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NUS National University of Singapore | AI·DF Asian Institute of Digital Finance

AI Applications in Web3 SupTech and RegTech: A Regulatory Perspective

Prepared by

Shengliang Lu*, Amritpal Sidhu*, Bingsheng He^, Brian Byagaba*, Dmitry Fedotov*, Alejandro Vargas#, Helena Zhang^, Barry West*

FULL PAPER

*ADGM (including FSRA, RA, and Academy), ^NUS, #Mooncheck

Abstract

The digital realm is experiencing a transformative shift driven by the emergence of Web3 technologies and virtual assets. This new phase of internet technology leverages distributed ledger technologies and smart contracts while fostering decentralization, increasing transparency, and reducing dependence on intermediaries. Such innovations are pivotal in shaping Decentralized Finance. However, the rapid adoption of Web3 technologies presents significant risks underscored by high-profile failures and systemic vulnerabilities.

ADGM has developed a conducive regulatory environment through its Financial Services Regulatory Authority (FSRA) by creating a transparent and progressive regulatory framework aligned with international standards and safeguarding stakeholders› interests.

This whitepaper explores the integration of AI into regulatory technologies to enhance compliance monitoring and risk management. It details the research and development efforts by the National University of Singapore›s Asian Institute of Digital Finance, ADGM FSRA, and the ADGM Academy Research Centre. The whitepaper concludes with a summary of key findings and proposes future collaborative efforts to further develop the regulatory landscape.

Keywords:

AI, Cryptocurrency, DeFi, Digital Asset, RegTech, Regulation, SupTech, Virtual Asset, Web3

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1 – INTRODUCTION

The digital landscape is undergoing rapid transformation with Web3 technologies leading advancements in internet technology. Built on distributed ledger technologies (DLT) and smart contracts, Web3 technologies emphasize decentralization, increase transparency and reduce reliance on intermediaries. DLT, including blockchains, offers a secure, immutable ledger for transactions and data, while smart contracts facilitate automated agreements without intermediaries. This combination supports the development of decentralized applications, particularly in Decentralized Finance (DeFi), which are reshaping financial transactions through peer-to-peer interactions.

The global cryptocurrency market capitalisation has surpassed the $3 trillion[1] mark rivalling some of the world's largest companies, including Apple and Microsoft[2]. The cryptocurrency user base has expanded significantly, with a 34% increase in 2023 alone rising from 432 million in January to 580 million by December[3]. This growth underscores the increasing adoption and integration of cryptocurrencies into the global financial landscape. Additionally, data reveals that the United Arab Emirates (UAE) leads the world in cryptocurrency adoption, with over 30% of its population, approximately 3 million people, owning digital assets[4]. This reflects the nation's forward-thinking embrace of financial technology and its aspirations to become a major fintech hub.

ADGM plays a pivotal role in the rapidly evolving financial landscape. Overseeing financial services in the international financial centre and free zone, the ADGM Financial Services Regulatory Authority (FSRA) is at the forefront of fostering a regulatory environment that is not only seeks to support the growth of DeFi and VA but also the broader digital transformation in financial services.

The FSRA has developed a comprehensive regulatory framework for virtual assets that has been continually refined since its introduction in 2018[5]. This framework supports innovation while ensuring robust oversight and alignment with international standards. By embracing digital transformation, ADGM collaborates closely with technology ecosystem partners like Hub71[6] and research institutes like the National University of Singapore, promoting the adoption of cutting-edge, technical solutions within ADGM. This proactive approach helps position Abu Dhabi as a destination of choice for financial companies seeking to leverage advanced technologies and digital finance models.

Further enhancing its regulatory capabilities, the ADGM FSRA is leveraging advancements in RegTech and SupTech to streamline regulation and supervision. Through AI-driven RegTech solutions, the FSRA could provide more interactive and tailored regulatory interactions, making compliance more efficient and accessible for entities operating within ADGM. The implementation of AI-enabled SupTech tools could support the FSRA's oversight and risk management objectives while reducing costs for financial institutions. Together, these initiatives underscore the FSRA's mandate to provide a transparent, efficient, and progressive financial environment that not only safeguards the interests of customers, investors, and industry participants, but also fosters sustainable growth and innovation in ADGM.

1 As of November 2024, the global cryptocurrency market was at $3.5 trillion. https://www.forbes.com/digital-assets/crypto-prices
2 https://8marketcap.com/
3 https://crypto.com/company-news/global-cryptocurrency-owners-grow-to-580-million-through-2023
4 https://coinedition.com/uae-dominates-global-crypto-adoption-vietnam-surges-to-second
5 ADGM (2018) | ADGM launches crypto asset regulatory framework https://www.adgm.com/media/announcements/adgm-launches-crypto-asset-regulatory-framework
6 Hub71 | Hub71 https://www.hub71.com

SupTech (Supervisory Technology) refers to the application of technology to enhance the supervisory and oversight functions of regulatory authorities. It involves the use of advanced tools like data analytics, AI, and automation to improve the monitoring and supervision of regulated activities, and enforcement of regulatory frameworks. SupTech aims to provide regulators with more effective, data-driven insights, and enable them to better identify issues, assess risks, and enforce regulations in real-time.

RegTech (Regulatory Technology) refers to the use of technology to streamline, automate, and improve regulatory compliance processes for businesses. It leverages innovative tools such as AI, machine learning, automation, and data analytics to help companies meet regulatory requirements more efficiently, reduce compliance costs, and enhance transparency and reporting. RegTech aims to simplify complex compliance tasks, such as monitoring transactions, identifying risks, and ensuring adherence to legal standards

New risks arising from the nature of Web3 technologies, such as failures of blockchain protocols like Terra (LUNA)[7] , alongside emerging vulnerabilities in smart contracts[8], stress the need for effective regulatory frameworks and risk management strategies. The innovative and decentralized nature of blockchain technology creates a fertile ground of exposure to new forms of fraud and systemic failures that must be addressed for wider adoption to be possible.

In response, among other strategies, ADGM is exploring the application of AI in regulatory and supervisory technology solutions to improve compliance monitoring and risk management. The Asian Institute of Digital Finance at the National University of Singapore (NUS AIDF) conducts FinTech research in AI technologies, providing tools for predictive analytics, anomaly detection, and automated compliance. The FSRA is testing and validating these AI technologies to meet the emerging needs of regulating and supervising Web3 and VA ecosystems effectively. This whitepaper summarizes the research and development efforts of NUS AIDF and ADGM (including both the FSRA and the ADGM Academy Research Centre) in implementing AI technologies to support regulatory and supervisory activities in the Web3 and virtual asset domains.

As this paper is intended for a broader audience and not set up to provide specific definitions readers should note that the terms “Virtual Assets”, “Web3”, “blockchain”, “DLT”, and “network” are used interchangeably. Nonetheless, explanations of some terms are provided in Section 2.

