencies that rely on cryptographic algorithms in order to secure transactions [18]. These kinds of tokens, which the most famous are Bitcoin and Ether, due to their intrinsic nature are not issued by a central authority, and the transactions performed between parties are validated thanks to a peer-to-peer system.

Stable Coins are cryptocurrencies that have their value anchored to an underlying asset, such as a fiat currency (e.g. US Dollar, Euro) or a commodity, ensuring a stable value related to a near 1:1 ratio to the underlying asset. They provide stability and serve as a medium of exchange and store of value (e.g., USDC). Examples of Stable Coins are Tether USD (USDT), Paxos Standard (PAX), which are backed to the US dollar, or Stasis Euro (EURS) which is anchored to the Euro.

Security Tokens represent traditional financial assets, as shares or bonds but are traded without the need of a broker. A particular type of these tokens are the real estate tokens that represent an investment in real estate assets and permit leverage on DLTs to provide fractional ownership, increased liquidity, and potential access to a wide range of investors in the real estate market (e.g., SwissRealCoin).

NFTs incorporate the ownership rights of a unique digital or real-world asset. NFTs can be exploited to foster copyrights (e.g., prevent digital creations from being copied) and (continuous) value creation and distribution through rights selling and/or royalties embedded in the token. Famous examples of NFTs could be Top Shots tokens, which represent NBA tokenized unique moments, or "Everydays: the First 5000 Days", a digital art masterpiece sold as an NFT by Christie's Auction House for 69,3USD million.

Commodity Tokens are tokens linked to a specific commodity, like gold, copper, or oat. These kinds of tokens aim to increase accessibility to commodities as an investment asset class by permitting small investors to acquire fractional parts of a commodity (and not requiring any physical settlement). Relevant examples are KAG Silver or Meld Gold. Utility Tokens are designed to be used for different purposes as part of the internal economy on a specific platform

or for fundraising vehicles.

Utility Tokens are used to allow access for users to features within the reference environment, such as data storage, computational power, and identity verification. As an example, we could look at Chainlink which aims to "enable smart contracts on any Blockchain to leverage extensive off-chain resources, such as tamper-proof price data, verifiable randomness, automation functions, external APIs, and much more".

Collateral Loan Tokens are a specific kind of token that represents a loan secured by collateral within a DeFi environment. These tokens enable borrowers to access funds without selling their underlying assets, providing a mechanism for leveraging their digital holdings within the DeFi ecosystem. Examples of this typology of tokens are Compound and Collateral.

Decentralized Finance (DeFi)

Decentralized Finance represents one of the fastest-growing applications that has been unlocked by the wide-spreading diffusion of DLTs. By DeFi we can refer to DLT-based environments that aim to make available several financial services without relying on any kind of Central Authority. In practice, DeFi environments consist of "Financial Protocols" that guarantee the execution of specific tasks in order to deploy different financial transactions and services. The Protocols are implemented on smart contracts that define the rules within the environment and rely on the DLT as the base system to be executed. The underlying DLTs and the smart contracts built on DeFi ecosystems ensure that no Central Authority is needed to complete and validate the transactions. Smart contracts, performing predefined and specific-purpose tasks, replace the intermediary within the transactions and users can therefore interact directly with smart contracts, instead of another user. To describe the fundamental composition and the core functionality of a DeFi environment, we will introduce the DeFi Stack Reference Model (DSRM) [2], which was first explained in the "BIS Working Papers No 1066 - The Technology of Decentralized Finance (DeFi)".

According to this model, we can distinguish three different core subsequential layers that compose a DeFi environment:

- **Settlement Layer**, which represents the base of the DeFi;
- **DLT Application Layer**, that comprehends:
  - **Crypto Assets;**
  - **DeFi Protocols;**
  - **DeFi Compositions.**
- **Interface Layer**, which represents the top of the pyramid and conceptually is just the end-user interface of the environment.

The Settlement Layer is the base on which the DeFi is built, and essentially, it is the Decentralized Ledger Technology at the base. The DLT guarantees the execution of financial transactions and, through the consensus mechanism built into the DLT itself, ensures the update of the ledgers across the network. The most diffused DLT in the DeFi space is Ethereum, with Solana, Polygon, and Cardano as other diffuse DeFi Blockchains. In the **DLT Application Layer**, all the specific features are embodied through smart contracts within the DeFi environment. **Crypto Assets** represent the "value" that is usually exchanged within the DeFi. They are expressed as tokens which, as we have shown in the previous paragraphs, could serve several different purposes. Thus, as the foundation of the value that is the base of the transactions within the network, we could easily understand the core importance that tokens cover inside a DeFi environment. Following the model, we find the **DeFi Protocols Layer**, where are linked all the DeFi Protocols that define the Financial Functionalities of the environment. "The Technology of Decentralized Finance (DeFi)"[2] distinguishes three main kinds of DeFi Protocols:

- Decentralized Exchanges (DEXs);
- Lending Protocols;
- Derivatives Protocols.

Decentralized Exchanges are protocols that aim to ease the exchange within the DeFi environment. In the Automated Market Makers (AMM) configuration, the traders execute the transaction against a liquidity pool, which could be defined as a smart contract that stores a reserve of the token supply. **Lending Protocols** are peer-to-pool DeFi protocols that enable the match between lenders and borrowers within the environment. Borrowers could access funds by interacting against a smart contract that pools the supplies that have been deposited by the lenders. These protocols use the pool size or the intrinsic demand of the environment to set the interest rates automatically. **Derivatives Protocols** enable the issuing and the exchange of decentralized crypto derivatives. These digital assets act as traditional derivatives instruments with the difference that are native to the DeFi environment. In practice, they take their value following the value of the underlying instrument/rights movements, which could be any kind of real-world asset or even another crypto asset. **DeFi Composition**, as the final part of the DLT Application Layer, is one the most innovative features of a DeFi environment. "A DeFi protocol composition occurs when an account leverages one or more accounts belonging to at least another DeFi protocol within a single transaction to provide a novel financial service"[12]. An example of DeFi Composition Protocols is Yield Aggregators that aim to maximize the profits of the investors. In practice, users allocate their assets into a pool of smart contracts (the Yield Aggregator) that invest them following a predefined strategy of portfolio optimization. At the peak of the DSR Model, we found the **Interface Layer** which is nothing less than the interface that users utilize to interact with the DeFi environment. Analyzing the features that characterize DeFi, it is clear how this kind of environment could lead to a potential revolution in the classic financial ecosystems. These environments, which are for their nature decentralized and open, could boost transactions and accessibility to financial services that normally are precluded to many market participants reducing the intermediatory fees as well. Other than enabling the tokenization of a variety of off-chain assets, DeFi could also push the born of new financial instruments.

On the other hand, the lack of a central authority leads to regulatory uncertainty with several possible frictions between market participants due to unclear legal treatment of assets exchanged in the environment as well as the lack of a framework that ensures protection against frauds.

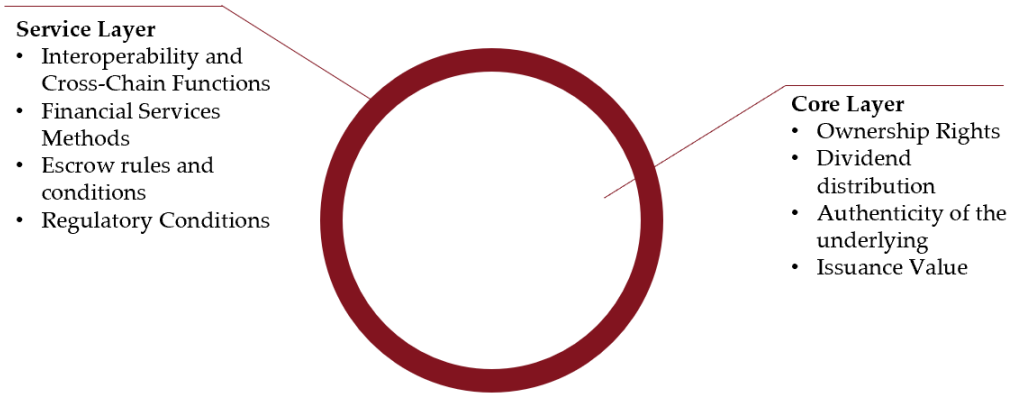


FIGURE 5: Token Anatomy: Service Layer, Core Layer

Asset Tokenization: What Is It?

Asset tokenization represents the process of registering a physical asset on a distributed ledger by incorporating the economic rights and claims of the real-world asset, such as a real estate asset, into a token. The potential benefits of moving the intrinsic rights of an asset from the real world to a DLT range from increasing market liquidity to improving transaction efficiency. This section will first delve into the characteristics of the tokenization process, from asset selection to token issuance, and end by explaining the potential benefits the process could bring to markets.

The Process

Tokens cover, as seen before, a crucial part of the DeFi environments being the main subject of every transaction among the market participants. They can be defined as the digital representation of real-world assets or rights, and we can delineate the asset tokenization process as the flow that allows to recording real-world assets from traditional ledgers to DLTs. The technical process that permits the transfer from the traditional to the digital ledger requires a "ramp" that locks assets in their platform of origin as collateral for the tokens, which are then issued on the programmable platform[1]. The real-world asset, or claim, continues to exist off-the-chain but its rights are transferred on-the-chain through the token issuance. The process involves six main phases:

1. **Asset Selection;**
2. **Asset Evaluation;**
3. **Regulatory Analysis;**
4. **Platform Selection;**
5. **Smart Contracts Development;**
6. **Token Creation and Issue.**

