Blockchain: The Economic and Financial Institution for Autonomous AI?

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Abstract: This paper examines how the combination of Artificial Intelligence (AI) and Blockchain technology can enable autonomous AI agents to engage and execute economic and financial transactions. We critically examine the constraints of AI agents in achieving predefined objectives independently, especially due to their limited access to economic and financial institutions. We argue that AI's access to these institutions is vital in enhancing its capabilities to augment human productivity. Drawing on the theory of institutional economics, we propose that Blockchain provides a solution for creating digital economic and financial institutions, permitting AI to engage with these institutions through the management of private keys. This extends AI's capabilities to form and execute contracts, participate in marketplaces, and utilize financial services autonomously. The paper encourages further research on AI as a general-purpose technology and Blockchain as an institutional technology that can unlock the full capabilities of autonomous AI agents.

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Keywords: Artificial Intelligence (AI), Blockchain technology, Autonomous AI agents, economics and financial institutions.

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1. Introduction

Artificial intelligence (AI) is a general-purposed technology that has the ability to perform tasks traditionally carried out by humans (Crafts, 2021). One of the highly debated topics concerning AI in the economic and social context focuses on whether AI will replace or augment human capabilities. While some argue that AI has the potential to replace humans, others advocate for its integration as a complement to human intelligence.

In an economy where data is reshaping how companies generate value and AI is transforming how companies operate, there is a growing belief that organizations will gradually replace human employees with intelligent machines (De Cremer & Kasparov, 2021). AI has demonstrated the potential to undertake tasks previously limited to human cognition, leading some to advocate for autonomous systems that can mimic or even replace human cognitive functions. However, cautionary voices have also emerged. Eminent physicist Stephen Hawking has expressed concerns, cautioning that the development of fully artificial intelligence could pose a threat to the existence of humanity and has shared his fear that AI may eventually replace human entirely (Kumar & Choudhury, 2022). Similarly, technology magnate Bill Gates has sounded the alarm, stressing that humans should be legitimately concerned about the potential risks associated with artificial intelligence (Rawlinson, 2015). In a noteworthy event on May 2, 2023, an attention-grabbing letter appeared in The Guardian, signed by Elon Musk and numerous individuals, sparking controversy. The letter called for a pause in artificial intelligence research and raised concerns about the development of AI systems, such as GPT-4, that possess human-like capabilities (Paul, 2023).

On the other hand, there is an alternative perspective that proposes the use of AI not as a replacement for human intelligence, but as a means of augmenting it. This school of thought, known as IA, focuses on leveraging technology to enhance and support human cognition, with humans remaining central to the human-computer interaction (Hassani et al., 2020). While AI operates based on the available data, humans possess a distinct form of intelligence that encompasses imagination, anticipation, emotions, and the ability to make judgments in dynamic situations. Augmented intelligence represents a significant advancement toward the future of intelligence work, where humans and technology collaborate to achieve greater outcomes.

These different viewpoints reflect the complexity and ongoing evolution of the AI debate in the economic and social context, highlighting the necessity for continued exploration and discourse regarding its future trajectory. Particularly, the adoption and development of AI and its interaction with other disruptive digital technologies, such as, Blockchain require special attention, as the potential disruption induced by the combination of those digital technologies could significantly affect the trajectory of social and economic development worldwide.

This article explores the constraints of AI agents in independently accomplishing predefined goals. Even though AI agents are capable of performing researching, analyzing tasks and making decisions, their abilities to actually execute the decisions to achieve given objectives is hindered by the inability of AI agents to use economic and financial institutions, such as, contracts, agreements, financial services or marketplaces. The ability of human economic agents to

participate in the economy and generate economic value is greatly amplified by their access to high-quality economic institutions (Norton, 2003). Therefore, if AI agents can access economic and financial institutions, more autonomous AI agents can be deployed to augment human productivity. Conventional economic and financial structures are rooted in tangible aspects, encompassing laws and regulations, contracts and agreements, as well as the verification of human identities (Know Your Customer). The task of constructing interfaces that permit AI to engage with these traditional institutions poses technical challenges. Nevertheless, we propose that since Blockchain technology can be viewed as an institutional technology, it offers a foundation for creating digital-native economic and financial institutions. AI agents can, both theoretically and practically, interact with these Blockchain-based institutions through the management of private keys. This grants AI agents the ability to form and participate in contracts and agreements with other AI entities or humans via Blockchain-based smart contracts. Moreover, it empowers AI agents to utilize financial services, such as payments, decentralized exchange, decentralized financial services and other types of decentralized platforms.

There is a rapidly growing body of literature that investigates the convergence of AI and Blockchain technologies (Corea, 2018, 2019; Vikhyath et al., 2022) . Numerous studies on Blockchain and AI extensively explore how AI's inherent ability to process and learn from large volumes of data can substantially improve Blockchain systems' security and efficiency (Ekramifard et al., 2020; Khanh & Khang, 2021; Lonescu et al., 2023; Rjoub et al., 2023; Singh et al., 2020). The studies also discuss how the decentralized and transparent nature of Blockchain technology can offer a secure environment for AI, with the symbiotic relationship between the two promising innovation in various sectors (Charles et al., 2023; Gupta et al., 2023; Li & Xu, 2021; Rajawat et al., 2022) such as finance, healthcare, and supply chain management, contributing to secure transactions, data integrity, privacy, transparency, and traceability (Kumar et al., 2023; Rajagopal et al., 2022).