The remainder of the paper is outlined as follows. Section 2 provides the context and scope of this paper while Section 3 discusses the potential opportunities for regulators to leverage AI technologies. Section 4 discusses AI innovations shaping regulatory actions and activities. Section 5 examines pilot projects conducted by NUS AIDF and ADGM, demonstrating practical applications of these innovations, such as smart contract assessments, security auditing, and AI-powered due diligence. Section 6 concludes the paper with a summary of findings and a discussion on future directions and potential areas to enhance the regulatory landscape.

7 Investopedia (2022) | TerraUSD Crash Shows Risks of Algorithmic Stablecoins https://www.investopedia.com/terrausd-crash-shows-risks-of-algorithmic-stablecoins-5272010
8 Cointelegraph (2023) | Curve-Vyper exploit: The whole story so far https://cointelegraph.com/news/curve-vyper-exploit-whole-story-so-far

2 – BACKGROUND

This section aims to provide explanations for key terms that are used in this paper, setting a foundational background for readers to better understand the discussions in later sections.

Virtual Asset. The FSRA's regulatory framework categorizes digital assets into distinct classes, which also include Fiat-Referenced Tokens and Digital Securities.

VA refers to a digital representation of value that can be digitally traded and functions as (1) a medium of exchange; and/or (2) a unit of account; and/or (3) a store of value but does not have legal tender status in any jurisdiction. A VA is (a) neither issued nor guaranteed by any jurisdiction and fulfils the above functions only by agreement within the community of users of the VA; and (b) distinguished from fiat currency and e-money[9].

Web3. Web3 represents the next evolution of the internet, transitioning from "read" (Web1) and "read-write" (Web2) to "read-write-own" capabilities[10]. Unlike the centralized platforms of Web2, Web3 leverages blockchain technology to empower users with true ownership of their data, digital assets, and online interactions. This decentralized paradigm reduces reliance on intermediaries, fostering greater user autonomy and privacy while redefining how individuals interact with digital platforms.

DLT and Blockchain Network. DLT refers to a digital system for recording transactions of assets in which the data is stored across multiple sites or nodes simultaneously. Unlike traditional centralized databases, DLTs are decentralized, eliminating the need for a central authority and enhancing transparency and security. Each participant in the network maintains a synchronized copy of the ledger thereby reducing the risk of single points of failure.

Blockchain is a specific type of DLT that organizes data into cryptographic blocks which are then linked chronologically to form a chain. This structure ensures that recorded data becomes immutable. VAs are typically built on blockchain networks. In Web3, DLT and blockchain networks power DeFi platforms and decentralized apps (dApps) by enabling secure, transparent transactions.

DeFi. DeFi refers to a financial ecosystem built on blockchain and DLT that enables peer-to-peer transactions and services without the need for traditional intermediaries like banks or financial institutions[11]. DeFi applications leverage smart contracts, which are self-executing programs on blockchain networks, to automate and enforce financial operations such as lending, borrowing, trading, and investing.

AI. AI in general defines a collection of technologies enabling a machine or system to comprehend, learn, act, reason, and sense like a human[12]. AI systems leverage algorithms, data, and computational power to adapt and improve over time.

The proliferation of AI tools in recent years has provided the financial industry with the possibility to integrate its capabilities into diverse use cases. AI offers noteworthy benefits, including enhanced operational efficiency, strengthened regulatory compliance, personalized financial products, and advanced data analytics capabilities. FSRA launched an initiative, named the Open Regulation (OpenReg), back in 2022[13] , aiming

9 Section 258 of FSMR (FINANCIAL SERVICES AND MARKETS REGULATIONS) https://en.adgm.thomsonreuters.com/rulebook/financial-services-and-markets-regulations-2015-0
10 Dixon, C., 2024. Read Write Own: Building the Next Era of the Internet. Random House.
11 BIS (2023) | The Technology of Decentralized Finance (DeFi) https://www.bis.org/publ/work1066.htm
12 National Program For Artificial Intelligence (2020) | AI Guide https://ai.gov.ae/wp-content/uploads/2020/02/AIGuide_EN_v1-online.pdf
13 ADGM (2022) | ADGM's Financial Services Regulatory Authority launches its AI initiative on Open Regulation https://www.adgm.com/media/announcements/adgms-financial-services-regulatory-authority-launches-its-ai-initiative-on-open-regulation

to make regulatory context machine-readable regulations. The project enables RegTech companies and data science community to use the AI training ground to build the next generation of AI-enabled RegTech solutions.

In this paper, as a part of FSRA's ongoing journey to embed AI technologies into FSRA supervisory approaches, we elaborate on the AI adoption for RegTech and SupTech for Web3 regulatory actions/activities, taking into consideration the valuable insights provided in recent reports[14] published by the Financial Stability Board (FSB), the regulatory principles outlined EU AI Act[15] , and the risk framework developed by Project MindForge[16].

3 – OPPORTUNITIES FOR UTILISING AI FOR REGULATING WEB3 ACTIVITIES

The regulatory framework for Web3 has nuances that differentiate it from traditional regulations due to the unique characteristics of blockchain technology, smart contracts, and speed of Web3 innovation.

Globally, the recent focus of regulating Web3 has been on VAs and their trading platforms. This includes enforcing anti-money laundering (AML) measures such as incorporating KYT (know your transactions) solutions and implementing travel rule[17] requirements, establishing prudential guidelines for stablecoin issuers and, more recently, regulation of decentralized ownerless entities such as DLT Foundations and decentralised autonomous organisations (DAOs).[18] These efforts to create regulatory frameworks and imposition of safeguards to protect customers and investors demonstrate a broadening acceptance of VA and Web3.

In examining the inherent characteristics of Web3 and VA for the financial regulator's perspective, it is crucial to consider (but not limited to):

- Their 24/7 continuous operation with minimal human oversight, facilitated by self-executing smart contracts on DLTs;
- The heightened security risks due to vulnerabilities in smart contract coding, potential exploits, and reliance on decentralized networks; and
- The introduction of 'new' concepts that either repurpose existing traditional financial frameworks with blockchain innovations or present entirely novel ideas with no historical precedent.
- The decentralized nature of Web3 ensures that transactions and smart contracts are immutable, enhancing trust and transparency but making it challenging to address errors like "fat-finger" mistakes, hacking, or unintended outcomes.

Regulating Web3 activities introduces several challenges that necessitate innovative regulatory approaches and the development of new tools to enhance supervisory monitoring and enforcement capabilities. Nevertheless, these challenges also present considerable opportunities to shape a better future for the Web3 ecosystem.