The first step involves the selection of the real-world asset that must be tokenized. This phase covers a crucial part of the process and will affect all the following stages. In fact, the asset class of reference of the chosen real-world asset will affect the evaluation methodologies that will determine its tokenized value, the reference regulatory framework, and potentially even the platform selection. For example, tokenizing a real estate asset or security is a different process from both the respective reference regulatory framework and the evaluation methods of the asset. The Asset Evaluation phase aims to define the value of the asset to which the token will be backed. The evaluation won't stop at the economic value of the assets but will include the analysis necessary to ensure the ownership rights of the assets, gauging the potential market demand, and assessing the potential future revenue and the token feasibility as well. The right choice of evaluation methodologies for the chosen asset type is crucial to avoid discrepancies between the real-world asset value and its representation on the DLTs. In concomitance with the Asset Evaluation, occurs the Regulatory Analysis which aims to identify the reference regulatory framework for the asset to be tokenized and to inquire the legal implications of its tokenization. In this phase, it is crucial to investigate the asset classification in force within the country of reference; for instance, securities, debt instruments, and real estate assets are subject to different regulatory requirements and constraints. Other than that, is important to understand the AML (Anti-Money Laundering), the KYC (Kwon Your Customer), and the data protection regulations to ensure the appropriateness of the future transactions of the token. Also, it is important to state that cross-border transactions will be influenced by both jurisdiction and framework. The selection of the technology and platform to rely on, and which the tokenized asset will be placed on, involves, for instance, decisions related to whether the network will be permissionless or permissioned, or whether the token will rely on the Blockchain or a different kind of DLT. Choosing the right native platform for the tokenized asset will cover a crucial part of the token's life, influencing deeply the course of its future transactions. In fact, the platform will influence first the scalability of the transaction's volume, and it will also affect the transaction costs (e.g., in terms of gas fees, or the possibility to perform cross-platform and cross-border interoperability). Obviously, these are only a few factors that will be affected by the choice of the platform: others could range from security implications to regulatory boundaries. Defined the platform, it's important to state the rules that will govern the token and the token behavior within the platform environment. That is possible through the development of smart contracts which, as stated before, could embed the automatic clauses and actions that will rule the interactions and the transactions of the tokens. This step concerns the definition of how the tokens are created, their ownership clauses, and their transferability. The possibilities enclosed in smart contacts could also enable the development of rules and clauses such as regulatory restrictions, voting rights, and dividends or coupon payment mechanisms. At this level of the process, it is also decided which standard (e.g.,

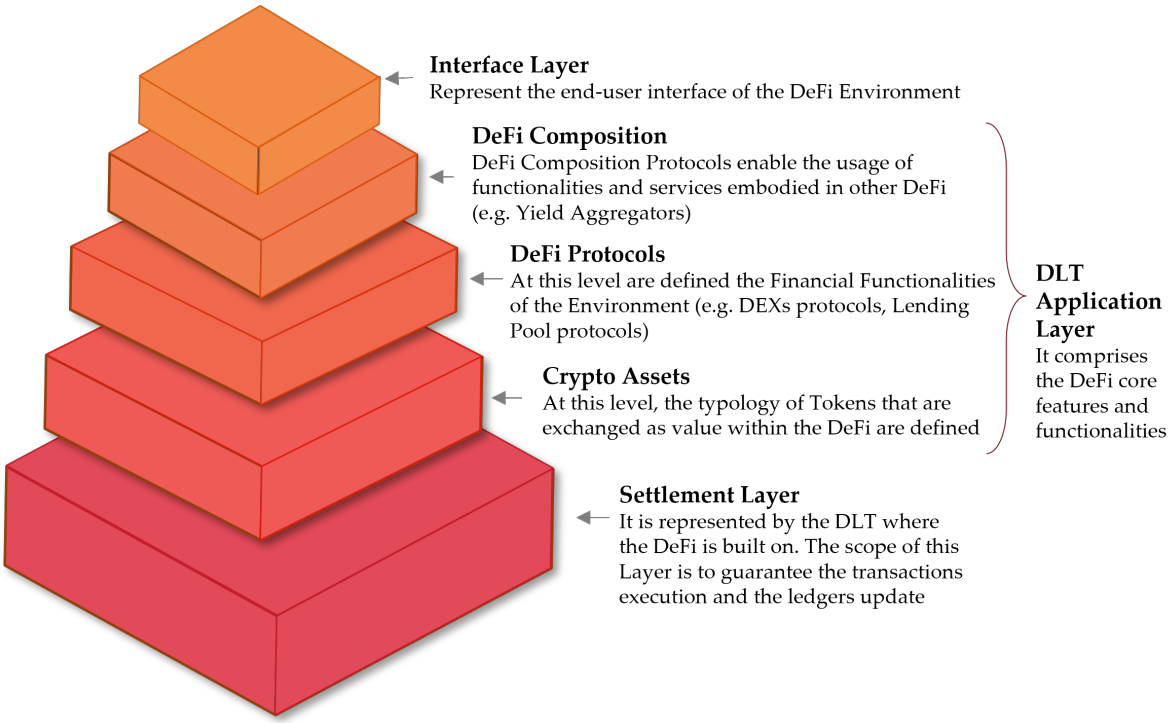


FIGURE 6: DeFi Stack Reference Model

ERC 20, ERC-3643) will be used for the token implementation. The token creation phase involves the modeling of the digital asset on the on-chain environment and the contextual lock of the real-world asset. As already said, this process relies on a "ramp" to technically ensure both the transfer of the value from a traditional ledger to a DLT and the consequential lock of the off-chain asset. In some cases, for instance for art pieces, it is also required to support a trusted custodian to segregate the asset and guarantee its safeness. The decisions regarding the tokenization model are also taken in this step, involving the consideration of the possibility of opting for fractional ownership, and the related number of tokens that will be issued, or for the individual ownership of the digital asset. The conclusion of the process will require the definition of the offering structure of the token issuance, implying to choose between public offering (ICO) or private placement.

Potential Benefits

The tokenization process, thanks to its nature that allows the on-chain transformation of a physical asset, could valorize the latent potential of the traditional real-world assets by bringing new lymph in some markets, generating economic value that otherwise would be unexploited. Following there will be reported some of the major benefits that could be related to the asset tokenization:

- **Markets Accessibility and Liquidity Boost:** Asset tokenization, through the fractionalization of the ownership, could widen the plethora of potential investors, opening markets that are usually presided over by institutional investors to retail investors. Also, the possibility of trading these fractional assets directly in an on-chain platform could be another very important factor in boosting markets' liquidity. For instance, a market historically characterized by high entry barriers and illiquidity of assets such as the real estate market that thanks to the ownership fragmentation could benefit from a much larger investor pool that could easily trade real estate tokens sidely boosting the market liquid. Solidblock and RealT are two interesting examples of the potential application of asset tokenization and the related benefits on the real estate market.
- **Transaction Efficiency:** Through the automation embedded in smart contracts features, asset tokenization could enforce faster, and potentially frictionless transactions. For instance, the settlement processes could take advantage of the smart contracts' conditions to speed up the elapsed time needed to complete a trade. A representative case of these possible improvements is the atomic settlement condition that could be coded into a smart contract that will permit an instantaneous exchange between two tokens once both parties submit their transaction.
- **Transaction Transparency Enhancement:** Tokenization guarantees the immutability of records and the safeness of transactions that is ensured by the consensus process typical of the DLTs exchanges.
- **Costs Reduction:** Relying to a DeFi environment the asset tokenization could benefit from the absence of central intermediaries leading to a reduction of transaction costs and of administrative expenses of the asset.

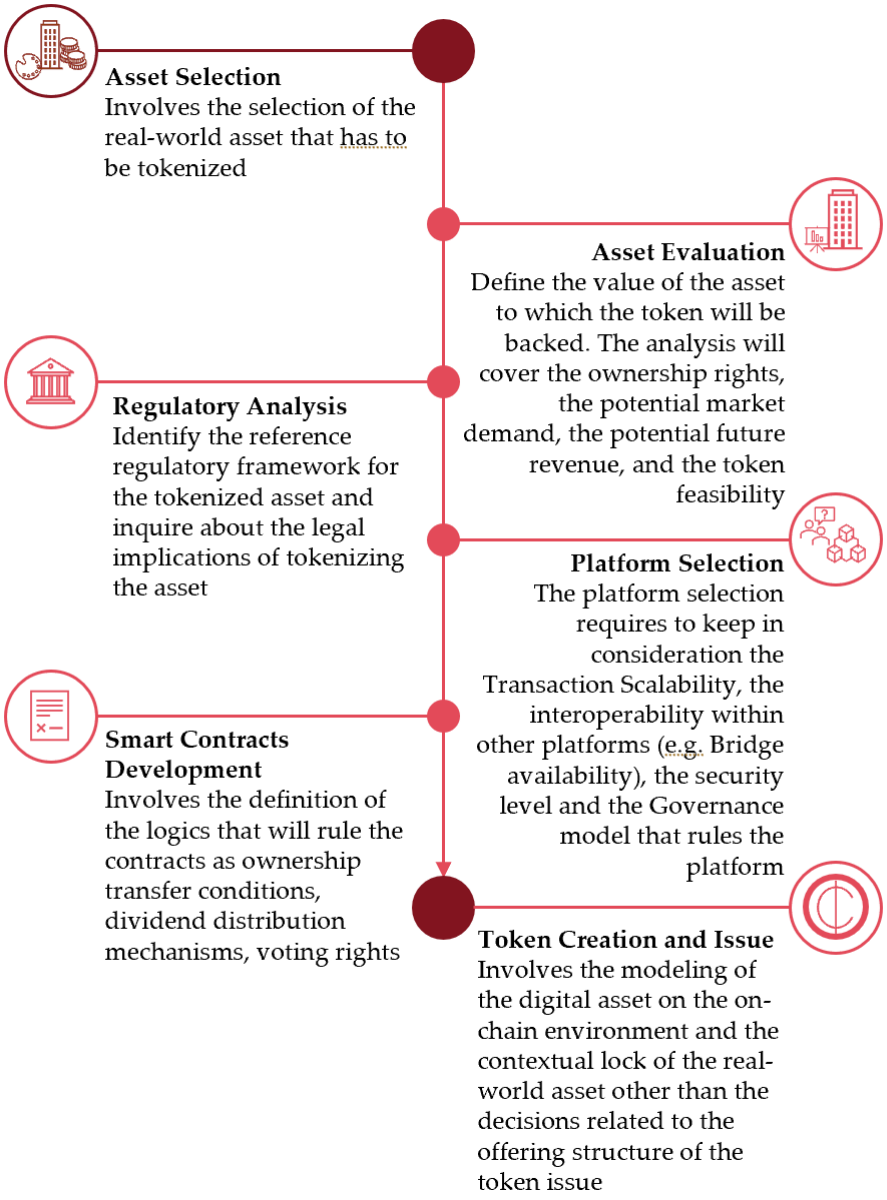


FIGURE 7: Asset Tokenization Process

Digital Assets Regulatory Overview

An Open Issue

As stated, asset tokenization is one of the most notable potential applications of DLTs in financial markets with several potential benefits that could boost both the economic growth and the development of markets. Despite that, leveraging on new technologies (as the ones described in the previous chapters) to do business opens up critical challenges, hardly accounted also due to the lack of robust and shared regulatory frameworks among different legislations. The growing impacts and interconnections that digital assets are having on traditional financial systems, combined both with the high volatility period that cryptos have been facing and the recent bankruptcies of important exchanges and market players (e.g. FTX, Three Arrow Capital), have enlightened the attention on the sector from several International Financial Authorities. These, in order to assure market integrity and risk mitigation, have begun to propose guidelines and recommendations to help National Authorities set a fair regulatory environment. Among others, the most notable works carried on by the International Financial Authorities are:

- The **"FSB Global Regulatory Framework for Crypto Asset Activities"**[11] published by the Financial Stability Board aims to promote the consistency between the international regulatory frameworks and to define a shared approach among the different supervisors. The framework proposes a set of recommendations to help in the definition of a shared regulatory framework over the regulation of crypto assets and global stable coins founded on a set of three guide principles:

    1. **Same Activity, Same Risk, Same Regulation**

This principle wants to ensure that the regulatory frameworks will take into consideration the risks to the financial market's stability that could be related to crypto assets and stablecoins. In particular, Regulators should apply the same, or equivalent, regulation to crypto activities that are similar to traditional financial assets.