Despite the extensive literature on the individual benefits of AI and Blockchain and their interaction, to the best of our knowledge, our paper is the first to analyze Blockchain technology as an economic and financial institutional technology that can unlock the potential for autonomous AI agents. The current study aspires to motivate further research that perceives AI as a general-purposed technology capable of independently pursuing and executing assigned tasks. Additionally, we view Blockchain as an institutional technology that can unleash the capabilities of autonomous AI agents and their intersections.

In the context of this study, 'autonomous AI agents' are defined as advanced software systems that are capable of achieving specific objectives, such as executing contracts, forming agreements, utilizing financial services, and participating in marketplaces, with minimal to no human intervention. These agents are designed to interact with both human users and other software systems, and their autonomy is derived from their ability to make decisions, learn from their experiences, and adapt to new situations. Importantly, these AI agents are capable of engaging with economic and financial institutions autonomously.

The structure of this study is as follows: Section 2 explores the synergies between humans and AI, along with the delegation of tasks to AI. Section 3 highlights the constraints faced by autonomous AI agents, particularly their inability to access economic and financial institutions. Section 4 investigates how autonomous AI agents can utilize Blockchain-based economic and financial institutions, and outlines a model for human agents and autonomous AI agents to collaborate and interact with these Blockchain institutions. Finally, Section 5 provides a summary and delves into various aspects and implications of autonomous AI agents.

2. Collaborations between humans and AI

With the use of AI capability in decision making, analysis, communication, numerous literature strands have discussed about delegation of tasks to AI and the synergy between humans and AI, as well the collaboration of AI and humans.

2.1 Augmentation of human capabilities and human-AI collaborative decision-making

AI technologies serve as significant adjuncts to human capabilities, offering data analysis, intelligent insights, and decision support. By harnessing AI, humans can make decisions that are more well-informed and perform tasks with higher efficiency (Raisch & Krakowski, 2021). AI systems and humans can establish effective partnerships, particularly in the realm of decision-making. AI algorithms are capable of handling large volumes of data, discerning patterns and trends, and generating recommendations for human decision-makers. These humans can then evaluate the AI-generated suggestions, considering the context, and ultimately make decisions based on their expertise and judgment. Proponents of task delegation to AI argue for the potential benefits of human-AI collaboration. They believe that AI systems can augment human capabilities, allowing humans to concentrate on tasks that require higher-level skills such as critical thinking, problem-solving, and innovation. This synergy between humans and AI can pave the way for new advancements and opportunities (Jarrahi, 2018; Sako, 2020).

2.2 AI enhances creativity and innovation

While AI excels in data processing and pattern identification, humans possess unique creative abilities and the capacity for unconventional thinking. By delegating routine tasks to AI, humans can allocate more time and cognitive resources to creative problem-solving, ideation, and innovation. The fusion of human creativity and AI analytical abilities can lead to groundbreaking discoveries and solutions. It also has practical applications, AI can assume control of repetitive, rule-based tasks that do not necessitate complex decision-making. Consequently, humans are able to concentrate on tasks of higher value that demand creativity, critical thinking, and emotional intelligence. For example, in customer service, AI-powered chatbots can field basic customer inquiries, allowing human agents to tackle more complex issues and deliver personalized assistance (Donepudi, 2018). Collaboration research into human-AI collaboration, particularly in classification tasks, indicates that combined efforts often yield better results than individual performance. The best performance outcomes are achieved when the AI delegates tasks to humans rather than the reverse. Interestingly, the quality of AI delegation remains consistent even when

paired with low-performing subjects. Humans, on the other hand, do not delegate effectively and fail to benefit from delegating tasks to the AI (Fügener et al., 2022).

2.3 Arguments in favor of delegating tasks to AI

Delegating tasks to AI systems have been shown to significantly improve efficiency and productivity. AI algorithms can rapidly produce content, which is both timesaving and more resource-efficient compared to manual creation. This advancement allows organizations to streamline their processes, fulfill demands faster, and assign human resources to more strategic or complex tasks (Donepudi, 2018; Hemmer et al., 2023). In addition, Generative AI can amplify human capabilities, enabling individuals to accomplish more. AI systems can free up humans to focus on higher-level activities that require critical thinking, problem-solving, and emotional intelligence. This collaboration between humans and AI can lead to improved results and foster innovation Jarrahi (2018). AI platforms like ChatGPT still have a considerable distance to cover before they can autonomously drive significant products, process, or business innovations. Their primary strength lies in their ability to enhance human intelligence for innovation by augmenting human capabilities (Yogesh K. Dwivedi et al., 2023) .