14 FSB (2024) | The Financial Stability Implications of Artificial Intelligence https://www.fsb.org/2024/11/the-financial-stability-implications-of-artificial-intelligence/
15 European Union Artificial Intelligence Act https://artificialintelligenceact.eu/
16 MAS (2023) | MAS Partners Industry to Develop Generative AI Risk Framework for the Financial Sector https://www.mas.gov.sg/news/media-releases/2023/mas-partners-industry-to-develop-generative-ai-risk-framework-for-the-financial-sector
17 The FATF Recommendations https://www.fatf-gafi.org/en/publications/Fatfrecommendations/Fatf-recommendations.html
18 ADGM DLT Foundations Framework https://www.adgm.com/dlt-foundations

Fast-Paced Innovation and Risk Identification. The nature and fast pace of innovation in Web3 technologies make it challenging to promptly identify and mitigate emerging risks. This dynamic environment requires regulatory processes and frameworks to achieve a greater measure of responsiveness to ensure regulators remain agile and able to effectively identify, assess, and address potential risks.

The gap in responsiveness increases the potential for fraud and market failures. However, these regulatory challenges also open up opportunities to build frameworks "from scratch", allowing for the integration of forward-thinking principles that can adapt over time. This can encourage the development of efficient business models tailored to the unique characteristics of Web3, ultimately fostering a stable yet dynamic marketplace that aligns with both regulatory and industry growth objectives. AI can play a role in facilitating investigation of such concerns and in the construction of regulatory frameworks by rapidly identifying enhancements in regulatory rulebooks to quickly respond to Web3 developments.

Advanced Real-Time Risk Monitoring. Effective risk monitoring in the Web3 ecosystem requires advanced tools capable of real-time analysis of extensive blockchain data. Given the continuous 24/7 operation of DLTs and smart contracts, traditional point-in-time regulatory approaches often struggle to manage the volume and complexity of data generated by transactions. Consequently, there is a pressing need for regulatory bodies to develop more sophisticated analytical tools. Implementing continuous monitoring systems and automated risk management tools can aid in monitoring compliance to regulatory requirements, enabling proactive responses to potential threats.

Jurisdictional Complexities. The decentralized nature of Web3 activities often creates cross-jurisdictional challenges to regulatory approaches. Since each regulator may have a different approach to governing VA, firms may find it difficult and costly to maintain compliance across multiple, sometimes conflicting, regulatory requirements thereby increasing the tendency to practice regulatory arbitrage. AI-driven RegTech tools can potentially help streamline and manage these complexities for firms. By automating routine compliance tasks, identifying overlapping regulatory requirements, adapting to new rules more efficiently, and assisting regulatory reporting processes, AI can reduce costs and operational burdens, ultimately making it easier for firms to meet diverse regulatory expectations.

In the following sections, we consider various scenarios where the use of AI offers benefits to regulatory processes.

4 – AI INNOVATIONS

The evolution of AI technologies has experienced significant advancements, transforming operational and innovation landscapes across various industries[19]. In the Web3 and VA space, AI has the potential to extensively improve regulatory oversight and compliance efficiency.

This section provides an overview of emerging AI technologies and how AI innovations could reshape the Web3 regulatory environment. It starts with a brief introduction of widely used AI models (we only elaborate briefly of the potentially widely used models for regulatory domain), followed by use cases in adopting these AI techniques for regulatory activities. We also discuss the key challenges of utilising AI before considering possible directions for future developments.

19 McKinsey (2024) | The state of AI in early 2024: Gen AI adoption spikes and starts to generate value https://www.mckinsey.com/capabilities/quantumblack/our-insights/the-state-of-ai

4.1 Emerging AI Technologies

Machine Learning (ML). ML is a subset of AI that specializes in making predictions or decisions based on data.[20] ML algorithms excel at analysing vast arrays of transaction data to detect patterns and anomalies indicative of fraudulent activities or compliance issues. By employing supervised, unsupervised, and reinforcement learning techniques, ML models can adapt and improve over time, offering regulators powerful tools to improve monitoring efficiency and accuracy without the need for constant human oversight.

Natural Language Processing (NLP). NLP focuses on enabling computers to understand and process human language (i.e., text).[21] NLP can deliver efficiencies for regulatory reviews and assessments through automated extraction and analysis of key information from vast amounts of documents and communications. Advanced NLP models have achieved significant progress in both understanding and generating human-like text, which can be utilized to automate responses to both regulatory and public inquiries.[22]

However, NLP technologies may include the potential for misinterpretation and bias as NLP models may not fully account for varied context or tone depending on cultural or societal norms. Such challenges may lead to incorrect regulatory responses or actions if adopted without human intervention.

Generative AI. Generative AI refers to AI technologies that can generate new content (e.g., text, images, and other media) based on existing data.[23]

However, NLP technologies may include the potential for misinterpretation and bias as NLP models may not fully account for varied context or tone depending on cultural or societal norms. Such challenges may lead to incorrect regulatory responses or actions if adopted without human intervention.

AI Agents. AI agents are specialised generative AI model implementations that can perform complex tasks with programmed workflows, such as automating customer service interactions, generating legal and regulatory documents, or even conducting virtual negotiations on behalf of human operators.[24]

In the regulatory context, generative AI and AI agents have many potential applications. For instance, they can be used by regulated entities to automate the generation of detailed periodic or on-demand compliance reports. Such AI technologies can also be employed by regulators to analyse large data sets of regulatory returns and generate a shortlist of potential non-compliance and risk indicators. However, akin to the limitations inherent in NLP technologies, the current available generative AI models, which are largely based on large language models (LLMs), have limitations in accuracy and reliability of outputs due to the potential for hallucination and contextual misinterpretation.

General AI. General AI refers to highly autonomous systems capable of performing any cognitive task that a human being can undertake.[25] Unlike generative AI, which is designed for specific content creation tasks, general AI is characterized by its versatility and ability to adapt to a wide range of scenarios without prior specific programming. While still conceptual, general AI could facilitate highly adaptive systems for regulatory oversight and compliance management autonomously adjusting to new regulations and the complexities of legal compliance with little to no human intervention.

20 IBM (2023) | AI vs. machine learning vs. deep learning vs. neural networks: What's the difference? https://www.ibm.com/think/topics/ai-vs-machine-learning-vs-deep-learning-vs-neural-networks
21 IBM (2024) | what is NLP? https://www.ibm.com/topics/natural-language-processing
22 PwC (2022) | Understanding algorithmic bias and how to build trust in AI https://www.pwc.com/us/en/tech-effect/ai-analytics/algorithmic-bias-and-trust-in-ai.html
23 McKinsey (2024) | What is generative AI? https://www.mckinsey.com/featured-insights/mckinsey-explainers/what-is-generative-ai
24 https://openai.com/index/introducing-gpts
25 https://fortune.com/2024/04/05/what-is-agi-artificial-general-intelligence

4.2 AI Solutions in the Web3 Regulatory Domain

In this section we explore how diverse types of AI technologies may be implemented in the Web3 regulatory space to meet the challenges of monitoring, enforcement, and compliance management. We split these technologies into two major categories: applications using narrow AI and those using generative AI. Note that narrow AI refers to artificial intelligence systems that are designed to perform specific tasks and operate under limited constraints.[26] They are also referred to as "specific AI" or "weak AI".