2. **High-Level and Flexible**
   The framework is designed to suggest high-level recommendations to Regulators leaving them enough free of movement to implement new frameworks and to be flexible in reacting to market changes.
3. **Technology Neutral**
   A technology-neutral approach focuses on defining regulatory guidelines without relying on a specific platform or technology. This means that Regulators should concentrate on defining frameworks that assess the economic functions or the risk related to the crypto activities rather than the technology on which they rely on.

- The **"Prudential Treatment of Crypto Asset Exposures"**[4], published by the Basel Committee on Banking Supervision (BCBS), has defined a harmonized standard for the treatment of the crypto assets "banks" exposure which requires banks to classify crypto assets in two distinct groups:
  - **Group 1:** composed of traditional tokenized assets with a risk level similar to their non-tokenized counterpart and crypto assets with effective stabilization mechanisms (stablecoins). The capital requirements for these cases are based on the risk weights of the underlying exposures.
  - **Group 2:** the bank exposures for all the crypto assets that don't fall under the group 1 must not exceed 2% of the TIER1 Capital and should fall near the 1%.
- The **"Updated Guidance for a Risk-Based Approach to Virtual Assets and Virtual Asset Service Providers"**[10] incorporates the guidelines of the Financial Action Task Force (FATF) in a matter of Anti-Money Laundering and Countering Financial Terrorism for Digital Assets and Digital Assets Providers promoting, as the FSB guidelines, a risk-based and technological neutral approach imposing also the adoption of specific AML and CTF requirements (e.g."VASP Travel Rule").

Other than the International Financial Authorities, some countries have shown growing attention to the necessity to develop a strong body of legislation regarding digital assets [16], which we can cite as notable examples:

- The Swiss **"DLT ACT"** recognizes the issuance and transfer of rights on the Blockchain, allowing the segregation of digital assets in case of custodian bankruptcy and introducing a special license for financial digital services providing.
- The Liechtenstein **"Blockchain Act"**, that allows the tokenization of any kind of assets and rights, foreseeing also the introduction of "Physical Validator", a mediator that ensures that the real-world assets or rights underlying the token can be verified and enforced.
- The Japan 2020 recognition of the digital asset in its regulatory framework through the amend of:
  1. **Payment Service Act (PSA)** which now include under its regulation digital currencies, utility tokens and crypto asset exchange services.
  2. **Financial Instruments and Exchange Act (FIEA)** which now covers the regulation of security tokens which represent shares, bonds, or fund interests in tokens.

Despite these initiatives of the International Authorities and the efforts of some countries, the regulatory landscape across the world is still suffering from a lack of consistency and harmonization within the countries. One of the most cited problems of the existing framework regards, in particular, the absence of a shared taxonomy and body of definition for digital assets.

MiCAR and The European Approach

The fragmentation in the legal treatment of digital assets among the Union Members has led the EU to plan a strategic program to minimize market fragmentation and boost the financial innovation of the European financial market. In order to obtain this notable result, the EU published in September 2020 the "Digital Finance Package"[8] which comprehended the strategies and the legislative proposals on crypto-activities and other digital initiatives. The Union, with this publication, has posed the goals of both being an example for other countries in the matter of digital asset regulation, and developing a much more innovative intensive, and competitive European financial market. The proposals inherent in the "Digital Finance Package" are set in two main categories:

1. The **"Renewed strategy for modern and safe retail payments"**, which wants to ensure the development of instant payments and create an innovative and competitive retail payments market.
2. The **"Digital Finance Strategy"**, which aims to develop a less fragmented digital European market and to promote a regulatory framework that can permit the growth of digital markets ensuring the digital operational resilience of the financial system.

Focusing on the latest part of the package, we can zoom in on four milestones (one is not part of the "Digital Finance Package" but follows its principles) that will define the harmonization of definitions and the regulatory field of digital assets within the Union:

- **(EU) 2018/843 5th EU Anti-Money Laundering Directive (5AMLD);**
- **(EU) 2022/858 Digital Ledger Technologies Regulation (DLTR);**
- **(EU) 2019/1937 MiCAR First Proposal;**
- **(EU) 2023/1114 Markets in Crypto Asset Regulation (MiCAR).**

With the **"5th EU Anti-Money Laundering Directive" (5AMLD)**, the first crypto-focused regulatory amendment made by the Union coming into effect in September 2020, the EU has amended the previous laws in the matter of AML/CFT including on its perimeter cryptocurrency exchanges and wallet providers. With the implementation of the 5AMLD, all the "providers engaged in exchange services between virtual currencies and fiat currencies"[6] (cryptocurrency exchange) and the custodian wallet providers, defined as "entity that provides services to safeguard private cryptographic keys on behalf of its customers, to hold, store and transfer virtual currencies[6], will fall under the European regulation for AML/CFT requiring them to verify the identity of their customers reducing both the risk of money

washing and the anonymity related with crypto transactions. Besides that, the 5AMLD has introduced mandatory checks and reporting obligations to identify and counter suspicious transactions. It is clear that the EU, with these interventions, has put the lens on improving the transparency within the digital asset market.

The **"(EU) 2022/858 Digital Ledger Technologies Regulation" (DLTR)** (in force since June 2022 and applicable starting from May 2023) has put another brick on the goal of identifying a shared regulatory framework among union members. The DLTR, brings a temporary six-year exemption on the current EU financial regulation for investment firms, central securities depositories (CSDs), market operators, and new market players, to allow the creation of financial market exchanges and settlements based on distributed ledger technologies. The DLTR aims at the development of a much more technology-integrated EU financial market following the principle of promoting the growth of the European financial system. The DLTR not only permits access to the markets to new players, but also extends the exemption on existing multilateral trading facilities (MTFs), organized trading facilities (OTFs), central securities depositories (CSDs), and central counterparties permitting them to potentially extend or replace their current infrastructure with a DLT based one. Always in the scope of harmonizing the new definitions involved with the crypto-focused technologies usage expansion, the DLTR has identified three categories of DLTs involved in the financial markets:

- **DLT Multilateral Trading Facilities ("DLT MTFs")** that are "multilateral trading facility that only admits to trading DLT financial instruments"[7].
- **DLT Settlement Systems ("DLT SS")** are "settlement system that settles transactions in DLT financial instruments against payment or against delivery, irrespective of whether that settlement system has been designated and notified in accordance with Directive 98/26/EC, and that allows the initial recording of DLT financial instruments or allows the provision of safekeeping services in relation to DLT financial instruments"[7].
- **DLT Trading and Settlement Systems ("DLT TSS")** that combines the services provided by DLT MFs and DLT SS.

At the end of the third year since the entry into force of the Pilot regime, ESMA will deploy a report regarding the impact on the European financial system of the introduction of DLTs and future proposals for the DLTR and the integration of DLTs in the EU market.

The **MiCAR (2023/1114)** represents much more than a regulatory framework, in fact, we can define it as the first cross-jurisdictional regulatory and supervisory framework for crypto assets. The EU, with MiCAR, aimed to create an ambitious shared framework, among all the Members, harmonizing both legal treatment and the taxonomy of digital assets that are not currently under any existing EU legislation. The framework will enter in force by the end of 2024 (30/12/2024) replacing all the existing rules at the national level. The MiCAR establishes the rules in matters of crypto assets issuance and trading admission focusing also on both the relative transparency and disclosure requirements. The crypto assets, "digital representation of value or rights which may be transferred and stored electronically, using distributed ledger technology or similar technology"[9], are the focal point of the framework which distinguishes three main categories of not regulated by current financial UE regulation crypto assets:

- **Utility Token:** "a type of crypto asset that is only intended to provide access to a good or a service supplied by its issuer"[9].
- **Asset Referenced Token (ART):** "a type of crypto asset that is not an electronic money token and that purports to maintain a stable value by referencing another value or right or a combination thereof, including one or more official currencies"[9].
- **Electronic Money Token (EMT):** "a type of crypto asset that purports to maintain a stable value "by referencing the value of one official currency"[9].

For the utility tokens, the MiCAR defines the requirements to proceed with their public offer, including that the proponent must be a legal person, and has to draft a paper that specifies the main details of the offer[9] and the communication standard which has to be satisfied.

The issuing of ART and EMT demands much more stringent requirements. In particular, for ART are expected some capital constraints: the issuer has to dispose at least of the maximum of EUR 350.000, 2% of the average amount of the reserve, a quarter of the fixed overheads of the preceding year. Instead, the EMT issuer must be an authorized credit institution or electronic money institution and the issued EMT must be at par value and on the receipt of funds. Other than that, the EMT should not grant any kind of interest and the issuer must invest the proceeds of the EMT issuing only in low-risk activities.

The MiCAR also identifies two sub-categories of the upon tokens:

1. **The significant asset-referenced tokens (SART);**
2. **The significant e-money tokens (SEMT).**

According to some specific dimensional thresholds, such as the tokens total value, the number of transactions, or the interconnections with the traditional financial system.

It is clear that the work done by the EU with the MiCAR represents an important step for the digital market's growth, but it does not cover all the aspects involved in the crypto environment. In fact, it is important to highlight that other well-known digital assets fall out of the MiCAR scope, in particular, we can point out Central Bank Digital Currencies (CBDC), NFTs, and DeFi protocols. It is important to note that the ECB, in its plan to promote financial innovation within the Union, has concluded in October 2023 the Digital Euro Investigation Phase that has detailed the possible characteristics and architecture that the European CBDC should rely on. The Digital Euro project is currently facing the, so-called, preparatory phase where are going to be consolidated and tested the features and the business processes defined during the previous phases (for a total view on the Digital Euro Project see "Digital Euro: Now and Beyond"[17]).