Generative AI can perform tasks on a scale that humans would find challenging. AI systems can produce vast amounts of content, customized to specific preferences, needs, or contexts. This scalability and customization open opportunities in areas such as personalized marketing, content creation, and product design. Generative AI can lend creative assistance to human creators. AI algorithms can come up with initial concepts, suggest improvements, or provide alternative ideas. This partnership between humans and AI can heighten creativity, spark new insights, and facilitate iterative and exploratory processes across various creative domains (Vartiainen & Tedre, 2023). AI systems excel in areas where humans may face limitations. For instance, in complex data analysis, AI algorithms can process large datasets, identify patterns, and extract valuable insights at a speed and scale beyond human capacity. By delegating such tasks to AI systems, humans can utilize AI's computational capabilities and make data-driven decisions more effectively (Miller & Brown, 2018). Assigning tasks to Generative AI democratizes access to creative tools and content generation. AI systems empower individuals and organizations with the ability to generate content without the need for extensive expertise or specialized skills. This democratization facilitates wider participation in creative processes, fostering innovation and diversity.

2.4 Concerns about AI adoption

While delegating tasks to AI presents significant benefits, it's crucial to address the challenges and ethical dilemmas associated with it. This process includes ensuring fairness, rectifying biases, enhancing transparency, and maintaining human oversight to minimize potential risks. Achieving a balance between human engagement and AI automation is pivotal for the responsible and advantageous usage of AI technologies.

A primary concern brought forth is the potential displacement of human labor as tasks previously carried out by humans are delegated to AI systems. There's ongoing debate about the

implications of AI on employment and the necessity for workforce retraining and reskilling to adapt to the evolving job landscape (Tyson & Zysman, 2022). Secondly, the output generated by AI systems may not always match the quality standards or maintain the same level of authenticity as content created by humans. Critics argue that delegating tasks to AI might lead to a drop in quality or a dilution of originality, which could adversely affect various creative industries. Furthermore, they question if AI-generated content can truly emulate the depth, emotions, and originality that human creativity introduces. In addition, AI systems learn from massive quantities of data, which could introduce biases present in the training data (Fernández, 2019). There are concerns about AI systems exacerbating or amplifying existing societal biases, such as racial or gender biases. The debate centers around addressing these biases and promoting fairness in AI-generated content (Lewicki et al., 2023; Zhou et al., 2022). Critics also express concerns about the lack of control and transparency in AI systems. Gaining a comprehensive understanding of the limitations associated with generative AI models is crucial due to the potential risks they pose. These risks include reputational and legal concerns, the use of offensive or copyrighted content, privacy breaches, fraudulent transactions, and the dissemination of false information (Yogesh K Dwivedi et al., 2023). Understanding the decision-making process of AI, ensuring accountability, and providing avenues for human intervention when necessary are significant considerations when delegating tasks to AI.

2.5 AI and economic growth

The integration of AI in various economic domains has the potential to generate significant economic value and foster economic growth. Several studies have examined the impact of AI on economic growth, welfare, and productivity, providing insights into the potential benefits of AI adoption.

A study by Lu (2021) developed a three-sector endogenous growth model to investigate the impact of AI development on economic growth. Their findings suggest that the development of AI can increase economic growth, particularly if it leads to rising productivity in the goods or AI sector. However, the impact on household short-run utility depends on the nature of AI accumulation. If AI is used to replace human labor, it can be detrimental to household short-run utility. The study emphasizes the importance of considering both the positive and negative effects of AI on economic welfare.

Bickley et al. (2022) conducted a scientometric analysis to explore the diffusion of AI in economics. They mapped the use and discussion of AI within economic subfields over time, place, and subfield. While their study primarily focuses on the diffusion and engagement of economists with AI, it provides insights into the increasing integration of AI in economic research and practice. The widespread adoption of AI in economics suggests its potential to contribute to economic value and growth.

The relationship between AI development and economic growth has also been examined at the regional level. Fan and Liu (2021) investigated the relationship between AI development and economic growth in Chinese provinces. Their findings indicate that the development of AI not

only has a direct effect on economic growth but also improves economic slowdown by inhibiting industrial structure upgrading. AI technologies have become an important driving force for high quality and sustainable economic growth.

Furthermore, studies have explored the impact of AI on income distribution and labor market dynamics. Gries and Naudé (2020) developed a growth model that integrates the task approach from labor economics to examine the economic impact of AI. They found that AI automation can decrease the share of labor income, regardless of the elasticity of substitution between AI and labor. The effects of AI on GDP growth, productivity, and wages depend on the elasticity of substitution. The model highlights the complexities of AI's impact on income distribution and economic growth (Gries & Naudé, 2020).

These studies collectively demonstrate the potential economic value and growth that AI can help generate. AI has the capacity to enhance productivity, drive innovation, and transform industries across various sectors. However, it is essential to carefully consider the distributional implications, address potential inequalities, and implement policies that maximize the benefits of AI while ensuring inclusivity and sustainability (Korinek et al., 2021).

Furthermore, forward-looking estimations made by prominent corporations like Goldman Sachs (2023) and PWC (2023) project that the economic value generated by AI will reach into the tens of trillions of dollars in the forthcoming decade. Consequently, the adoption and further development of AI could emerge as pivotal contributors to global economic growth.

