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Digital Finance – Global

Convergence of AI and blockchain could recode multiple industries

Summary

Artificial intelligence (AI)[1] and distributed ledger technology (DLT), of which blockchain is the best known example,[2] are each transformational technologies, and in combination they can bring about even greater change. AI has taken a leap forward with the introduction of large language models (LLMs),[3] which users can query without needing computer code, although their underlying data is typically not accessible. Because blockchains transparently record data in a way that cannot later be modified, LLMs could use them to make their underlying data sets public and secure. Meanwhile, AI's powerful pattern recognition capabilities could help spot cyber threats to blockchains early, and AI could also improve smart contract[4] automation. These are only a few use cases for combined AI and blockchain, a convergence that could reshape many sectors and activities, from supply chain management to digital finance markets. Together, the two technologies also form the future state of the internet, a decentralized, more user-controlled environment called Web3.[5]

AI and blockchain, linked by data, can be mutually beneficial when combined. Data is a vital link between AI and blockchain. Both technologies rely on vast data sets, and in combination, each technology enhances the strengths and mitigates the weaknesses of the other. AI can help address limitations of smart contracts – self-executing agreements coded into a blockchain – including potential coding errors or security flaws. Blockchain, in turn, can improve AI's data integrity and transparency. The combination of AI and blockchain is already being tested in sectors and activities ranging from supply chain tracking to medical record storage and management to trading within decentralized finance.

Risks arise from combination of AI and blockchain: The numerous risks that stem from the two technologies' convergence can be grouped into six categories: data-related risks, including safeguarding privacy, data accuracy and data protection; regulatory risks, operational risks, technology risks, governance risks and social risks, such as job losses arising from automation.

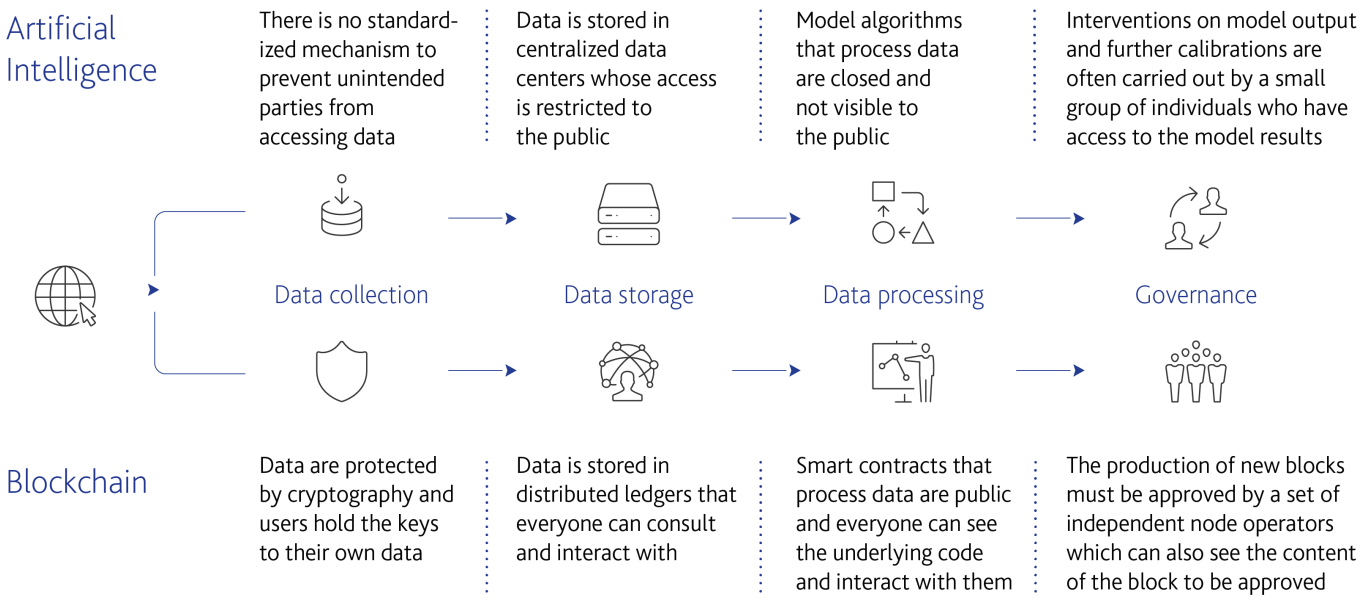
Convergence of AI and DLT could foster new solutions for regulation: Regulating each of these transformative technologies on its own is difficult, because responsibility for undesired outcomes is either opaque (AI) or decentralized, with no single entity to hold accountable (blockchain). Together, though, the technologies could yield regulatory and enforcement solutions. The development of Decentralized Digital Identity (DID) based on distributed ledger networks, for example, could give AI an immutable trail that increases transparency.