Asset Tokenization: Lending Perspectives

DeFi Lending and Over-Collateralization Issues

By looking at DeFi's history, given its goal to redefine traditional financial services (also TradFi), lending was one of the first applications that gained popularity, thanks to the promised offer of a transparent, permissionless, and open-source financial service environment. Traditional lending processes involve financial institutions acting as intermediaries between borrowers and lenders, introducing complexities such as credit checks, collateral requirements, and various fees. DeFi lending challenges this status quo by establishing decentralized platforms that enable individuals to lend and borrow directly without the need for intermediaries thanks to smart contracts, that automate the lending

processes, ensuring trust and transparency through their open and verifiable nature. Starting from the "DeFi Summer" of 2020, Total Value Locked (TVL) in DeFi lending protocols peaked at $50 billion in early 2022, up from nearly zero in end-2020, but in June 2022 there was a major drop due to the Terra Luna crash[3] as shown in Figure 8. This event, together with the macroeconomic framework of late 2022 represents a turning point in the DeFi lending industry, thus creating a growth opportunity for tokenization of assets on lending protocols.

Before 2022 the crucial feature of DeFi lending was that it relied heavily on crypto collateral. The most common lending protocols focused on offering crypto loans with a trustless approach. This means that the users could easily lock their crypto assets on the DeFi lending platform without worrying about intermediaries. The borrowers could directly opt for loans from the decentralized platform with the help of P2P lending. This is a focal point: the total absence of the trust element represents the deepest difference from the traditional lending process perpetuated over centuries by Banks.

In addition to it, the DeFi lending protocol helps lenders to earn interest on crypto assets. As compared to the conventional loan processing system of banks, DeFi lending enables individuals to become a lender just like a bank. An individual could easily lend their assets to others and accrue interest on that loan. Traditional financial intermediaries often impose various fees, including application fees, processing fees, and origination fees while DeFi lending minimizes these costs by directly connecting borrowers and lenders, bringing more favorable terms for both parties. The typical DeFi loan was disbursed in stablecoins, while the collateral consists of a riskier unbacked crypto asset, making the whole process self-referential. As already stated, stablecoins are a type of cryptocurrency whose value is tied to another asset class to keep a stable, steady value and typically are pegged to fiat currencies in a one-to-one ratio, but, if the peg breaks during adverse market conditions, the whole system might collapse. The figure 9 gives an outline of what happens when the peg breaks. This is particularly true for algorithmic stablecoins, like TerraUSD (UST) or Ampleforth (AMPL) which, unlike asset-backed stablecoins, employ smart contracts and algorithms that automatically re-balance supply to maintain their value relative to the target currency.

A business case that has been already well documented is the one regarding the Terra Luna crash of May 2022[3]. UST was supposed to keep a one-for-one peg to the US dollar by being convertible into one dollar's worth of LUNA (a native crypto on Terra Blockchain), and vice versa. To ensure sufficient demand for UST, the lending protocol Anchor offered a deposit rate of around 20% on UST. Attracted by high returns, new users bought LUNA to mint UST, leading to a steady increase in the value of LUNA. As soon as UST dropped below its peg, due to a $2 billion withdrawal on the Anchor lending platform, a classic run dynamic took place among investors in the hope of selling LUNA and making a profit. Therefore, given the size and speed of the shock, there were not enough parties willing to buy all the newly minted LUNA coins and, consequently, the price of LUNA crashed too. When the LUNA crypto network collapsed, it's estimated that $60 billion was wiped out of the digital currency space.

These kinds of lending platforms are a key part of the decentralized finance (DeFi) ecosystem, but their institutional features mostly facilitate speculation in crypto assets rather than real economy lending. In this sense, the Terra Luna crash teaches us two important lessons that need to be assessed in DeFi lending near future:

- **Absence of Trust:** in TradFi, the credit origination process starts with the assessment of the borrower's creditworthiness that relies on the collection of documents and information such as credit scores and financial statements in order to mitigate credit risk; in DeFi lending protocols, on the other hand, this kind of assessment is simply not feasible due to the anonymity of borrowers, anyone can be a creditor, even non-human agents: they simply need to have funds to borrow, a valid address, and a way to send and receive valid information from a protocol. Furthermore, in traditional finance, a loan can be flexible and the contractual terms may be modified by banks according to the latest hard and soft information collected; in DeFi there's no space for such flexibility, contractual terms are pre-programmed and cannot rely on soft information if we take, for example, loan and deposit rates, they are determined only by the level of supply and demand in the pool, according to formulas specified in the smart contract. For instance, in AAVE's protocol borrow interest rates are derived from the Utilisation Rate (U), the interest rate curve is split in two parts around an optimal Utilisation Rate and the interest rate R_t follows the model below[5]:
  - If U $\leq U_{Optimal}$: $R_t = R_0 + (U_t / U_{Optimal}) R_{Slope1}$
  - If U> $U_{Optimal}$: $R_t = R_0 + R_{Slope1} + (U_t - U_{Optimal} / 1 - U_{Optimal}) R_{Slope2}$

  Given these assumptions, the only way to ensure the repayment of the loan is by posting some amount of collateral.
- **Overcollateralization:** to obtain the loan from a lending pool, the borrowers are requested to pledge any collateral accepted by the protocol through a borrowing smart contract, typically crypto assets. The Blockchain native crypto assets so far, tend to have a very high price volatility. Taking a closer look at lending platform protocols, we can see that smart contracts assign each collateral type a haircut, or margin, that determines the minimum collateral borrowers must pledge to receive a loan of a given amount; minimum collateralization rates typically range between 120% and 150%[14] on major lending platforms, leading to over-collateralization. Together with collateralization rates, almost every protocol defines a liquidation threshold (also named, in AAVE protocol, "health factor") as the percentage at which a position is considered undercollateralized. If the collateral price falls below this threshold, anyone with sufficient liquidity can act as a liquidator, repay the lender, and keep a share of residual collateral. The posting of collateral does not eliminate credit risk for lenders, indeed and commonly, the underlying assets of liquidity pools are mostly stablecoins such as USDC and USDT, however, tokens used as collateral are volatile cryptos (e.g. ETH, BTC, YFI, YNX). The difference between assets and liabilities used in DeFi lending leads to high procyclicality: the amount of lending that can take place depends on the total value of assets eligible as collateral, thus creating boom-bust cycles. It can be seen very clearly studying the evolution of AAVE V2 TVL over the last few years: when collateral prices increase (BTC and ETH, fig.1), collateralization ratios fall, easing the borrowing constraints and expanding loan volumes (April-November 2021); on the other hand, when crypto prices fall, like in the 2022 "crypto winter", lenders run to pull out their deposits from lending protocols and by doing so exacerbate even more the procycli-

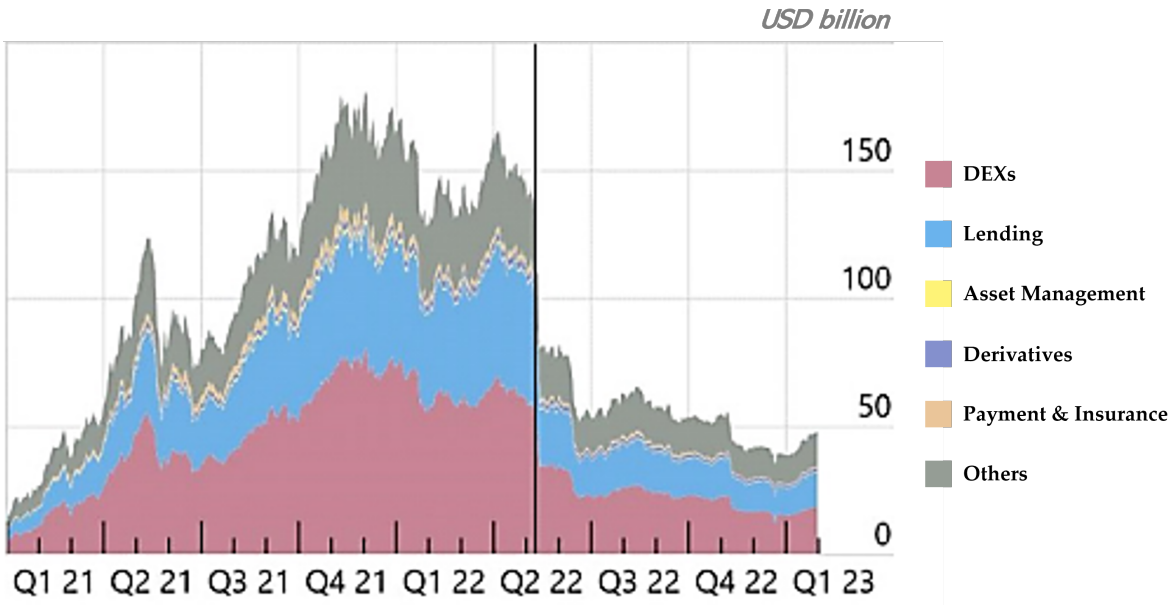


FIGURE 8: Daily Total Value Locked in DeFi by type of Activity (2021-2023), Financial Stability Board

cality effect; from December 2021 to June 2022 decentralized exchanges trading volumes dropped 40%, in the same period TVL for DeFi protocols experienced a 67% drop.

Introducing Real-World Assets on DeFi Lending Platforms

Despite the inherent fragilities described before, DeFi Lending might still fulfill its potential and try to fill the gap with Traditional Finance; the Total Value Locked (TVL)[26] in Lending protocols, in August 2023, was $10.300 billion meaning that currently, the scale of DeFi is quite small compared to the trillions of dollars outstanding of traditional finance debt. The turning point that could boost Defi lending might be the engagement in its protocols of large-scale tokenization of real-world assets to break out of the vicious circle of over-collateralization and cease to be a self-referential system dominated by speculation. Real-world assets could also act as a connection point with the centralized financial system, tapping into real-world business capital and from institutional investors. The self-referentiality experienced by the decentralized lending systems so far leads also to a great contradiction even in terms of the DeFi Manifesto: the collateral posting requirement results in a very high entry barrier for the debt market, meaning that only individuals who have already a great amount of deposits could become borrowers; If DeFi wants to fulfill its promise of making financial services more accessible, it must be able to reach the vast audience of small and medium-sized enterprises that struggle to access traditional financial channels. Finally, real-world assets tokenization, such as stocks, commodities, government bonds, and real estate might introduce much more stability into lending protocols and by doing so reduce credit risk. To study the state of the art of asset tokenization in on-chain lending processes, we will analyze three business cases of the current key players in this emerging market. We will see how they are incorporating elements of institutional finance with the goal of reducing credit risk.