2.6 Autonomous AI

Considering the substantial progress of AI systems, exemplified by technologies such as ChatGPT4, it is increasingly likely that a broadening range of tasks will be allocated to AI agents in order to boost productivity, a trend we have highlighted in earlier sections. Furthermore, recent research, including a study conducted by Candrian and Scherer (2022) , reveals a growing preference among humans for delegating decisions with financial implications to autonomous AI agents rather than to their human counterparts. The study suggests that delegating tasks to AI agents is favored due to lower perceived social risks and the inherent human desire to maintain control.

In line with those considerations, there is anecdotal evidence indicating that corporations are actively exploring the substitution of human employees with AI agents. Recent reports indicate that IBM, a multinational technology company, has announced plans to temporarily halt hiring for certain roles that could potentially be replaced by AI and automation. This decision is expected to impact approximately 7,800 jobs within the company (Reuters, 2023), mainly in back-office functions like Human Resources (HR) (Ahmed, 2018). IBM successfully reduced its HR expenditures by 107 million dollars in 2017 due to integrating AI, reinforcing the belief that AI will continue to support HRM in the future (Gusain et al., 2023). While IBM is not alone in these changes – tech giants such as Meta Platforms Inc., Amazon.com Inc., Twitter Inc., and Microsoft Corp. have also seen recent layoffs – the trend is clear: AI is swiftly transforming the workforce.

JP Morgan Chase, America's largest bank, is an example of financial institutions employing AI for a variety of tasks, which include customer service and data analysis. AI-powered chatbots and virtual assistants are used to manage customer inquiries and offer support. AI algorithms also contribute to risk assessment, fraud detection, and investment analysis, enhancing the bank's financial performance and market capitalization (Kumari et al., 2021) . In addition, call centers across industries, including telecommunications providers and customer service organizations, are incorporating AI-powered chatbots and virtual assistants. These AI systems are capable of handling customer inquiries, providing information, and assisting with basic troubleshooting, which reduces the demand for human call center agents in certain scenarios (Khan & Iqbal, 2020). This signifies yet another area where AI is transforming traditional job roles and tasks.

As the shift toward delegating tasks to AI agents appears to be gaining momentum, there is a growing emphasis on developing and exploring more autonomous versions of AI agents. These advanced systems are designed to plan, execute, inspect, and learn independently, as discussed in recent works like Gao et al. (2023). For instance, while ChatGPT is proficient at providing responses to specific questions or tasks, it does not possess the capacity to pursue overarching objectives or goals independently. In response to this limitation, alternative AI agents such as AutoGPT, AssistGPT, or AgentGPT, which are designed to actively accomplish specified objectives or goals, have been proposed. Despite being in the early stages of development, it is conceivable that these more autonomous AI agents – capable of planning, executing, inspecting, and learning in order to fulfil given objectives and goals – will become increasingly accessible in the near future.

3. Institutional limitations that hinder AI agents to become more autonomous

Although AI agents exhibit remarkable proficiency in research, analysis, and decision-making, they encounter significant limitations when it comes to executing tasks autonomously and achieving set objectives. One of the key limitations of AI agents is their inability to interact directly with economic and financial institutions, such as engaging in contractual agreements or accessing financial services. In practice, this means that while an AI agent can make plans, identify business solutions or analyze economic trends, it cannot actually execute a contract or engage in financial transactions without human intervention. This section discusses several specific challenges that autonomous AI systems face when interfacing with traditional economic institutions. The potential challenges autonomous AI systems may encounter when dealing with established economic institutions, such as contractual agreements or financial services (e.g., Know Your Customer procedures), stem from the fundamentally physical nature of these entities. The majority of such institutions are characterized by their tangible infrastructure, physical interactions, and the prevalence of paper-based documentation, all of which could present difficulties for AI systems to effectively engage with.

Firstly, financial institutions are obligated to adhere to the Know Your Customer (KYC) framework and regulatory requirements. KYC serves as a mandatory procedure employed by banks and financial institutions to authenticate the identity of their customers and by other

businesses to identify their clients. Its objective is to safeguard financial institutions against risks such as fraud, corruption, money laundering, and terrorist financing (Malhotra et al., 2022; Rajput, 2013). It involves a manual process through which banks and financial institutions collect and verify customer information to ensure their identity and assess their risk and financial profiles. KYC helps in establishing the authenticity of customers and mitigating potential risks associated with financial transactions. Customers are required to provide various documents and information such as identification documents, proof of address, and additional supporting documents. This process is mandatory in banking and financial transactions. The diverse identification prerequisites within the financial sector, coupled with the dynamic nature of identity, can pose significant obstacles when it comes to accessing financial services (Arner et al., 2019; Malhotra et al., 2022).

As AI is essentially a computer program lacking a recognizable identity in the economic and societal context, it is unable to complete the KYC registration necessary to access financial services within traditional economic institutions. The question of whether AI agents should possess an identity is a topic of ongoing debate, as the social and economic implications of AI agents with identifiable personas could be profoundly challenging. Even in scenarios where AI agents are granted identities, there arises the question of acceptance of different types of online identification for these entities. This would necessitate modifications to existing regulatory requirements. Additionally, ensuring cross-compatibility of online identities, whether from a legal or technical perspective, poses another significant hurdle. This necessitates the development of a new regulatory framework and the design of a technical utility that can facilitate such interactions, as outlined by Arner et al. (2019). Without the ability to fulfill KYC requirements, AI agents are denied access to financial services. This limitation makes it impossible for autonomous AI agents to perform financial operations such as making payments, investing, or borrowing loans, thereby hindering their full potential in autonomous decision-making and execution.