AI and blockchain, linked by data, can be mutually beneficial when combined

Although AI and blockchain may appear fundamentally different, a vital link between them exists – data. Both technologies rely on and are designed to harness vast data sets. AI is an active technology,[6] analyzing its surroundings and generating solutions based on historical exposure to large amounts of centrally stored data. In contrast, blockchain operates passively,[7] recording data entered by its decentralized user base.

The combination of both technologies enhances the strengths and mitigates the weaknesses of each (Exhibit 1, below). Blockchain has data protection and a system for distribution that AI lacks. AI has high-speed data analytic capabilities that blockchain does not.

Exhibit 1
AI and blockchain: complementary technologies



Source: Moody's Investors Service

Together, AI and blockchain can help remove obstacles encountered by each technology on its own. Smart contracts, for example, are self-executing agreements coded onto a blockchain, and have the potential to automate and simplify transactions. However, they have several limitations, including the potential for coding errors and security flaws, difficulties with legal enforcement across jurisdictions, and a lack of flexibility after deployment. Complexity and data limitations associated with smart contracts can also be significant barriers to expanding their use.

AI can make smart contracts safer and more effective

AI can remedy some of these problems. AI-driven tools can significantly strengthen smart contracts' cybersecurity by pinpointing specific weaknesses in their underlying code. By analyzing legal texts, AI can help verify that smart contracts' terms and operations comply with relevant laws. Machine learning algorithms could make smart contracts, normally considered unalterable once deployed, more adaptable to changing circumstances after the contracts have already been launched. However, unlocking this potential benefit would require resolving difficulties that could arise because machine learning, which is based on statistical methods, does not always produce the same output for a given input; such unpredictability could run counter to blockchain nodes' need for consensus to ensure a transaction's validity. AI can also improve the data quality that is fed into a smart contract, ensuring that the contract functions as intended.

Exhibit 2

AI can improve smart contract functionality and security

Smart contract weaknesses

- Coding errors and security
- Legal enforcement
- Lack of flexibility
- Complexity and cost
- Reliance on oracles

Potential solutions provided by AI

- Improve code quality and security by analyzing code for loopholes or vulnerabilities
- Creating more adaptable smart contracts that can adjust to changing circumstances
- Automating the writing and deployment process, reducing complexity and cost
- Analyzing and cleaning data before feeding it into the smart contract to ensure accuracy

Source: Moody's Investors Service

The convergence of AI and blockchain holds transformative potential for multiple industries

The combination of AI and blockchain is already being tested, and has the potential to be transformative across many different businesses and activities. The exhibit below shows a few examples of partnerships and projects that are combining both technologies, from supply chain tracking to medical record storage and management to trading within decentralized finance (DeFi)[8] platforms.