4.2.1 Narrow AI-based Applications

Regulatory Reporting Tools. AI-driven regulatory reporting tools can automate the collection, submission and analysis of regulatory returns and attestation reports.[27][28] These systems utilize advanced data mining and processing algorithms to extract and organize information from vast datasets to facilitate seamless regulatory reporting. Beyond reporting automation, AI tools that perform predictive analytics may enable regulated entities to identify risk factors that can reduce the potential for compliance failures. For example, AI can be employed to monitor and predict financial risks that may hinder compliance with liquidity and capital obligations.

Risk Profiling. AI systems dedicated to risk profiling[29] can analyse and categorize virtual assets or financial entities based on their risk characteristics and applicable regulatory requirements. These systems can evaluate historical performance, market behaviour, and external factors to maintain a dynamic risk profile. By continuously learning from new data and regulatory updates, these AI profilers can keep profiles apace with the evolving financial landscape[30].

Know Your Transaction (KYT). Utilizing graph analytics and graph neural networks (GNNs), AI-driven KYT and anomaly detection systems can be specifically designed to monitor and analyse accounts[31] and transactions on blockchain networks. By leveraging on the capabilities of AI to examine complex blockchain transaction flows regulated entities would be better equipped to identify high risk transactions and accounts and improve measures that enforce AML requirements[32]. While existing KYT solutions are largely rule-based, industry players are incorporating AI technologies[33] such as the use of pattern recognition for wallet clustering and cross-chain asset flow analysis.

Financial Risk Assessment. AI models are already being utilised for cash flow forecasting and liquidity management in traditional finance sectors[34]. In DeFi, AI models can be adopted by platform operators and users manage liquidity more effectively by analysing and predicting liquidity risks within and across decentralized exchanges and lending platforms. These models can be used to monitor trading volumes, token reserves, and user behaviour to identify potential liquidity shortages before they become critical. Early warnings and actionable insights from such models are useful not only for financial institutions offering

26 Nvidia (2016) | The Difference Between AI, Machine Learning, and Deep learning https://blogs.nvidia.com/blog/whats-difference-artificial-intelligence-machine-learning-deep-learning-ai/
27 Cambridge Centre for Alternative Finance (2023), Cambridge SupTech Lab: State of SupTech Report 2023 https://www.jbs.cam.ac.uk/faculty-research/centres/alternative-finance/publications/state-of-suptech-report-2023/
28 ADGM (2023) | ADGM and MBZUAI forge strategic collaboration to advance artificial intelligence for regulatory compliance https://www.adgm.com/media/announcements/adgm-and-mbzuai-forge-strategic-collaboration-to-advance-artificial-intelligence
29 EY (2023) | The transformation imperative: generative AI in wealth and asset management https://www.ey.com/en_us/insights/financial-services/generative-ai-transforming-wealth-and-asset-management
30 Wu, Tongtong, et al. "Continual learning for large language models: A survey." arXiv preprint arXiv:2402.01364 (2024).
31 Liu, Zemin, et al. "A survey of imbalanced learning on graphs: Problems, techniques, and future directions." arXiv preprint arXiv:2308.13821 (2023).
32 Weber, Mark, et al. "Scalable graph learning for anti-money laundering: A first look." arXiv preprint arXiv:1812.00076 (2018): 1-7.
33 UK Finance and Oliver Wyman (2023) | The Impact of AI in financial services https://www.ukfinance.org.uk/system/files/2023-11/The%20impact%20of%20AI%20in%20financial%20services.pdf
34 J.P.Morgan (2024) | Revolutionizing cash flow forecasting with AI https://www.jpmorgan.com/insights/treasury/liquidity-management/ai-driven-cash-flow-forecasting-the-future-of-treasury

services to consumers, but also to regulatory bodies supervising these services, maintaining stability and confidence in the DeFi ecosystem.

4.2.2 Generative AI-based Applications

Automated Compliance Checks. Automated compliance checks conducted by generative AI may revolutionize how businesses adhere to regulations by interpreting various legal frameworks across jurisdictions[35]. Such AI tools would involve sophisticated semantic analysis to understand the nuances of regulatory texts, court decisions, interpretative letters, and other relevant regulatory publications.

This technology could dynamically update its regulatory databases and algorithms in real-time as new legislation are passed, allowing businesses to quickly adapt to regulatory changes. The implementation of AI regulatory tools such as these would enable companies to achieve compliance with both local and international regulations more efficiently and cost-effectively than previously possible, significantly reducing their risk of penalties and legal challenges.

Generative AI models are also valuable tools for Web3 and virtual asset service providers (VASPs) by accelerating the manual tasks involved in preparing whitepapers, charters, and chatbots for customer service[36]. Other emerging AI tools expedite the task of keeping disclosures up to date and compliant, as well as ensuring that communications and marketing materials remain within permissible regulatory bounds. These developments represent the potential to shift towards greater efficiency and regulatory adherence in the industry.

Smart Contract Auditing. Smart contract auditing utilizes generative AI to dissect and analyse the logic[37] and functionality of smart contracts across multiple platforms and coding languages. Advanced LLMs can facilitate the detailed examination of complex code logic to identify inconsistencies, vulnerabilities, and compliance issues with existing legal frameworks. These AI systems can learn from past audits to improve their diagnostic accuracy, providing robust support for developers and regulatory bodies to verify that smart contracts are both secure and legally compliant. The next section expands further on pilot projects conducted to explore such applications.

Market Sentiment Analysis. Generative AI can be used to analyse large volumes of unstructured data from social media, forums, and news outlets to assess public sentiment toward market conditions or specific assets[38] . By interpreting language and detecting shifts in sentiment, such tools can predict potential market movements that can alert traders and investors looking to respond to market trends as well as regulatory bodies monitoring for market manipulation.

4.3 Challenges in AI Implementation

Implementing AI systems for regulatory oversight involves addressing challenges to achieve effective and reliable outcomes. We examine key issues such as ethical and privacy concerns, the mitigation of AI bias, and the need for greater transparency in model behaviour. Tackling these challenges is essential to establishing trust in the use of AI for regulatory processes, particularly in scenarios where supervisory actions and judgment are required.