Maple Finance

Maple Finance, launched in 2021, is a capital market built on Ethereum and Solana Blockchains, designed to give users access to different lending pools where they can put their assets and earn interest. Anyone who has tokens hosted on Ethereum or Solana Blockchains could become a lender, but not everyone could be a borrower. Indeed, Maple aims to be an alternative to the traditional debt market for institutional borrowers, and on September 2023 had a TVL of $65.383.953. The minimal loan amount is $1.000.000 and to gain access to a loan from a specific lending pool, some identifying information must be provided and the Delegate of the pool, which is typically a fund or a credit professional, must conduct due diligence, including KYC and AML checks. There are several lending pools in which investors can deposit the pool's liquidity asset (e.g., USDC, wETH) and each one of them is managed by a single Pool Delegate who is responsible for negotiating loan terms with borrowers, performing due diligence, and liquidating collateral in the event of a default. Considering the operational model of individual lending pools, we can already assume that the Maple protocol has sacrificed a degree of decentralization in exchange for greater credit stability. Beyond the well-known lending pools secured only by digital assets, Maple has recently launched liquidity pools backed by real-world assets: Cash Management Pool and AQRU Real World Receivables Pool.

- **Cash Management Pool:** with an outstanding loan value of $25.847.358 is a cash management solution for stablecoin holders backed by U.S. Treasury Bills or reverse repurchase agreements fully collateralized by U.S. Treasury Bills. The pool lends USDC to a standalone SPV established by the borrower, which generates yield by investing the proceeds on permitted U.S. government instruments. The weighted average maturity of the borrower portfolio must remain no more than 30 days and the target APY is that of the 1-month U.S. T-bill rate, less fees and expenses.

[26]Total Value Locked represents the amounts of assets deposited by the liquidity providers in the lending protocols, source DeFiLlama.

[27]Source: AQRU receivables monthly pool update September 2023.

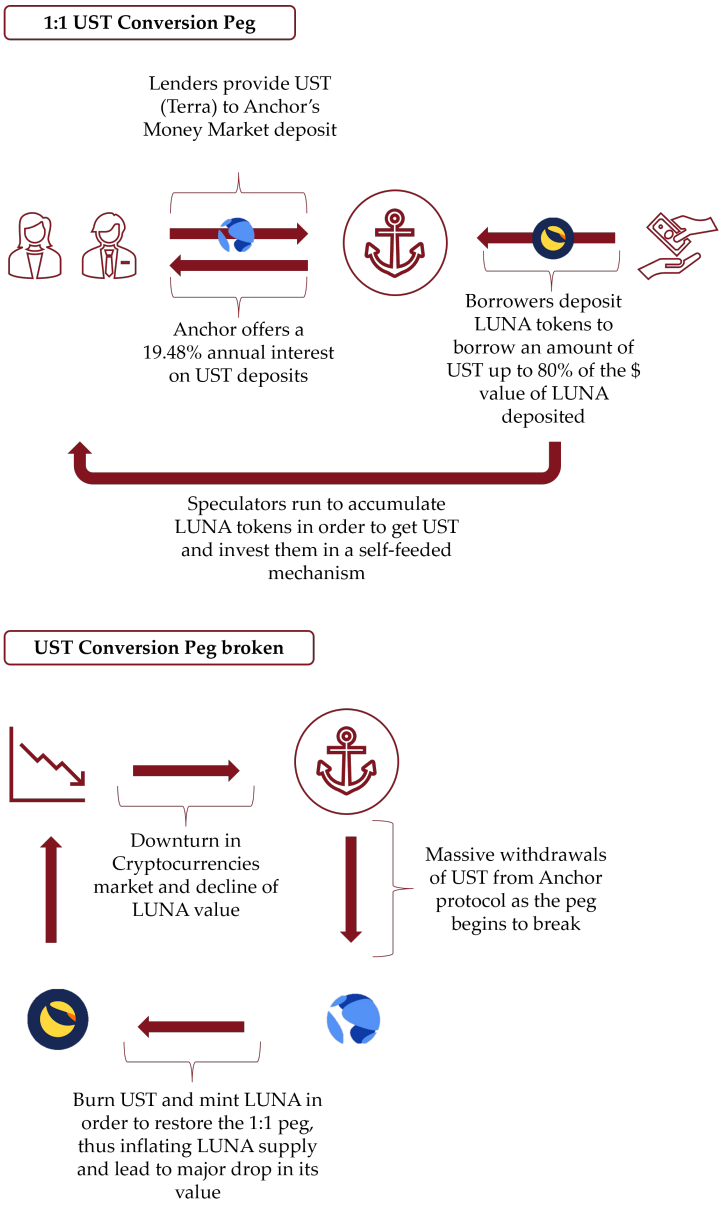


FIGURE 9: *Anchor Protocol lending process and Terra/LUNA collapse*

- **AQRU:** is a digital asset investing platform with an outstanding loan value of $16.164.482[27]. The overall strategy of AQRU Real World Receivables pool is to provide liquidity to U.S. businesses by purchasing their receivables, with a focus on tax credits provided by the U.S. Treasury. The market that backs AQRU liquidity pool is the IRS Receivables marketplace; the U.S. government's revenue service periodically undertakes schemes to supply liquidity to targeted sectors of the economy, recently in the form of Employee Retention Credit (ERC) that consists of a fully refundable tax credit for employers that paid qualified wages during the Covid pandemic. The sole borrower of the pool is Intero Capital Solutions which acts as a facilitator by purchasing tax credits owed to U.S. businesses and providing them liquidity thanks to AQRU funds; once the IRS settles the receivables, the disbursement of funds is then managed by Intero through an escrow account ensuring that all parties with interest are settled before any proceeds are returned to the original tax credit recipient. The pool offered, in August 2023, a yield of 16,2% and is available only to accredited investors who have passed the KYC check, the minimum deposit size is $50.000 USDC.

Goldfinch

Founded in 2020, Goldfinch is a decentralized lending platform built on the Ethereum Blockchain that allows collateralization of on-chain loans using off-chain assets and income. On-chain loans are issued in USDC provided by investors to the protocol, borrowers (mostly off-chain lending businesses) propose deal terms in order to gain access to credit lines and create a Borrower Pool. Borrower Pools are specific to individual borrowers and represent the credit lines from which borrowers draw capital to fund their real-world lending. The assessment of individual Borrower Pools is done by a specific category of investors called Backers who eventually invest directly with first-loss capital earning in

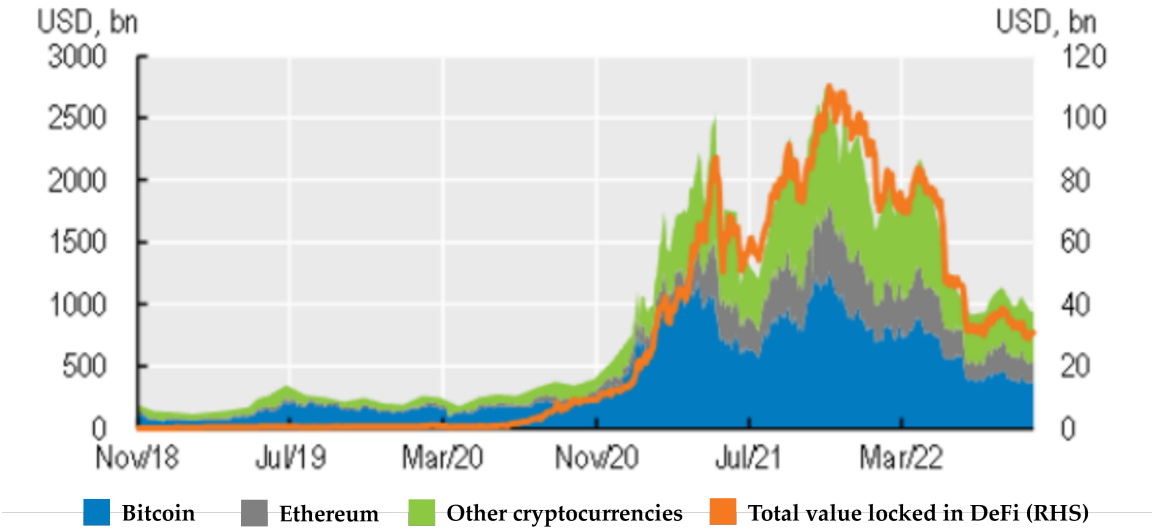


FIGURE 10: Market Value of Major Crypto Assets (Source: CoinMarketCap)

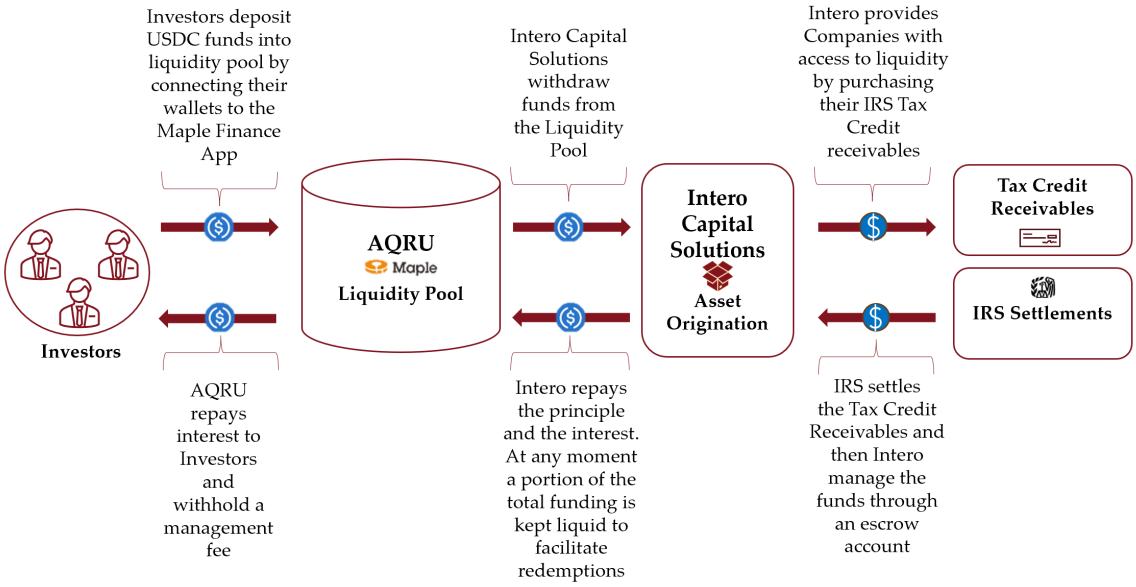


FIGURE 11: AQRU Operational Flow

return the protocol's highest yield (in August 2023 Borrowing Pools on Emerging Markets targeted a 17% USDC APY). Goldfinch protocol, on the other hand, allows investors to choose a lower-risk strategy, by providing USDC not to any specific individual Borrower Pool, but in the Senior Pool of the platform with a second-loss capital that optimizes diversification by automatically allocating its funds across all Borrower Pools according to the assessment of Backers. The distinctive feature of the Goldfinch platform is the "Trust through Consensus" mechanism, used to determine how to allocate capital from the Senior Pool: where more Backers supply to a specific Borrower Pool, the Senior Pool increases the ratio with which it adds leverage. The Trust through Consensus mechanism implies that in order to count individual Backers the protocol must ensure they are represented by different individuals; therefore, all Backers require a unique entity check to participate in a pool and KYC check for U.S. investors. The process that goes through the consensus of Backers aims to replace the over-collateralization issue with the borrower proposals screening in order to reduce credit risk. Prospective borrowers submit a term sheet to the network's Backers, who evaluate individual deals, including off-chain collaterals that are legally enforceable, and covenants. Furthermore, borrowers are required to launch a data room for due diligence that should include some minimum information such as an overview speaking to the borrower's historical performance, transaction structure for the Borrower Pool, and a security overview document explaining how collateral will work in the instance of default. In addition, borrowers also set up a two-way communication channel for potential investors where they can ask questions, find clarification on due diligence documentation, or request additional information. By taking a closer look into Goldfinch protocol architecture, it can be seen that Borrower Pool's smart contracts have both a junior and a senior tranche: Backers supply first-loss capital to the Pool's junior tranches, while Senior Pool investors supply capital to the Pool's senior tranches. As soon as a Borrower makes repayments to its Borrower Pool, the pool applies the payment first to any interest and notional