Exhibit 3

Multiple industries and companies are combining AI and blockchain, to explore diverse concepts

Most are in the pilot phase, while some are already operational

Supply Chain	World Food Programme (WFP): Testing AI to predict where and when food shortages are likely to occur and using blockchain to track distribution of food aid in real time	Nestle: Partnered with OpenSC which uses blockchain and AI to enable supply chain tracking, immutable real-time transactions, and better visibility into the supply structure	Walmart China: Partnered with VeChain to monitor temperature-controlled products while still in transit, which will help reduce the risk of spoilage and contamination and promotes food safety	Provenance: UK-based company uses blockchain and AI to trace products like seafood and fresh produce
Health-care	Merative*: Working on projects related to secure sharing of patient data via blockchain and AI-driven diagnostics **previously IBM Watson Health*	MediBloc: Blockchain-based healthcare data platform empowering patients to take control of their medical records and provide enhanced healthcare outcomes with AI-driven insights	MedicalChain: Securely store patient data on the blockchain and enable AI-driven diagnostics and treatment recommendations	Hu-manity.co: Offers a blockchain-based app that allows individuals to own, manage and share the healthcare data with AI systems and researchers
DeFi	MakerDAO: Exploring ways to launch several AI tools to optimize governance tasks such as monitoring and data siloing	Spectral: Developed a platform that powers inference feeds for smart contracts built by independent machine learning modelers	NumerAI: Decentralized hedge fund where users can develop their AI models and earn NMR, the Numerai native token as reward	Hera: Decentralized exchange aggregator that allows traders to find the best route for swaps with an AI-powered algorithm
Other	SingularityNET: Decentralized AI marketplace, providing unrestricted access to AI creations for individuals and enterprises worldwide	Matrix AI Network: First AI-optimized blockchain network whose upcoming version is envisioned as a general-purpose decentralized platform	DeepBrain Chain: First AI computing platform powered by blockchain	Fetch.ai: Leverages AI and blockchain to automate web transactions through autonomous agents to negotiate deals based on preset parameters, enhancing efficiency and transparency

Source: Moody's Investors Service

Blockchain can improve AI's data security, transparency and operational efficiency

If AI can strengthen blockchain's cybersecurity, blockchain, through its immutable nature, can also help maintain the integrity of AI's stored data. Storing AI models on distributed ledgers, for example, creates an audit trail. And of course, distributed ledgers are by definition a rich source of data sets for AI, and could enable data management and model distribution.

However, there are limits to the benefits blockchain can offer in storing data for AI applications. The training sets of LLMs are typically massive, exceeding the storage capacity of blockchain-based solutions. Furthermore, delays that can occur in accessing or retrieving data stored on a blockchain could hinder the training process of LLMs. As a result, although open-source LLMs might use blockchain-based solutions, tech companies spearheading cutting-edge LLMs may show less inclination to adopt them, given these practical constraints.

Exhibit 4
AI can be integrated with DLT in three layers

LEVEL 01
Transaction layer

Artificial Intelligence (AI) agents can engage in transactions, exchanging data and/or tokens as payment. This creates a network where tokens encourage data sharing

LEVEL 02
Smart contract layer

The current smart contract infrastructure is being upgraded with AI tools. These instruments enhance the conditions that determine the execution of the smart contracts, making them more robust and secure

LEVEL 03
Data storage layer

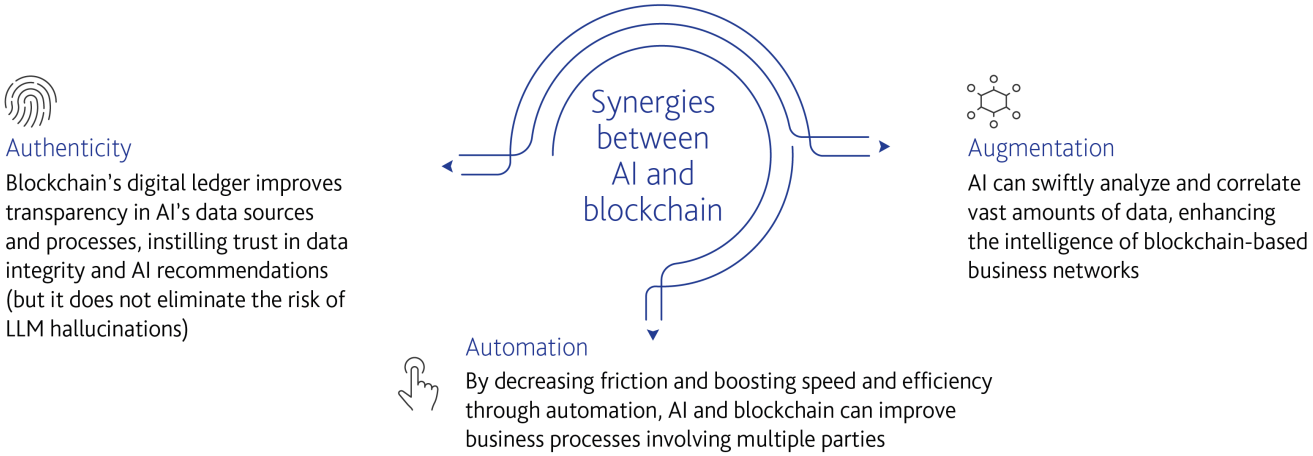
Artificial Intelligence (AI) models are developed and fine-tuned using decentralized distributed ledgers, a method that enhances the security of data storage. This type of ledger also reduces costs associated with data storage and allows for greater programmability