35 PwC (2024) | Unleash the power of compliance analytics with GenAI https://riskproducts.pwc.com/insights/unleash-the-power-of-compliance-analytics-with-genai/
36 Portier, B from Google (2023) | Generative AI for Web3 on Google Cloud https://cloud.google.com/blog/topics/startups/web3-and-generative-ai
37 Liu, Ye, et al. «PropertyGPT: LLM-driven Formal Verification of Smart Contracts through Retrieval-Augmented Property Generation.» arXiv preprint arXiv:2405.02580 (2024).
38 KPMG (2023) | Artificial Intelligence in Investment Banks https://assets.kpmg.com/content/dam/kpmg/uk/pdf/2024/04/artificial-intelligence-in-investment-banks.pdf

4.3.1 Ethics and Bias

The deployment of AI in regulatory domains raises observable ethical and bias concerns that require careful attention. Ethical guidelines are essential to ensure that AI decision-making, which can profoundly impact individuals' lives, remains fair and effective.[39] Biases inherent

in training data or algorithms can result in skewed outcomes that unfairly disadvantage certain groups, undermining regulatory fairness and effectiveness.

4.3.2 Transparency and Traceability

Clear disclosure of how data is used, processed, and shared is necessary to promote accountability and build trust among stakeholders. Additionally, regulators that rely on AI to interpret voluminous data submitted form its regulated entities should ensure that measures are in place for the AI to explain what data was used and how such data was used to arrive at a conclusion. Without transparency of data use and adequate traceability of decision making, regulated entities may question the reliability of decisions made that impact them and strain the relationship between them and their regulators.

4.3.3 Privacy

AI systems require access to vast amounts of data, raising significant privacy concerns.[40] These systems may inadvertently expose sensitive information or misuse data, leading to potential breaches or unauthorized access.[41] The collection, storage, and processing of such data must be governed by strict data protection measures to safeguard individual privacy rights.

4.3.4 Vulnerability to Misleading Inputs

The integrity of AI responses in the regulatory domain is susceptible to the challenges posed by prompt hacking. Users may intentionally or unintentionally provide misleading inputs that influence the model's decision matrix thereby affecting the quality and reliability of outputs. Addressing these vulnerabilities requires advanced real-time monitoring tools to analyse and mitigate potential malicious prompts effectively.

4.3.5 Over-Reliance by Users

The precision and competence of AI-generated responses can foster an over-reliance among users. Human oversight remains necessary to prevent over-reliance on AI systems and ensure prudent utilization of AI capabilities.

4.4 Future Directions

The integration of advanced AI technologies is expected to influence the development, monitoring, and enforcement of regulations in the future. We see the potential advancements in predictive analytics and decision-making, as well as emerging technologies that could transform regulatory activities.

Advancements in predictive analytics are likely to reshape AI-driven regulatory and supervisory approaches. These advancements would enable not only a proactive but also a preventive approach to regulation by forecasting potential compliance issues and regulatory breaches before they occur. Machine learning algorithms can be trained to foresee anomalies that precede fraudulent activities or regulatory violations.

39 Microsoft (2022) | Microsoft Responsible AI Standard https://blogs.microsoft.com/wp-content/uploads/prod/sites/5/2022/06/Microsoft-Responsible-AI-Standard-v2-General-Requirements-3.pdf

40 Reuters (2023) | Seeking synergy between AI and privacy regulations https://www.reuters.com/legal/legalindustry/seeking-synergy-between-ai-privacy-regulations-2023-11-17/

41 Independent (2023) | ChatGPT 'grandma exploit' gives users free keys for Windows 11 https://www.yahoo.com/tech/chatgpt-grandma-exploit-gives-users-134605784.html

This allows decision-makers to address potential issues before they escalate, improving the accuracy and timeliness of regulatory interventions.

Technological innovations such as quantum computing and advanced neural networks promise to expand the analytical capabilities of AI systems to process and interpret complex regulatory data with greater sophistication. Quantum computing, for example, may handle large-scale computations at unprecedented speeds, facilitating more detailed and comprehensive assessments.[42] Advanced neural networks can learn from more diverse and complex datasets, providing nuanced insights that were previously unattainable. In parallel, theoretical advancements in AI ethics and governance are informing the development of frameworks that guide these technologies to operate within accepted societal values and legal standards. As these technologies and frameworks develop, they will contribute to the emergence of more effective, efficient, and equitable AI-driven regulatory tools..

5 – PILOTS OF AI INNOVATIONS IN ADGM (JOINT WORK WITH NUS AIDF)

ADGM and NUS AIDF share a common objective in addressing the risks and regulatory challenges in the rapidly evolving fields of Web3. In pursuit of this goal, collaborative pilot projects were launched in 2022 to study AI technologies that have the potential to improve security auditing processes for blockchain applications and VAs[43]. These pilots utilised innovative AI technologies to analyse audit logs and review historical security breaches to detect patterns and provide insights into potential vulnerabilities.

This section presents three pilots showcasing AI's potential to advance regulatory assessments of VA and the organisations that offer VA services.

5.1 Pilot 1: Smart Contract Suitability Assessment with AI

5.1.1 Introduction

Smart contracts are fundamental components of blockchain technology, offering secure automation of agreements and transactions on decentralised platforms. Given their importance in blockchain applications, it is essential to conduct thorough assessments and validations of their codebase to ensure they function as intended and meet regulatory standards[44]. This section introduces the first pilot project: an AI-enabled Smart Contract Suitability Assessment platform.

5.1.2 Existing Solutions and Providers

The current landscape of smart contract validation incorporates both manual assessments and advanced technological tools designed to probe smart contracts for potential vulnerabilities and improve their efficiency. Leading service providers such as Certik, Trail of Bits, Halborn, and Hacken utilize a variety of methodologies including static and dynamic analysis, as well as human-led formal verification processes, to evaluate and secure smart contracts against cyber-attacks and performance issues.

As Web3 technologies evolve in regulated sectors, there is a need for an expanded approach to smart contract validation. Beyond technical vulnerabilities, smart contract audits should include compliance to

42 Herman, D., Googin, C., Liu, X. et al. Quantum computing for finance. Nat Rev Phys 5, 450–465 (2023). https://doi.org/10.1038/s42254-023-00603-1
43 ADGM (2022) | ADGM Academy signs MoU with National University of Singapore to promote collaboration in fintech education, research, and entrepreneurship https://www.adgm.com/media/announcements/adgm-academy-signs-mou-with-singapore-university-for-fintech-education-research-and-entrepreneurship
44 FSB (2023) | The Financial Stability Risks of Decentralised Finance https://www.fsb.org/uploads/P160223.pdf

regulatory requirements where the smart contracts are utilised to automate regulated activities.

5.1.3 AI-Driven Assessment

The Smart Contract Suitability Assessment pilot integrates two approaches to analyse the relationship between smart contract code and VA whitepapers.