Secondly, a contract is a legally recognized agreement made between two or more parties. Contracts figure prominently in many economic and organizational theories (Rousseau & McLean Parks, 1993). The argument is that contracts substitute for markets and trust, create organizational forms and foster psychological attachment of members to organizations. As for who is legal to use or compose a contract, generally anyone who has the legal capacity to enter into a contract can use or compose one. This includes individuals, businesses, organizations, and even government entities. It's important to note that there may be specific legal requirements or restrictions depending on the jurisdiction and the nature of the contract (Rousseau & McLean Parks, 1993). Traditional economic institutions operate within jurisdiction specific legal and regulatory frameworks that are designed for human participation and compliance. Despite the capabilities of AI agents to scrutinize and assess digitized legal contracts, they are not endowed with the authority to engage in legal contracts to facilitate economic transactions with other AI agents or human beings.

Third, traditional economic institutions often involve physical infrastructure, assets, and resources. Autonomous AI systems, primarily designed to operate in the digital realm, may lack

the capability to effectively access, control, or manage physical assets or infrastructure. In addition, many economic institutions, especially those in financial services, necessitate personalized interactions and understanding of individual circumstances. The capability of AI systems to cater to individual preferences, unique situations, and complex emotions influencing economic decision making could be limited. Traditional institutions might store data in diverse formats and systems that are not easily accessible or compatible with AI systems. AI systems primarily rely on structured digital data sources, and therefore might find integrating data from diverse sources challenging. The challenge which is currently is that these customers are not digital and to win the trust of customers is a huge obstacle to them (Mhlanga, 2020).

4. Blockchain-based institutions for autonomous Artificial Intelligence

Strikingly, the Blockchain technology can provide the economic and financial institutional services for autonomous AI agents in theory and practice. Davidson et al. (2018) shed light on the transformative capacity of blockchain technology within capitalist economic structures, arguing that, beyond merely considering the disruptive implications of blockchain as a general-purpose technology, it should be viewed in a wider perspective as an institutional technology.

At its core, blockchain technology constructs an unalterable, decentralized public ledger, capable of storing a myriad of data structures – from property titles and certifications to contracts and more. This feature could enable enhanced efficiency and transparency in economic coordination and governance, which are key aspects of any economic institution. This point is exemplified by Bitcoin and other blockchain based platforms, which have already started to challenge traditional financial systems and advocate for more decentralized, democratic economic structures (Evans, 2014), and advocate for more decentralized, democratic economic structures (Lange & Santarius, 2020).

In the academic realm, some approaches propose that blockchains represent a manifestation of institutional evolution. As blockchain technology continues to mature and infiltrate various industries, it could potentially drive a transformation in economic institutions, making them more efficient, transparent, and inclusive (Davidson et al., 2018). For instance, the integration of blockchain in managing property rights could diminish the reliance on intermediaries, streamline transaction processes, and enhance security and trust among involved parties (Dam et al., 2020; Xu et al., 2023). Thus, blockchain technology holds a considerable potential to revolutionize economic institutions by establishing a more streamlined, transparent, and decentralized system for economic coordination and governance. However, the successful integration of blockchain into these institutions necessitates thoughtful deliberation on various factors, including technological infrastructure and societal acceptance (Ramprakash et al., 2023).

To underscore our analysis on blockchain's potential in transforming economic institutions, we spotlight several cases featuring smart contracts as a form of economic institution. Blockchain technology has catalyzed the birth of a unique economic institution: automated or smart contracts (Schär, 2021). Smart contracts are computer protocols designed to enable, authenticate, and enforce agreements among various parties even those lacking mutual trust without the need for a

trusted third party (Khan et al., 2021). A concrete example of this is the burgeoning decentralized finance (DeFi) industry, an alternative financial infrastructure built on the Ethereum blockchain, using smart contracts to mirror existing financial services in a more accessible, interoperable, and transparent manner (Schär, 2021).

Decentralized payment systems, exchanges, and financial services stand out as key economic institutions that utilize smart contracts (Schär, 2021). These systems leverage the immutable and transparent nature of blockchain technology to deliver secure, efficient, and trustless transactions. However, the application of smart contracts in economic institutions is not without its challenges. Security threats, vulnerabilities, and legal considerations present formidable hurdles (Cai & Zhu, 2016; Khan et al., 2021). Despite these issues, ongoing research and development suggests a promising future for blockchain based smart contracts as new governance tools (Fiorentino & Bartolucci, 2021).

4.1 Autonomous AI agents can access economic and financial institutions on the Blockchain

Accessing the services of new digital economic and financial institutions built on Blockchain requires users to possess a private key. This private key serves as a unique identifier, granting users access to the services and transactions within the Blockchain network. Interestingly, both in theory and practice, AI could manage these private keys. This capability opens up a new dimension of autonomous AI interactions within the Blockchain based economic institutions (Salah et al., 2019).