owed to the senior tranche and then to the junior tranche. This structure is meant to incentivize Backers who actively assess the creditworthiness of individual Borrower Pools and define the lending terms; indeed, they will be the first to experience loss in case of default. There's also a more explicit incentive the protocol grants to Backers: in order to compensate them for evaluating Borrower pool terms and providing first-loss capital, 20% of the Senior Pool's nominal interest (i_n) is reallocated to Backers, according to the following formulas:

- i_{Senior}=i_n*(1-p-j)
- i_{Junior}=i_n*(1-p+r*j)

This means that Senior Pool earns an effective interest rate that is the 70% of the nominal interest rate, considering a 10% of protocol reserve allocation (p) and the 20% of junior reallocation (j). The junior pool, instead, gains an effective interest rate that is higher than the nominal interest rate of the Borrower Pool, due to the incremental effect of leverage ratio (r)[28] and junior reallocation (j). On September 2023 there were 11 active deals on the Goldfinch platform accounting for a total loan amount of $90.435.000; the average borrowers are Credit Funds Fintech Companies that finance small and medium-sized businesses in developing markets, that usually experience serious constraints in raising funds in their domestic financial systems.

Centrifuge

Centrifuge launched Tinlake in 2019 as an open marketplace and investment dApp[29] built on the Ethereum Blockchain that uses a DAO (Decentralized Autonomous Organization) to govern the protocol. Tinlake allows businesses to borrow against their real-world assets such as invoices, real estate, machinery, mortgages, and royalties. In order to create an on-chain representation of the off-chain real-world assets, borrowers need to tokenize their financial assets into NFT and use them as collaterals in Tinlake pools to draw funding. The main feature of Tinlake NFT is that it contains the relevant information required for pricing, financing, and valuation. Centrifuge protocol aims, just like other protocols at least in their public statements and documentation, to increase the liquidity of real-world assets, that are often illiquid in order to help small and medium enterprises access financial services. On the other hand, Centrifuge enables investors to participate in asset-backed loans within the DeFi ecosystem mostly uncorrelated with crypto market volatility. Centrifuge, once a single asset has been tokenized, uses a well-established instrument of traditional financial markets to improve the asset liquidity profile: asset securitization. The protocol governance system pools together multiple assets into a liquidity pool that collects investors'funds. Any asset in the pool is priced and then the issuer borrows liquidity from the pool, over time, accruing debt per asset is repaid by the issuer including interest payments and principal repayments. One of the major obstacles to real-world asset tokenization is the enforcement of asset legal structure on-chain. Centrifuge tries to assess this issue by tying a Special Purpose Vehicle (SPV) to each pool. The SPV the asset originator's business separated from the financing activity underlying the pool in order to minimize default correlation, furthermore, just like in TradFi, to securitize assets, its legal ownership is transferred by the asset originator to the SPV. The legal framework for each pool closely mirrors the structure of Centrifuge's smart contracts and the real-world relationships among the involved parties. The design of this framework is guided by two primary objectives:

1. The primary aim is to provide investors in the pool with the highest level of protection possible, offering them avenues for recourse concerning the real-world assets used as collateral in the pool. The ultimate source of truth is maintained on the Blockchain. All responsibilities and obligations are meticulously encoded within on-chain smart contracts, ensuring a transparent and secure environment for investors.
2. Secondly, SPV serves a crucial role by maintaining the integrity and independence of the financing process.

Similarly, to other DeFi protocols, Centrifuge allows investors to choose among different risk exposures and yield on the same asset class by structuring a pool in senior, mezzanine, and junior tranches, each one represented by a specific token. The senior token also called the yield token, is protected against defaults by the junior token which receives the proceeds after all other tranches have been served in a typical waterfall structure. To mitigate the risk for senior and mezzanine investors, each tranche, except the junior one, is set with a subordination ratio that determines the protection level of upper tranches. More in detail, the subordination ratio is the percentage of the Asset Pool that must be covered by the losses of subordinated tranches below in the waterfall. For example, a subordination ratio of 10% for the senior tranche means that the senior tranche should in any case be protected by a combined mezzanine and junior tranche accounting for at least 10% of the total asset pool. The waterfall structure carries, furthermore, a trade-off between risk and return: all the tranches above the junior one grant a fixed return, while the junior "first-loss" tranche relies on a variable rate due to the possibility of capturing the excess returns greater than the fixed rates of the tranches above.

Market Perspectives

The use of real-world assets in DeFi lending platforms could be one of the crucial steps to bridge the gap between decentralized finance and traditional finance. Currently, many DeFi platforms primarily focus on crypto assets like Ethereum and cryptocurrency derivatives. However, the introduction of real-world assets presents new opportunities and challenges. The case studies mentioned here are currently the largest in terms of TVL, but they are not the only ones in the market: the real game is being played on the ability to make as many types of financial assets legally valid on the Blockchain as possible. According to some sector studies, the asset tokenization market is expected to reach an estimated value between 10 trillion USD[19] and 16 trillion USD[13] by 2030. A significant portion of this growth will come from private debt, which will be brought on the chain, approximately 2.8 trillion USD. These estimates are based on observing the market values of major off-chain asset classes (Debt, Private Equity, Real Estate, Investment Funds, Public Equity), which are projected into the future with a growth rate consistent with the macroeconomic context (ranging from 2% to 8% annually). It is estimated that a portion of this growth (a conservative estimate of 1%) can be brought on the chain, increasing the Total Value Locked in

[28] According to Goldfinch Whitepaper the leverage ratio increases linearly from Bmin, the minimum number of Backers necessary for leverage, to Bmax, the maximum number of Backers necessary to achieve the maximum potential leverage, Lmax.

[29] Decentralized Application are distributed applications that rely on a DLT or a Blockchain, instead of a single computer, and operate autonomously thanks to smart contracts.

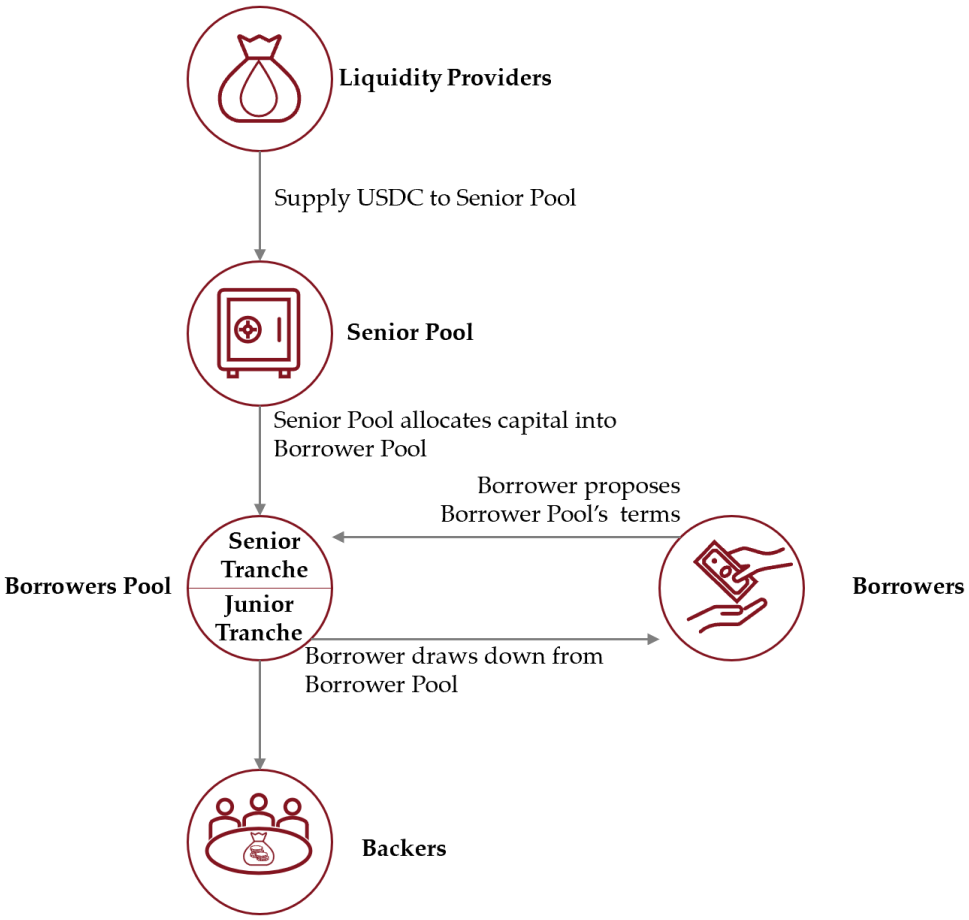


FIGURE 12: Goldfinch Protocol Mechanics

DeFi protocols. If we start from these assumptions, it is reasonable to think that a significant portion of the growth in tokenized assets will be absorbed by DeFi lending platforms since potentially any asset class, once brought on-chain, can be used as collateral for a loan. The macroeconomic context of rising inflation and interest rates could push more and more companies and individuals to seek alternative and faster sources of liquidity in Decentralized Finance protocols, especially if DeFi operators will prove their ability to provide solutions to the intrinsic illiquidity of certain off-chain assets. We have seen how in the recent past, the DeFi lending industry has attempted to address these issues by enhancing certain features of the utilized protocols:

- **Affordability:** Many potential real-world investors are deterred by the high minimum amount, which ranges from $250.000 to $5 million, depending on the asset type such as real estate, bonds, or hedge funds. Concerning this specific point, as we have seen in the previous paragraphs, the trend in lending pools is to further reduce the minimum threshold required for investors, for example The minimum investment to participate in a Tinlake pool is currently 5.000 USD equivalent, and as stated in Centrifuge FAQ section: "Centrifuge is working hard to decrease this. This minimum is in place due to the operational efforts required to onboard an investor to a pool."
- **Fractionalization:** Some assets, like real estate or industrial properties, cannot be easily divided among investors, making it hard to create smaller, accessible investment opportunities. Although fractionalization is a common practice in traditional financial markets, Blockchain technology and smart contracts ensure that the fractionalized asset is divided and distributed according to predefined rules, protecting the rights of token holders.
- **Institutional Adoption:** Institutional investors, such as banks, asset management firms, and pension funds, are increasingly delving into tokenized assets to diversify their portfolios and enhance liquidity. The involvement of these major players is anticipated to infuse substantial capital into the market. As we have seen in the previous paragraphs, the shift away from overcollateralized lending models based on crypto assets and the introduction of real-world assets has significantly reduced the underlying volatility and the overall credit risk, making them attractive to institutional players.
- **Diversification:** The continuous advancement of Blockchain technology is enhancing scalability, security, and efficiency. With an increasingly robust Blockchain infrastructure, a wider array of asset classes can be supported, and a higher volume of transactions is accommodated, making it increasingly appealing to investors. On this target, various initiatives by major market players are underway. Recently, Centrifuge launched Prime, a suite aimed at large investors that allows the building of highly diversified portfolios based on the risk profile sought by the investor. Solutions range from those ensuring high liquidity, consisting of Treasury Bills and

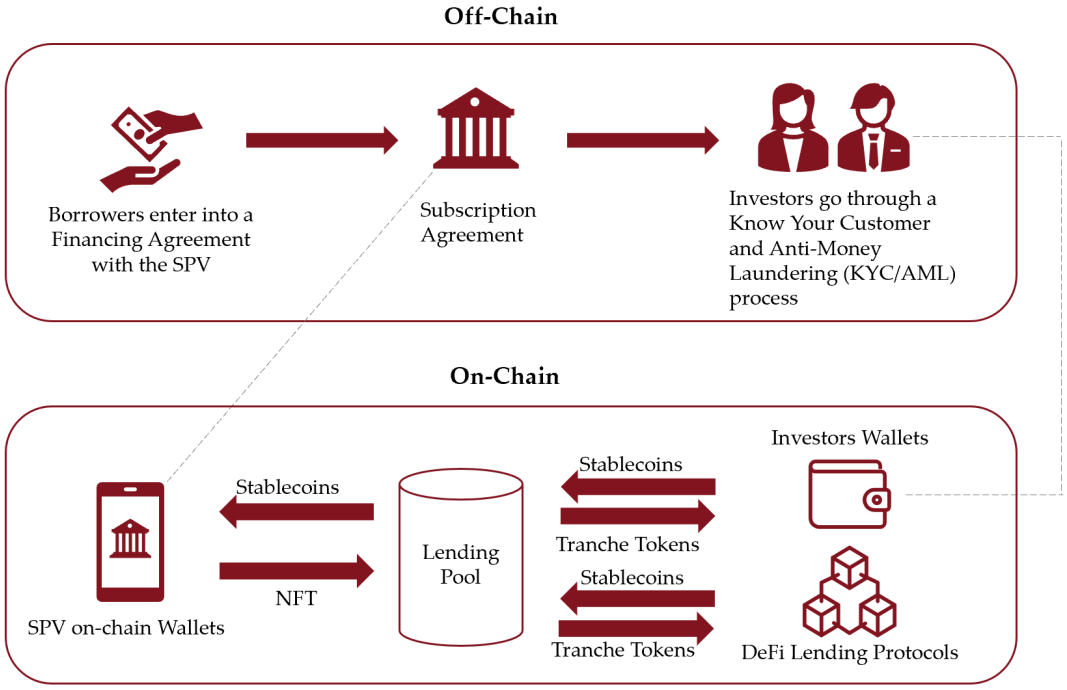


FIGURE 13: Centrifuge Pool structure and relationship with off-chain world

Money Market Funds, to allocations targeting a yield of over 13%, comprising ESG, receivables, real estate, and trade financing.

In conclusion, the actual realization of market perspectives for asset tokenization and the probability of reaching trillion-dollar growth scenarios depends on the market participants'ability to enhance all the aspects mentioned above and on an additional factor that influences all the previous ones: regulatory evolution. As we have seen in paragraph 3.2, the European Union is moving in the right direction in terms of regulatory harmonization with the MICAR regulation. If other supranational institutions follow suit, DeFi lending platforms, and decentralized finance in general, could truly bridge the gap with traditional financial markets and become a viable alternative for investors worldwide.

Real Estate Market: a Tokenization Opportunity

The empirical evidence suggests that both residential and commercial real estate markets are typically characterized by low liquidity, especially during "cold" periods (Krainer, 2001) high transaction costs (Bian, Waller, and Wentland 2016), elevated search costs (Ling et al.,2018) and high entry barriers due to the considerable minimum capital requirements. These specific features and the related risks have undoubtedly influenced the investment returns of the entire real estate market, discouraging business activities within the sector. Real Estate Investment Trusts (REITs) and other private equity investment vehicles with real properties as underlying assets have contributed to overcoming some of the challenges caused by the intrinsic characteristics of the real estate market that we have already mentioned. For instance, REITs allow to profit from properties without the need to manage and carry out physical property maintenance. REITs are also tradable on the secondary markets; hence these types of assets are more liquid than direct real estate investments and they are also accessible with a low level of initial capital. In addition, REIT investments are supported by a strong and consolidated regulatory environment. We can cite as an example the case of the United States, where REITs need to be registered with the U.S. Securities and Exchange Commission (SEC). Nevertheless, REITs do not allow investing in individual properties, but only into property portfolios. Therefore, investors cannot specifically select their investment vehicles according to their preferences. Moreover, investors usually need to pay up-front fees and management fees in exchange for REIT funds administration and governance. The advent of tokenization and Blockchain technology could have a positive effect on the entire real estate market, as it has been already established by the last research based on real-life data and examples. However, there are also some negative features related to the use of these technologies, whose use is clearly limited by the lack of a fully reliable regulatory environment, that is still under development in most countries. In this paragraph, we set aside the regulatory context focusing instead on the main characteristics of real estate tokens pointing out some advantages and disadvantages related to these types of digital assets and then we analyze the empirical evidence already available on this argument.

The main features of Real Estate Tokens

Real estate tokens can be described as fractions of assets representing properties incorporating the related rights and obligations, that are offered to the public through Security Token Offerings (STOs). The characteristics of these investments are defined within smart contracts located in the Blockchain that are executed automatically when determined conditions are met, allowing security, traceability, efficiency, and speediness of the various procedures, eliminating the need for human interventions, and avoiding

operating errors. Transaction costs can be reduced since there is no need for intermediaries. Properties fragmentation as well as the possibility to trade real estate tokens in the secondary markets make these types of assets more liquid than traditional real estate ones, which might need several years to be sold at a fair price and require maintenance to avoid their decay. Moreover, there are no entry barriers for small-scale investors, who can access this market with small sums of money with the aim of diversifying their portfolios. Another advantage provided by these digital assets compared to REITs is represented by the possibility to individually select each single property that investors want to include in their digital wallets. On the other hand, omitting the lack of a complete and integrated regulatory environment and a well-defined taxation system, real estate tokens have many other limitations. If we want to mention one of them, smart contracts are continually threatened by hackers. After a cyber-attack, the money embedded in the contracts may become impossible to trace. Furthermore, the process necessary to obtain the authorization to launch a platform for a STO is long and tortuous and this element can disadvantage entrepreneurs who want to embark on new ventures.

Evidence from the Market

Most of the studies available from the literature are based on the analysis of various samples of US real estate tokens available for trading in a digital platform owned by RealT, a pioneering firm in this market niche. Despite the similarity of the selected samples, which are primarily composed of properties located in Detroit (MI) and Chicago (IL), each study differs from the others regarding the research methodology and investigation topic. We propose an accurate selection of these papers to summarize the main evidence available to date on the argument. Swinkels (2022) published a detailed analysis of a sample of 58 residential properties tokenized by the company RealT between October 2019 and February 2021, which represents the total number of tokens issued by the enterprise during the analyzed period. All the properties within this sample are located in the US: in particular, 52 of them are positioned in Detroit (MI). In RealT's business model, token holders receive the rent (after subtracting costs) for each specific property according to the number of tokens owned. With regard to this specific sample, the investments have been executed through the Ethereum Blockchain. Summarizing the results, the median value of the properties is USD 65.211, token prices mostly fall in the range of USD 45-60, while rents used to be close to USD 6. Most of the properties have between 150 and 400 holders and the number of owners increases in accordance with the value of the underlying property. However, the authors consider this sample too small to provide valid conclusions about the performance of these token assets, even if prices seem to be correlated to economic fundamentals. Steininger, B. I. (2023) analyzes the return-risk pattern of 180 tokenized properties located in the US and finds that this variable does not have a strong correlation with any other asset classes, highlighting the opportunity to use real estate tokens as portfolio diversifiers. Kreppmeier et al. (2023) examine a sample of 173 US tokenized properties available in the RealT platform and find that investors prefer to buy tokens during Security Token Offering (STO) processes instead of investing in this type of assets through the secondary markets. Another important finding is that investors try to evade transaction costs when they buy or sell tokens and they are influenced by crypto market-specific sentiment when purchasing tokenized property fractions. Kull, F., & Naumann, T. (2022) analyzed the performance of a token index constructed on the returns of a sample of tokenized properties issued within the RealT platform against various benchmarks, such as the S&P Case-Shiller MI-Detroit (DetroitHI) home price index and S&P Case-Shiller IL-Chicago (ChicagoHI) home price index (FederalReserve Bank, 2022), arguing that token indices do not outperform the benchmarks during the selected period. Furthermore, this research paper provides an articulated point of view on the effect of the liquidity increase generated by the advent of real estate tokens. Specifically, there are both positive and negative possible consequences of liquidity soaring within this market. Starting with the first category, some of the effects may be improved transparency, market efficiency, and more accurate asset valuation. Regarding the second class, price changes have the potential to negatively affect some investors and intermediaries that generate their gains thanks to the information asymmetries that characterize the real estate market.