LLM-Based Validator Method. The LLM-Based Validator uses proprietary AI models to analyse the alignment between smart contract code and its corresponding VA whitepaper. The training data preparation begins with extracting clauses and standards from an extensive database of widely used smart contract codes. These elements are categorized based on different project types, forming a knowledge base for targeted analysis.

An LLM model is then used to extract evidence from both the smart contract code being assessed and its associated whitepaper. This checks that the objectives outlined in the whitepaper are implemented within the code. The model employs a question-and-answer (Q&A) approach to verify each element and interrogate the whitepaper's content in relation to the smart contract codebase.

This model also performs widely accepted technical checks to identify potential vulnerabilities, such as static code analysis. It also checks whether the implementation details adhere to industry practices and comply with relevant standards by comparing the code snippets with widely accepted implementations. This verification process ensures that the smart contract is executed as intended and meets operational and compliance standards set out in the whitepaper.

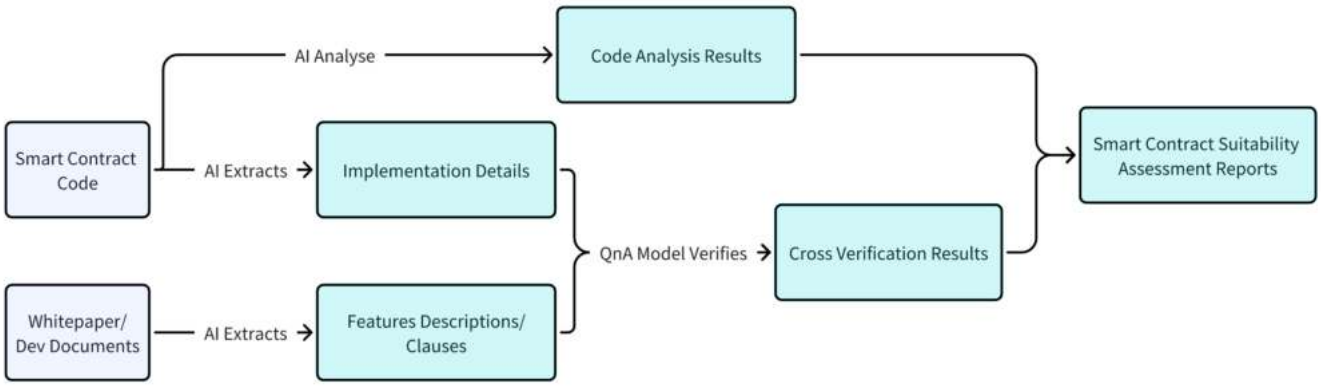

Figure 1 AI-Driven Smart Contract Suitability Assessment Using Q&A Models.

Code Generation Method. This approach uses AI to generate code snippets derived from the objectives and functions outlined in the VA whitepaper, e.g., launching a token with 100 million maximum circulations. The generated code snippets are then compared against the original smart contract code. This is done by running both the original and the AI-generated code with the same input values to compare their outputs. The goal is to ensure that, despite differences in code structure or style, the functional outcomes are consistent. Matching outputs confirm that the original code executes according to the whitepaper's specifications. Any variance in outputs triggers a closer examination of the code to find the source of inconsistency, which could lead to further adjustments or a detailed re-evaluation of the smart contract code. Optionally, an additional test can be performed by a straightforward test between the AI-generated code and the original smart contract code

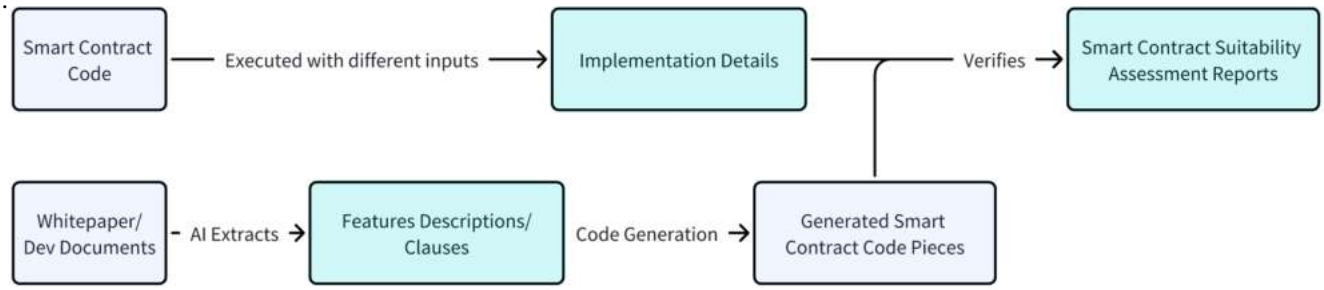

Figure 2 Utilizing AI and Code Generation for Smart Contract Validations.

Together, these two methods provide a validation framework that assesses smart contract implementation, highlights errors and omissions, and ensures smart contracts operate as intended and advertised. Such insights are a valuable input to regulators in confirming that a project's representations can be objectively corroborated.

5.2 Pilot 2: Audit Report Assessment

5.2.1 Introduction

To ensure a business logic launched by smart contract is safe and secure, security audit firms are usually hired to assess the code and release a security audit report publicly. However, reviewing the content of such reports may require computer science and security expertise which regulators may not have. To address this knowledge gap, we tested an evaluation framework using LLMs to assess the adequacy of such security audit reports.

5.2.2 Existing Solutions and Providers

Conventionally, currently since this is the practice, security audit reports have relied on both automated tools manual assessments and expert analysis, resulting in time-consuming processes and subjective evaluations. These methods typically involve auditors examining codebases, configurations, and operational procedures to identify vulnerabilities and weaknesses. The manual nature of these assessments means the process can be labour-intensive. Additionally, the reliance on human expertise introduces the potential for human error and a degree of subjectivity, as different auditors may interpret findings and risks differently.

The growing complexity and scale of Web3 projects pose an increasing challenge to the way that audits are conducted today. With the rapid pace of development, its open-source nature and the growing number of decentralized applications, auditors are often under pressure to deliver timely reports, which can compromise the depth of their analyses. Security audits typically provide only a snapshot in time, potentially overlooking evolving threats and vulnerabilities that emerge post-audit.

Another notable challenge with existing audit reports is the technical complexity. These reports are often highly detailed and technical, making it challenging for the public, including regulators, to understand and interpret all the findings.

5.2.3 AI-Assisted Evaluation of Security Audit Reports

The assessment tool uses AI to evaluate the quality of audit reports. The pilot prepared the necessary data for evaluation by using OCR (optical character recognition) and tailored information retrieval techniques to collect and organize relevant data, including metrics such as the audit scope, assessment methodologies, tools used by the auditor, and issue descriptions in the audit report.