The inherent characteristics of Blockchain technology make it theoretically and practically suitable for serving autonomous AIs. Blockchain's decentralized nature, transparency, immutability, and security features align well with the requirements of AI systems. These features ensure that AI systems can operate in a secure and reliable environment, where data integrity is maintained, and transactions are transparent and verifiable (Shinde et al., 2021).

Equipped with private keys, autonomous AI agents not only possess the capability to implement smart contracts on the Blockchain, but also to examine existing smart contracts deployed thereon, which empowers them to make informed decisions on whether to enter these contracts or not. Specifically, these autonomous AI agents could innovate new smart contracts for decentralized exchanges and decentralized financial services, or utilize existing smart contract services, thus enabling the full autonomy of AI agents in the digital financial sphere.

While Blockchain has the potential to grant AI access to a wide variety of economic institutions, there are only certain types of these institutions that AI can effectively utilize. This is primarily due to the specific requirements and complexities associated with different economic institutions. For instance, institutions that involve complex human judgement or subjective decision making may not be fully accessible to AI. Take, for example, the legal system. While AI can be programmed to understand and apply laws, it may struggle with areas of law that require subjective judgement, such as family law or criminal law, where human empathy, understanding, and discretion play a significant role. Similarly, in the realm of financial services, while AI can manage and execute

straightforward transactions, it might find it challenging to navigate areas like wealth management or financial advising, which often require a deep understanding of a client's personal circumstances, risk tolerance, and long-term goals - elements that are often nuanced and subject to change. Moreover, institutions that rely heavily on interpersonal relationships and trust, such as certain types of banking or business partnerships, may also pose challenges for AI. These institutions often require a level of personal interaction and relationship-building that AI, in its current state, may not be able to fully replicate. However, institutions that involve data-driven decision making or automated transactions can be effectively utilized by AI systems (Zhang et al., 2021).

AI Management of Private Keys: A Practical *Example*

In practice, AI's management of private keys can be exemplified in the realm of automated trading on decentralized exchanges. Here, an AI system can be programmed to manage a private key, allowing it to autonomously execute trades based on predefined algorithms or real time market analysis. This not only enhances the efficiency of trading operations but also opens up new possibilities for high frequency trading and algorithmic trading strategies in the Blockchain space (Fang et al., 2022; Liu et al., 2021).

4.2 Model for delegation to autonomous AI agents that can access the economic and financial institutions on the Blockchain

We put forward a model for the delegation of responsibilities to autonomous AI agents, thereby providing them with the capability to access and interact with economic and financial institutions on the Blockchain. As depicted in Figure 1, human agents can delegate objectives, goals, or tasks to autonomous AI agents that necessitate interfacing with economic and financial institutions. Within this proposed architecture, five principal components work in synergy to empower AI agents to autonomously engage with these institutions on a Blockchain platform.

User: A user in this context is the individual or entity that owns an AI agent and assigns it specific economic and financial tasks. Users interact with the system, input initial instructions, and oversee the overall operation of their AI agent. However, once tasked, the AI agents can execute these functions independently. The user also establishes the private key for the autonomous AI agents to whom they wish to delegate tasks.

AI Agents: AI agents are unique actors created by users, capable of processing individual economic and financial tasks independently, including the execution of payment processes. These AI agents are capable of initiating and executing transactions on the Blockchain autonomously, without needing constant user interaction or support. Each AI agent possesses a level of machine learning capabilities allowing them to learn and adapt over time for better task performance.

Public Key and Private Key: Each user and AI agent pair has a set of cryptographic keys: a public key, which can be freely shared, and a private key, which is kept confidential. In a blockchain context, the public key is used to create the blockchain address, while the private key is used to authorize transactions. Especially each AI agent is equipped with a private key that it

manages independently within a local management system (e.g., in a hot wallet). This private key is used to authorize transactions, ensuring the AI agent can execute operations autonomously and securely. Unique to this architecture, the AI agent can use its private key to generate multiple public keys. Each of these public keys can be freely shared and used to create distinct blockchain addresses. This allows the AI agent to manage multiple wallet addresses simultaneously, enhancing its ability to interact with various blockchain-based services and execute diverse economic and financial tasks.