Source: Moody's Investors Service

Meanwhile, decentralized platforms built on distributed ledgers such as blockchain could help AI manage computationally intensive tasks such as model training.[9] Conventional cloud-based solutions, which are centralized, often bring high expenses, when not appropriately managed, and potential risks to data privacy. Decentralized network technologies provide a remedy by enabling distributed computing, which can be implemented on top of cloud infrastructure or even integrated into a decentralized cloud model, blending the characteristics of both paradigms. This not only cuts costs but also bolsters privacy and taps into globally underused computational resources. Emerging companies are now constructing decentralized infrastructures that aggregate processing resources – both graphics processing units (GPUs)[10] and central processing units (CPUs)[11] – providing them to organizations in need of AI model training (Exhibit 5).

Exhibit 5

AI and blockchain will have mutual benefits in several broad areas



Source: IBM, Moody's Investors Service

Blockchain could enable secure financial transactions for future autonomous AI agents

There are also ongoing efforts to create AI agents that will be capable of independent action, without a need for continuous human intervention. It will likely be many years before such autonomous AI agents become reality. But if and when they do, the concept is fairly straightforward: a human user could simply assign a task to their AI agent, and the agent would carry out the necessary steps to complete it. To illustrate, a user might instruct their AI agent to buy a ticket on the cheapest direct flight to a specified destination. The agent would then conduct a comprehensive survey of various airlines, identify the most cost-effective option, and place a booking for the user.

However, this scenario presents a significant challenge: the question of how the AI agent would pay for the flight. The initial payment method that might be considered is the use of credit or debit cards, given their ubiquitous role in daily transactions. AI model developers could store this sensitive information.

Alternately, for additional security, an AI agent could be designed with its own unique blockchain wallet,[12] accessible solely by the agent itself. Concurrently, a multi-signature smart contract wallet could be established. This would require the deposit of funds into the multi-signature wallet, and the approval of both the individual and the AI for any transaction to be executed. Should the AI fail to perform as instructed, the potential financial damage would be limited to the funds in the multi-signature wallet. In addition to being more secure, this last approach would also absolve the AI's developers of legal liability, because they would not be holding any funds on behalf of the individual, akin to the operational model of payment services like Google Pay.

Blockchain and AI together could help usher in AI's next phase: artificial general intelligence

Even beyond autonomous agents, artificial intelligence could further advance to what is called artificial general intelligence, or AGI. AGI, still at the conceptual phase, aims to move AI from its current level of proficiency, in which the technology can be used to execute specific tasks, to a state in which it can solve problems independently. AGI can be described in a sense as having the capacities of a highly advanced autonomous agent, yet not all autonomous agents will attain AGI-level proficiency.

Unlike GenAI, which operates based on predefined input-output sequences, AGI's goal is to emulate human thought processes, encompassing learning, reasoning, comparison, and inference. GenAI is not necessarily a direct precursor to AGI; each inhabits distinct domains on the AI spectrum. However, GenAI has known benefits and risks, while AGI will forge a path into uncharted territory. Technological advancement aside – and the hurdles to clear on this front are formidable, which is why AGI remains a distant goal – the realization of AGI involves profound ethical considerations and would require responsible development to align the technology with human values. Questions pertaining to transparency, accountability, and effects on the workforce loom large in discussions about AGI.