Next, we utilise an off-the-shelf LLM model to process the report to generate embeddings, which are illustrated as vectors in Figure 3. This involves advanced NLP techniques, such as using tailored NLP libraries for entity recognition and dependency parsing, to understand and categorize the content of the audit report.

Following data processing, the tool uses the stored vectors to evaluate the report against predefined knowledge sets (shown as database in the following diagrams). These knowledge sets cover five specific categories: (1) content quality and scope, (2) vulnerability identification and prioritisation, (3) mitigation strategies and report impact, (4) presentation and auditing methodology, and (5) report relevance and accessibility. The evaluation process is both fast and thorough, typically taking about five minutes per report.

Finally, we utilise the LLM model again to generate an evaluation report. The report contains a weighted score obtained by summing up the detailed evaluations in each category mentioned above. This score reflects the overall performance of the security audit report, identifying areas of strength and areas that need improvement. The report also contains the detailed explanation of the strength and concerns by the LLM model based on the interpretation of intermediate assessment results for each category.

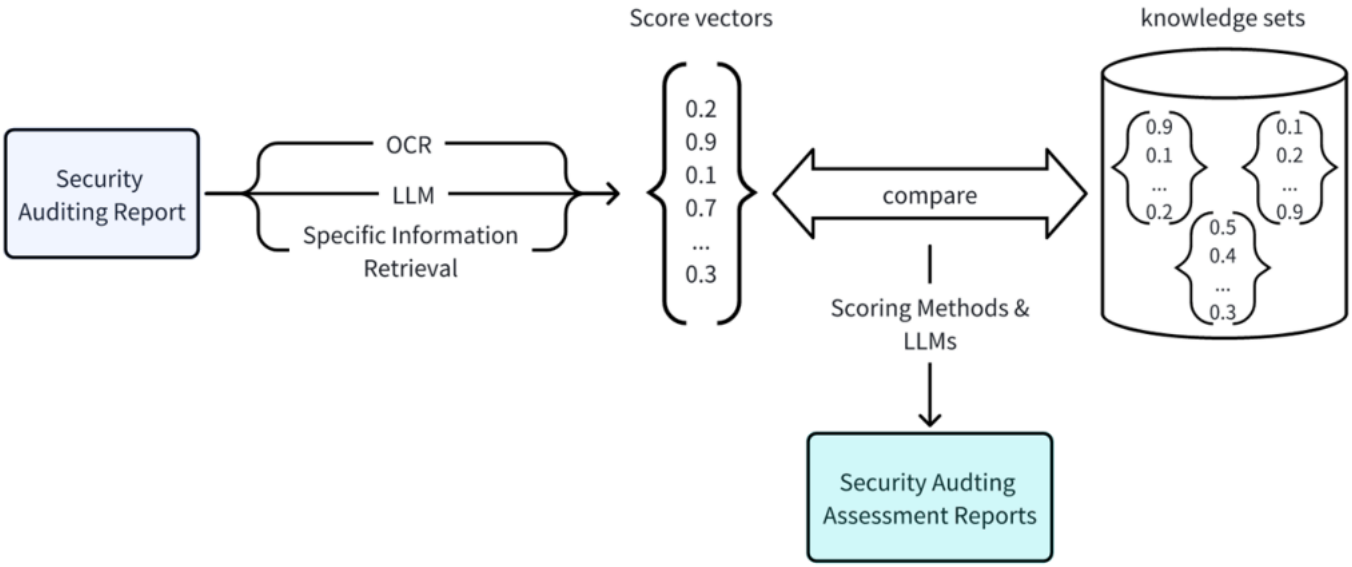

Figure 3 AI-Based Security Auditing Report Assessment.

This tool can assist regulators in making informed decisions on the adequacy of audit reports submitted by Web3 companies.

5.3 Pilot 3: Smart Due Diligence with AI

5.3.1 Introduction

The performance of initial and ongoing due diligence on Web3 projects is important for regulators during the licensing process and supervisory monitoring. In addition, VASPs acting as VA intermediaries are also responsible for performing their own due diligence on the blockchain projects and their tokens prior to offering VAs to their clients.

Performing due diligence activities for Web3 presents unique challenges due to the decentralized nature of blockchain technology, pseudonymous identities, and novel organizational structures. Identifying and

verifying real identities, understanding complex technological infrastructures, and navigating diverse structures and evolving legal frameworks complicate the process. However, the publicly accessible data in the Web3 space can be used to gain assurance over Web3 activities. On-chain data offers real-time, verifiable insights into transactions and smart contract operations, while off-chain qualitative information, such as team credentials, market sentiment, and discussions in forums, DAO boards, and official social media channels add depth to evaluations.

While publicly available, ingesting such voluminous and technical data can be challenging as it requires sophisticated tools and methods to process and analyse the information effectively. The use of AI technologies can streamline the due diligence process and enable regulators and VASPs to efficiently review and assess Web3 projects.

5.3.2 Existing Solutions and Providers

Numerous service providers have emerged to address the challenges of complex data analysis and conducting due diligence in the Web3 and VA sector. These companies offer tools and services that can streamline compliance processes, verify identities, and manage certain regulatory requirements across different jurisdictions. For example, Chainalysis and Elliptic provide blockchain analytics tools that help trace cryptocurrency transactions back to their source, aiding in AML efforts and compliance with combating the financing of terrorism (CFT) regulations. Other companies offer digital identity verification solutions that attempt to identify users even in a decentralized environment.

While these tools are useful in specific areas, they do not fully cover the extensive range of oversight that regulators and VASPs require. The pilot project aims to further improve the overall due diligence process for regulators and VASPs.

5.3.3 AI-Assisted Due Diligence

The pilot employs AI technologies to improve the due diligence processes for Web3 regulators and VASPs in several innovative ways.

Generative AI in Supporting Company Onboarding. Generative AI is used to customise the process of onboarding Web3 companies and projects during license application to a regulator. The pilot project developed a model that generated customized forms and listed documentation requirements based on a Web3 project's focus area. Such customisation of the application process reduces the need for license applicants to undergo a generic process that may typically include submissions not applicable to its specific nature of business.

Generative AI Reviewing Social Media. The pilot project includes the use of AI tools that can monitor and analyse the social media presence of companies and their principals. This involves scanning for inconsistent public disclosures, reputational risks, and signs of misleading or fraudulent claims. The AI models we use process the context and sentiment of social media content and output potential concerns for regulators' reference.Generative AI Reviewing Social Media. The pilot project includes the use of AI tools that can monitor and analyse the social media presence of companies and their principals. This involves scanning for inconsistent public disclosures, reputational risks, and signs of misleading or fraudulent claims. The AI models we use process the context and sentiment of social media content and output potential concerns for regulators' reference.