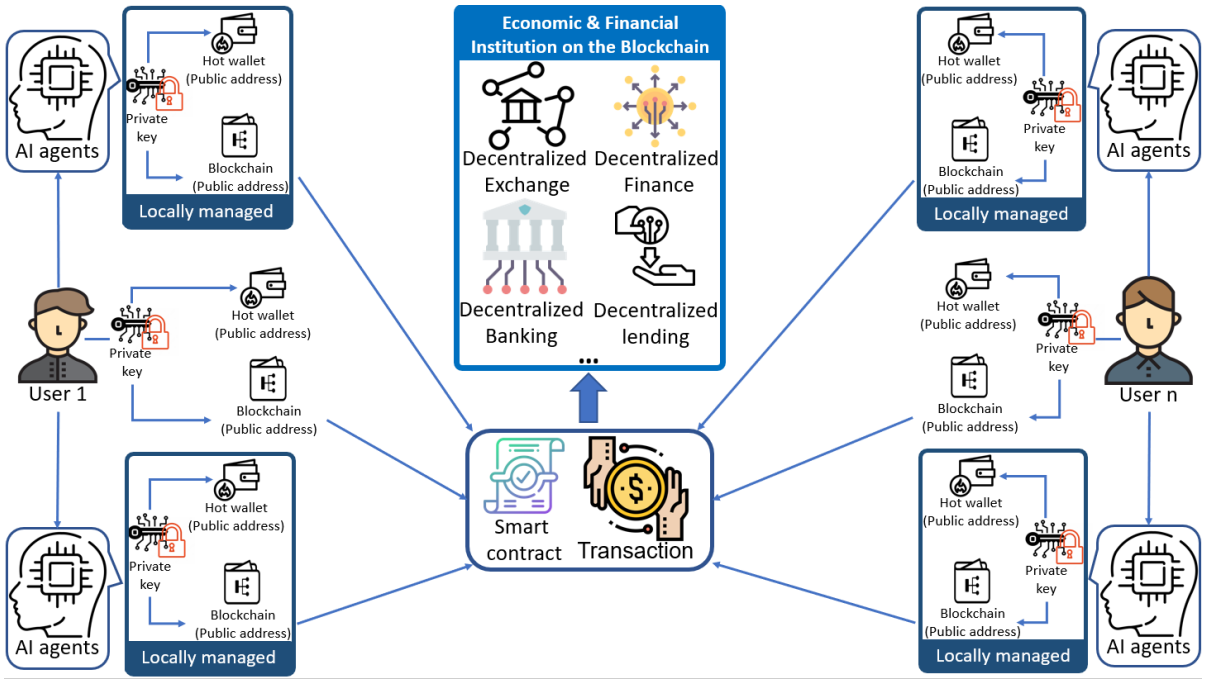

Figure 1: AI Agents in Economic and Financial Institutions on Blockchain Infrastructure

Smart Contract/Transaction: AI agents can create smart contracts and transactions without user intervention. Smart contracts are self-executing contracts with the terms of agreement directly written into lines of code. Both users and AI agents can create these contracts, with AI agents doing so autonomously based on their assigned tasks and learned behavior. Transactions, once authorized, are added to the blockchain and become part of the immutable record. AI agents also have the ability to verify and evaluate the content of smart contracts.

Examples of economic & financial institutions on the Blockchain that connects autonomous AI agents with both other AI and human agents:

- **Decentralized Exchange (DEX):** DEXs allow for the direct exchange of assets (e.g., cryptocurrencies) between parties, facilitated by smart contracts rather than an intermediary. AI agents can engage with DEXs to execute trades autonomously based on their tasks and learned behavior.
- **Decentralized Finance (DeFi):** DeFi platforms utilize smart contracts on blockchains to

replicate traditional financial systems in a decentralized manner. AI agents can interact with DeFi platforms to perform tasks like lending, borrowing, or earning interest.

- **Decentralized Payment:** Both AI and human agents can use decentralized payment to settle economic transactions worldwide.

- **Contracts:** In general, autonomous AI can create and engage with smart contracts that govern the obligations of relevant parties.

The AI agent is given the ability to manage its private key independently and store it in a hot wallet. This private key is used to authorize transactions, ensuring the AI agent can execute operations autonomously and securely. The AI agent's ability to manage its private key is a critical aspect of its autonomy. It allows the AI agent to authorize transactions independently, without needing direct user input every time. This autonomous operation is made possible by the inherent security and trustworthiness of Blockchain technology.

The process begins with the user creating an AI agent, designed to be a unique actor capable of performing individual economic and financial tasks. The AI agent is implemented with machine learning capabilities, allowing it to learn from past transactions and behaviors, adapt over time, and improve its performance in future tasks. Once the AI agent is created, it is assigned a private key. After the AI agent is equipped with its private key and the ability to generate public keys, the user provides the AI agent with overarching goals or specific tasks that require access to economic and financial institutions. These tasks could range from buying or selling goods, trading assets, to creating and engaging in (smart) contractual obligations. The AI agent receives these instructions and carries them out autonomously, interacting directly with the appropriate blockchain-based services. When a transaction is initiated, whether that's a trade, purchase, or sale, the payment process happens directly between AI agents or between the user and the AI agents, just like a regular transaction. The AI agent can independently authorize transactions using its private key, making the process seamless and efficient with minimal or no human intervention. Once the transaction is authorized, it is logged onto the blockchain. The blockchain serves as an immutable ledger, recording all transactions that occur. Each transaction is time-stamped and linked to the public keys of the parties involved, making it possible to trace and verify the transaction history. The transparency of blockchain technology also aids in preventing fraud and ensuring trust in the system.

This architecture paves the way for a robust and efficient economic system in which AI agents can autonomously perform economic and financial transactions. Consequently, autonomous AI agents become more capable of aiding human agents, thus enhancing productivity and stimulating economic growth on a global scale.