The integration of blockchain with machine learning techniques, augmented by retrieval augmented generation (RAG) – a natural language processing approach that combines the ability to find relevant information with the skill to create more humanlike responses – could offer a transformative way to advance toward AGI. The combination of blockchain, machine learning and RAG holds significant potential for facilitating collaborative learning, ensuring data integrity, and fostering development of AGI by enabling secure, decentralized training and deployment of advanced AI models and agents. However, the realization of such an integration is contingent on various technological and ethical factors.[13] This synergy could also bring about heightened security and governance within blockchain systems.

Numerous risks arise from the convergence of AI and blockchain

Along with many positives, the integration of AI with blockchain brings numerous risks that can be grouped into six categories: Data-related risks, regulatory risks, operational risks, technology risks, governance risks and social risks.

Data-related and security risks are central, because both AI and blockchain are highly dependent on data. Privacy and data protection become vulnerable given AI's need for vast data access, which can inadvertently expose sensitive information. In addition to risks to data security, there are broader platform-level cybersecurity risks that would be significant in any endeavor combining the two technologies. Additionally, the quality of data is pivotal for both technologies, and any inaccuracy or bias in the data could lead to erroneous decisions or perpetuated inequalities. The issue of overfitting in AI, where models trained on specific distributed ledger data perform poorly on other data sets, also falls within this category.

There is also a potential to magnify errors through a feedback loop; although blockchain offers immutability and security of data, any errors recorded on it are permanently stored, and if faulty data is employed as an input for machine learning models, the AI algorithms may learn from and perpetuate these errors.

Lack of comprehensive regulation is another hurdle faced by emerging technologies, and will likely slow the convergence of AI and blockchain, because differences in rules across jurisdictions and the complex nature of legal liability pose financial and compliance risks to businesses operating at the intersection of the two sectors. Current legal frameworks struggle to keep pace with technological advancements, emphasizing the need for a harmonized regulatory approach to ensure a secure environment for sustainable growth.

Operational risks encompass a diverse set of concerns, including scalability issues that may be exacerbated by AI's extensive data needs, and interoperability challenges. Furthermore, the risk of centralization can introduce single points of failure and compromise the system's resilience.

Technology risks relate to potential flaws in software or system architecture. Errors in coding, implementation, or design can lead to faulty AI predictions, blockchain security vulnerabilities, or even systemic failures. Ensuring robust, well-tested code and system designs is crucial to mitigate these risks.

Governance risks involve the decision-making processes in the operation and evolution of a given system. Decisions about data usage, system updates, or responses to security incidents, if not handled correctly, can lead to misuse of data, system stagnation, or inadequate responses to threats. Transparent and accountable governance structures are essential to manage these risks.

Social risks include risks such as potential job losses that might result from automation. Should AI and blockchain converge, with their combined potential to accelerate and magnify automation by enabling more efficient and streamlined operations, the risk of job losses could be higher than if AI and blockchain remained on separate paths. Moreover, security and operational risks associated with the convergence of AI and blockchain could pose data privacy risks to individuals. Managing these risks is crucial for ensuring the responsible and equitable development of AI and blockchain technologies.

Together, these risks highlight the need to balance the interests of multiple stakeholders when leveraging the powerful combination of AI and blockchain, and to implement such a combination responsibly.