Real Estate Tokenization Projects

SolidBlock

SolidBlock was the first company to enter the real estate tokenization industry in 2019 with the digitalization of the St. Regis Hotel in Aspen (CO), which probably represents the most famous case of real estate tokenization that has been also realized in compliance with the SEC regulation. This company is an example of Tokenization as a Service (TaaS) which interconnects Blockchain and Web3 technologies. SolidBlock allows people to buy, sell, raise money, or collateralize properties and manage them in a user-friendly platform, that includes Customer Service with live chats and on-demand reports. Even though it is not easy to find information about the fees for the services offered, the firm supports owners and investors in all the phases of real estate tokenization, from security issuance to secondary market trading. SolidBlock uses Ethereum-standard (ERC20) real estate tokens to represent property shares.

The SolidBlock model from DIBS (Distributed Brokerage System) implies a two-stage process:

- The first step involves asset securitization, which for DIBS requires the tokenization of a share of the asset that is less than 50% of its value.
- Thanks to Web3-enabled digital platforms the asset is issued and traded within the market. At this stage, DIBS will perform all compliance checks according to US and Global regulations.

A peculiarity of DIBS platform is that the Web3 platform links different independent brokers that could distribute any asset listed on DIBS while paying them commission every time they connect investors to listed deals.

SwissRealCoin

SwissRealCoin is a security token linked to a portfolio of Swiss commercial real estate managed through a Blockchain software named "MIA". This project is currently set on hold. The Swiss RE market has been historically characterized by low volatility and high stability. The SRC business model aims for a constant growth of the invested Portfolio thanks to the reinvestment of 80% of the received rents on new properties. In order to sustain the token's liquidity, the SRC will be traded on licensed exchanges. Additionally, the program will ensure the right of all the token-holders to participate in a portfolio liquidation vote. Tokens can be purchased through FIAT, Bitcoin (BTC), or Ethereum (ETH).

RealT

RealT represents the most famous real estate token platform in the US as we have already mentioned in the previous paragraph. The company has been able to tokenize hundreds of properties in this country, especially in the areas of Detroit and Chicago. On the technology side, RealT tokens can be purchased or sold through both the Ethereum Blockchain and the Gnosis chains. RealT platform allows investors to buy, sell, and collateralize real estate. The collateralization processes take place on the RMM platform, where users can contract for loans by placing RealT tokens as collateral. Users can borrow stablecoins and when a default event occurs, real estate tokens are used to repay the loans. The possibility to borrow stablecoins on the RMM platform allows people to get liquidity without the need to sell their real estate tokens and it does permit them to continue to benefit from the income generated by the rents. The collateralization rate is typically set at 50% so that investors can borrow up to half of their property tokens'value. Collateralization allows also to increase the profitability of the operations thanks to the leverage effect, which is obtainable through the reinvestment of the borrowed stablecoins. We underline that the use of leverage does increase the risk profile of the portfolio and might generate major losses.

Italian Real Estate Tokenization Market Perspective: The BlockInvest Case

Tokenization could represent a valid investment alternative to the traditional real estate investment vehicles already available in the Italian market, thanks to its intrinsic characteristics: efficiency, transparency, innovation, and accessibility. The Italian Fintech startup RealHouse SRL and the platform they own named BlockInvest represent a perfectly fitting example of an entrepreneurial initiative that aims at the development of this specific market niche. As evidence of this, in December 2021 the bank Credit Agricole Italia, aware of the potential of this startup, finalized its first investment in an Italian startup and has also included the startup in the acceleration program of Le Village by CA Milano, which is a Credit Agricole open innovation Hub. Regarding tokenization, in January 2020 RealHouse SRL together with InvestiRe SGR SPA and Immobiliare Casati SRL concluded the first real estate Security Token Offering (STO) in Italy, tokenizing two properties located in Rome through the Ethereum Blockchain. The agreement is based on a Non-Performing Loan (NPL) originated by Unicredit which is guaranteed by those two properties. In particular, RealHouse SRL has created and stored in the Blockchain the "digital portfolio" and the documentation related to the entire operation. Immobiliare Casati SRL has issued an equity token called RHC1 with its own intrinsic value and then a new Special Purpose Vehicle (SPV) has been created in order to manage the credit and the property development, also allowing a successful fundraising stage: around EUR 3 million have been collected among private accredited investors. Although the BlockInvest example related to the NPL market highlights the potential of the application of tokenization to the Italian real estate sector, there are still several obstacles to the full realization of an efficient real estate token marketplace in Italy. The first of them is undoubtedly the current legislation: there has been no significant development over the few last years regarding the introduction of real estate tokenization into the Italian legislative landscape. The lack of clear and complete legislation on this matter slows down the development of this market niche, delaying the entry of the most ambitious investors within the sector as well as the realization of an efficient real estate token marketplace.

Conclusions

In conclusion, the analysis delves through the transformative potential that real estate and lending asset tokenization could bring to the markets in the coming years. However, the insights that emerged in the paper scratch only the surface of the impact that asset tokenization could have on the traditional financial landscape. First, the fractional ownership and decentralization that characterize asset tokenization have the power to diminish and break traditional markets entry barriers, fostering market liquidity and widening the plethora of possible investors. Additionally, the absence of centralized authorities could enhance the exchange possibility thanks to the reduction of costs and bureaucracy ensured by the overtaking of middle intermediaries. As we have seen, the regulatory environment could be a critical factor in the development of digital assets. As witnessed in the paper some international regulators and the European Union, with the MiCAR are moving forward in the right way but globally the work on the regulatory playfield for digital assets is far away from being done, and Regulators, market players, and emerging FinTech start-ups must collaborate in order to promote and develop the future architecture of the digital asset's environment. In conclusion, real estate and lending asset tokenization represents more than a technological advancement; it embodies a paradigm shift in how we conceive and interact with financial instruments. In particular, the possibilities of using real-world tokenized assets as collateral in the DeFi lending environment could bring new lymph in these markets being a propellor to the mark growth. On the other hand, the possibility of ownership fragmentations could make investments in real estate assets much easier also for retail investors that are historically a not significant share of this market. Looking forward, it becomes evident that the applications of asset tokenization extend beyond real estate and DeFi lending, which are not the only one that could play a key role in reaching the full potential of asset tokenization; there are, indeed some other potential applications that deserve in-depth analysis, for instance, supply-chain management, asset management and insurance market which could be the subjects of dedicated future papers.

References

[1] **Aldasoro, I., Doerr, Gambacorta, L., Garratt, R. and Koo Wilkens, P.** *The tokenization continuum*. BIS Bulletin series N. 72, April 2023.

[2] **Auer, R., Haslhofer, B., Kitzler, S., Saggese, and Victor, F.** *The Technology of Decentralized Finance (DeFi)*. BIS Working Papers N. 1066, January 2023.

[3] **Badev, A. and Watsky, C.** *Interconnected DeFi: Ripple Effects from the Terra Collapse*. FED Finance and Economics Discussion Series, May 2023.

[4] **Basel Committee on Banking Supervision.** *Prudential treatment of cryptoasset exposures*. December 2022.

[5] **Chiu, J., Ozdenoren, E., Yuan, K. and Zhang, S.** *On the Inherent Fragility of DeFi Lending*. Bank of Canada Staff Working Paper N. 14, August 2022.

[6] **European Union.** *Communication COM(2020) 591 final on a Digital Finance Strategy for the EU - COM(2020) 592 final on a Retail Payments Strategy for the EU*. September 2022.

[7] **European Union.** *Directive (EU) 2018/843 of the European Parliament and of the Council art.1.3 of 30 May 2018*. May 2018.

[8] **European Union.** *Regulation (EU) 2022/858 of The European Parliament and of the Council of 30 May 2022*. May 2022.

[9] **European Union.** *Regulation (EU) 2023/1114 of the European Parliament and of the Council of 31 May 2023 on markets in crypto-assets, and amending Regulations (EU) No 1093/2010 and (EU) No 1095/2010 and Directives 2013/36/EU and (EU) 2019/1937*. May 2023.

[10] **Financial Action Task Force.** *Updated Guidance for a Risk-Based Approach to Virtual Assets and Virtual Asset Service Providers*. October 2021.

[11] **Financial Stability Board.** *FSB Global Regulatory Framework for Crypto-Asset Activities*. July 2023.

[12] **Kitzler, S., Victor, F., Saggese, P. and Haslhofer, B.** *Disentangling Decentralized Finance (DeFi) Compositions*. Technische Universitat Berlin, November 2021.

[13] **Kumar, S., Suresh, R., Liu, D., Kronfellner, B. and Kaul, A.** *Relevance of on-chain asset tokenization in Crypto Winter*. Boston Consulting Group X ADDX, August 2022.

[14] **Magri, V.** *Chiusa la prima operazione immobiliare in blockchain in Italia grazie a Investi RE e Realhouse*. Crowdfunding Buzz, January 2020.

[15] **Mazzoni, N., Morisani, G. and Ciminelli, V.** *Asset Tokenization: Potential and Challenges of a Disruptive Technology*. Just In Time, July 2023.

[16] **Mazzoni, N., Stabellini, C. and Zanolli, M.** *Digital Assets: A Regulatory; Overview*. Just In Time, September 2023.

[17] **Menegon, A., Colombo, G.,Mori, G., Mazzoni, N., Bainotti, M., Campaniolo, G., Migliaccio, E., Nava, L., Stabellini, C. and Zanolli, M.** *Digital Euro: Now and Beyond*. Argo Collection N.6, December 2023.

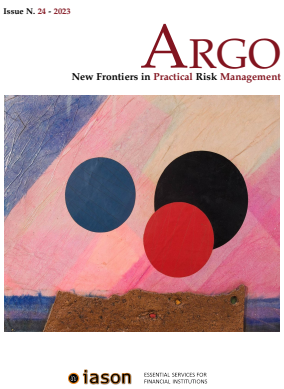
[18] **Mori, G. and Bainotti, M.** *The Crypto Ecosystem: Key Elements and*

Risks. Just In Time, November 2023.

[19] **Samaties, P.** *Tokenization of Real-World Assets*. Roland Berger, October 2023.

[20] **Tapscott, D.** *Token Taxonomy: The Need for Open-Source Standards Around Digital Assets*. Blockchain Research Institute, February 2020.

In the previous issue



Issue N. 24 - 2023

Incremental Valutation Frameworks

Advances in Incremental Valuation of Financial Contracts and Definition of the Economic Meaning of the Capital Value Adjustment (KVA)

Environmental, Social, and Governance Risks

Market Risk Modeling Extension with Climate and Environmental Risk Factors

Credit Risk

LGD Stress Testing: a Bayesian Averaging Modeling Approach

Interest Rate Risk on the Banking Book

Managing IRRBB: Overview of the New EBA Guidelines and the Importance of an Advanced Sight-deposits Behavioural Model

Last issues are available at www.iasonltd.com/research/