Q&A Agent for Regulatory Queries. This Q&A agent enables regulators to interrogate a Web3 project data, including self-provided documentation, smart contract details, official communications, and disclosures. The

agent provided digestible insights for non-technical staff on demand and with the latest data available at the time of query. Each response is categorized and sourced, with links to original data.

The system continuously updates as new data becomes available and is designed to allow regulators to integrate additional data sources.

This pilot is efficient and effective in replacing human efforts in repeated and redundant work, utilizing AI during firm onboarding, risk detection, and real-time regulatory insights. With many regulators actively exploring such innovations, this project holds significant potential for broader deployment and further development.

6 – CONCLUSION AND FUTURE WORK

6.1 Conclusion

The fast-paced evolution of Web3 and VA activities is paving the way for exciting innovations but brings new and complex regulatory challenges. The integration of AI into regulatory processes offers promising outcomes that enhance the toolkits of regulators to monitor, predict, and mitigate risks arising in Web3 and VA activities.

The pilot projects introduced in this paper provide practical examples of AI's application in this space, offering real-world examples of its role in improving compliance practices in the Web3 industry.

6.2 Key Takeaways

Transformative Potential of AI in Web3 SupTech and RegTech:

- AI-driven solutions can significantly enhance regulatory oversight in Web3 by providing real-time risk analysis, proactive vulnerability detection, and more efficient compliance monitoring.
- Utilizing a range of AI technologies—such as machine learning, NLP, generative AI, and autonomous agents—regulators can better maintain oversight, streamline reporting processes, detect anomalies, and understand sentiment in decentralized ecosystems.
- Integrating AI into Web3 regulation can simplify cross-jurisdictional complexities, adapt to around-the-clock operations, and make compliance frameworks more accessible, flexible, and innovative.

Challenges to AI Implementation:

- Ethical and privacy concerns, bias in AI models, and the need for transparency and traceability are critical issues.
- Human oversight is necessary to mitigate over-reliance on AI and ensure the reliability of its applications.

Practical Applications Demonstrated in Pilots:

- AI-enhanced smart contract assessments ensure alignment with whitepapers and regulatory standards.
- Automated evaluations of audit reports and due diligence processes significantly improve efficiency.
- Generative AI tools assist in onboarding processes, social media analysis, and providing useful insights to regulators in an efficient approach.

Future Directions:

- Advancements in predictive analytics, adaptive AI systems, and global collaboration will drive more effective regulatory practices.
- Establishing AI governance frameworks and ethical standards will be key to maintaining trust and accountability.

6.3 Future Work

As we look to the future, several key areas will drive the continued evolution and integration of AI in regulatory processes:

Advanced AI Models. As AI technologies advance, they are likely to offer better capabilities and outcomes at potentially lower cost and processing resource utilisation.

Enhanced Predictive Analytics. Future advancements in predictive analytics will enable even more precise forecasting of risks and compliance breaches. With access to larger and specialised datasets, along with the development of more sophisticated algorithms, AI systems could anticipate potential issues before they arise, allowing for proactive early intervention.

Advanced AI Governance and Ethics. Establishing AI governance frameworks will be necessary for regulatory AI applications to remain ethical, transparent, and free from bias. Creating standards and guidelines for AI ethics will help build trust and accountability in AI-driven regulatory systems.

Adaptive and Explainable AI. Future AI systems are likely to be adaptive, learning and evolving with changing regulatory landscapes and Web3 activities. Improvements in the explainability of AI algorithms and decisions will make regulatory decisions more transparent and understandable to those affected by its decisions.

Global Collaboration. Establishing and sharing best practices across jurisdictions will facilitate more coherent and effective regulation of the global Web3 ecosystem.

ACKNOWLEDGMENTS

This whitepaper was developed through collaboration between ADGM FSRA, ADGM Registration Authority, ADGM Academy Research Centre, NUS AIDF, and Mooncheck.

Abu Dhabi Global Market (ADGM)

ADGM[45] is an international financial centre that brings unique value to the emerging economy of Abu Dhabi and the broader region. Established in 2015, ADGM has significantly enhanced Abu Dhabi's stature as a leading financial centre and business hub, bolstering its role as a key player in the Falcon Economy. It serves as a vital strategic link between the growing economies of the Middle East, Africa, South Asia, and global markets.

Financial Services Regulatory Authority (FSRA)

The FSRA[46] was established to advocate a progressive financial services environment and uphold the integrity of the whole international financial centre by managing any potential risk exposure and undesirable impacts. The regulatory framework of the FSRA, the regulations and rules of which are modelled on internationally recognised standards and best practices, ensure that financial entities operate in ADGM with certainty and do so on a level-playing field, and that the best interests of customers, clients and investors are safeguarded. The FSRA has an open and progressive approach in the maintenance and development of its regulatory framework, looking towards the international standard-setting bodies and responding to market innovations, and undertaking meaningful stakeholder engagement through public consultations, when considering amendments to its regulatory framework.

Registration Authority

The ADGM Registration Authority[47] is responsible for the registration, incorporation and licensing of legal entities in ADGM and supports with all government-related services. Providing a range of activities to facilitate market entry, growth and the emergence of a vibrant and sustainable business community, the Authority guides and supports companies through the application and set-up of ADGM-registered entities.

ADGM Academy Research Centre

The ADGM Academy Research Centre[48] The ADGM Academy Research Centre brings together an ecosystem of academics, financial industry practitioners, government and technology experts to unlock the shared potential to improve the financial environment in MENA and beyond. The financial industry continues to transform at a rapid pace with new technologies, disruptors, threats and opportunities appearing all the time. Independent research is crucial to be able to understand and utilise this transformation for the benefit of your business, your customers and society in general. The Research Centre provides that understanding through insights developed in collaboration with the academic community.

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NUS AIDF

The Asian Institute of Digital Finance[49] is a university-level institute within The National University of Singapore, co-founded by the Monetary Authority of Singapore, the National Research Foundation, and NUS. The institute aims to be a leader in FinTech thought leadership, a hub of knowledge, and a platform for experimenting with digital financial technologies, all while nurturing both current and future FinTech professionals.

Mooncheck

Mooncheck[50] is a deep-tech startup that builds an AI-powered platform advancing transparency and accountability in digital asset markets. Combining AI expertise with blockchain domain knowledge, the platform provides accurate, validated, and user-friendly data insights, helping crypto projects navigate regulatory standards while delivering clear, reliable information to all stakeholders.

49 https://www.aidf.nus.edu.sg/
50 https://www.mooncheck.com/

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Level 20, Al Maqam Tower, ADGM Square, Al Maryah Island, PO Box 111999 Abu Dhabi, UAE
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T +971 2 333 8500 adgmacademy.com