Convergence of AI and blockchain could foster new solutions for regulation

From a regulatory standpoint, AI and blockchain pose a very similar challenge to regulators, in that both technologies challenge the very notion of accountability. In the realm of AI, it can be difficult to trace inputs and outputs generated by the algorithms, and the decision-making process of AI models is often opaque and inaccessible, obscuring the lines of responsibility when an AI system's actions lead to undesired outcomes. It is also not always possible to be certain whether a specific output has been produced by an AI agent or a human. Regulatory frameworks are meant to address the accountability dilemma, and regulators are trying to develop appropriate rules for the supervision of AI applications. For instance, in the EU, the AI Act proposed to subject certain AI systems such as foundational models to strict governance rules to minimize data traceability issues and associated risks, although tech and legal experts have expressed concerns about potential flaws in this regulatory approach.[14,15]

On 30 October 2023, President Biden issued an executive order[16] that aims to promote the safe, secure, and trustworthy development and use of AI. This comprehensive order represents a significant step in enhancing accountability in AI development and deployment across various sectors. As companies assess the impact of this order, they must consider not only their own AI usage but also the extent to which third-party vendors' AI capabilities are integrated into their products and services.

Decentralized finance (DeFi) protocols often raise accountability issues, but from another angle: in the absence of a (centralized) legal person or entity to be held accountable in case of malfunction, legal systems struggle to enforce rules. DeFi often therefore challenges legal and regulatory norms.

However, in that regard as well, the convergence of AI applications and digital finance could hold immense potential. The development of decentralized digital identity (DID)[17] based on distributed ledger networks could provide AI a robust and immutable trail that increases transparency and makes AI applications more trustworthy. In the context of interoperable and interconnected systems,

DID could enable a growing number of interactions among different platforms that allow AI to scale without compromising its transparency.

Endnotes

1 Artificial intelligence (AI) is a collection of technologies dedicated to creating systems capable of performing tasks that usually require human intelligence, such as understanding text or recognizing patterns.

2 Distributed ledger technology (DLT) is a collection of systems recording transactions in multiple places almost simultaneously. Blockchain is a type of DLT, that consists of a list of records, called blocks, that are securely linked together using cryptography.

3 A large language model (LLM) is a machine learning model capable of understanding and generating humanlike language, often trained on vast amounts of text data. Large language models have billions of parameters.

4 A smart contract is a program running automatically when certain predetermined conditions are met. They are used to automate the execution of an agreement without involving an intermediary.

5 Web3 refers to a new type of internet ecosystem built on blockchains, decentralization, and token-based economies. While AI is not inherently required for Web3, it could bring additional functionality and intelligence to Web3 applications.

6 AI actively engages with data, learns from it, and responds to its environment, making it a versatile and adaptive technology.

7 Blockchain operates passively by recording and securing data entered by its decentralized user base without the need for active central control.

8 Decentralized Finance (DeFi) is a segment of the crypto asset industry providing financial services through decentralized entities.

9 **For instance**: One can compare Ethereum's present computational abilities with the potential for future blockchain-based computational advancements. Ethereum faces limitations from factors like network congestion and scalability issues. Concerns also arise regarding potential centralization of computational capabilities, vital to preserve the decentralization nature of the blockchain to prevent the concentration of control in a few entities. Thus, while anticipating technological enhancements, it is vital to preserve blockchain's decentralized nature, striking a balance between innovation and decentralization.

10 Graphical processing unit (GPU) is a type of electronic circuit designed to accelerate the rendering and creation of images and videos. GPUs are also highly efficient at performing the calculations needed to train neural networks.

11 A central processing unit (CPU) is a key piece of a computer's hardware. It is the primary physical component that interprets and carries out the basic instructions, contained in software, that drive a computer.

12 Blockchain wallet is a software or hardware enabling users to store and use cryptocurrencies. A wallet acts as an interface to a blockchain, which records cryptocurrency ownership. A wallet can be custodial, meaning that a third party holds the wallet keys, or noncustodial, meaning that the user owns the keys.

13 Incorporating retrieval augmented generation (RAG) principles into LLM design has the potential to foster the development of more robust, ethical, and contextually-aware language technologies.

14 See: Demystifying the Draft EU Artificial Intelligence Act

15 See: The EU's AI Act could have a chilling effect on open source efforts, experts warn

16 See: Executive Order on the Safe, Secure, and Trustworthy Development and Use of Artificial Intelligence

17 Decentralized identity (DID) is an emerging system of digital identity management that, unlike other systems, enables individuals to own and control their digital credentials.

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