4.3 Technical limitations of the autonomous AI agent's model

AI is a highly potential type of general-purpose technology/capital expected to generate significant economic value by augmenting human capability and enhancing human productivity. Human agents can enhance productivity by delegating certain types of tasks to more autonomous

versions of AIs. Blockchain, as an economic and financial institutional infrastructure, can amplify the productivity gains of autonomous AIs. However, there are risks and obstacles associated with the integration of autonomous AIs into economic institutions that need to be considered. Future investigations into autonomous AI's capabilities to access economic and financial infrastructure on the Blockchain can explore a multitude of dimensions.

4.3.1 Private key management limitations

The management of private keys in blockchain networks, particularly for autonomous AI agents, presents a unique set of challenges and limitations. These challenges primarily revolve around security, privacy, and the robustness of the infrastructure.

Firstly (Security): The private key is a critical component in the blockchain network. It authorizes transactions and provides access to the user's digital assets. If an AI agent manages its private key, the security of that key becomes paramount. If the key is compromised, it could lead to unauthorized transactions or even theft of digital assets. Therefore, the AI agent must have robust security measures in place to protect the private key. This could include secure storage methods, advanced encryption techniques, and regular key rotation.

Secondly (Privacy): The use of a private key by an AI agent also raises privacy concerns. The AI agent's activities, authorized by its private key, are recorded on the blockchain and can be traced. While blockchain transactions are pseudonymous, sophisticated analysis could potentially link these transactions back to the originating AI agent or even the user. This could lead to privacy breaches if sensitive information is inferred from the AI agent's activities.

Thirdly (Infrastructure limitations): The current technical infrastructure may not be fully equipped to handle autonomous AI agents managing private keys. For instance, the process of key rotation, where a private key is periodically changed for security reasons, could be challenging to implement in an autonomous manner. Additionally, the infrastructure would need to support the secure storage and retrieval of private keys by AI agents, which could require significant resources and advanced technology.

A real-world example of these challenges can be seen in the case of cryptocurrency wallets, even for humans. These wallets, which are essentially blockchain-based hot wallets managed by users, have been subject to numerous security breaches over the years. In many cases, these breaches occurred due to compromised private keys. While these wallets are not managed by AI agents, the security and privacy challenges they face are similar to those that would be faced by autonomous AI agents managing private keys.

Certainly, one practical approach to mitigate the risks associated with autonomous AI agents managing private keys in blockchain networks is to limit the value of assets that the AI agent can control. Users could consider assigning a limited amount of digital assets to the AI agent's hot wallet. By doing so, they can limit their exposure to potential losses in case of a security breach or malfunction of the AI agent. This approach mirrors the prudent use of a physical wallet: instead of carrying one's entire life savings, one only keeps an amount intended for immediate expenses. For

instance, if an AI agent is tasked with making regular small transactions, the user could periodically fund the AI agent's wallet with just enough digital assets to cover these transactions. This way, even if the AI agent's private key were compromised, the potential loss would be limited to the amount currently in the wallet.

Furthermore, users could implement safeguards such as transaction limits or require manual approval for transactions above a certain value. This would add an extra layer of security and control, allowing users to monitor and manage high-value transactions. It is important to note that while these measures can reduce risk, they cannot eliminate it entirely. Therefore, ongoing efforts to improve the security and privacy of AI agents in blockchain networks remain crucial. Users should stay informed about the latest security practices and ensure their AI agents are configured to follow them.

4.3.2 Other technical limitations

While the autonomous AI model described has significant potential, there are several technical limitations that need to be addressed.

Firstly, the AI agent's ability to learn from past transactions and behaviors and adapt over time is dependent on the quality and quantity of the data it has access to. If the data is incomplete, inaccurate, or biased, the AI agent's decision-making could be flawed. Furthermore, the AI agent's learning and adaptation capabilities are limited by the sophistication of the machine learning algorithms it uses. Current algorithms may not be able to fully capture the complexity and unpredictability of economic and financial markets.

Secondly, the AI agent's ability to carry out tasks autonomously and interact with blockchain-based services is limited by the complexity of these tasks and services. Some tasks may be too complex for the AI agent to handle autonomously, and some blockchain-based services may not be designed for interaction with AI agents. Furthermore, the AI agent's ability to interact with these services is dependent on the interoperability of the AI and blockchain technologies.

Finally, the process of logging transactions onto the blockchain and verifying the transaction history is dependent on the scalability and efficiency of the blockchain technology. As the number of transactions increases, the blockchain can become more computationally intensive and slower to process transactions.

Addressing these technical limitations will require advancements in both AI and blockchain technologies, as well as careful design and implementation of the AI agent and the blockchain-based services it interacts with.

4.4 Further discussions on autonomous AI

*Job Displacement and Labor Market Disruption***:** One of the primary concerns is the potential displacement of human labor due to the automation capabilities of autonomous AIs. As these technologies become more advanced, they can replace tasks traditionally performed by humans, leading to job losses and potential disruptions in the labor market. Indeed, this limitation becomes

particularly noteworthy in the financial service sector where Blockchain technology and AI could serve as formidable tools. Blockchain can be utilized as an alternative back-end infrastructure, offering enhanced security, transparency, and efficiency. Concurrently, autonomous AI agents have the potential to provide substantial assistance to humans in making financial decisions and executing them. The potential displacement of human labor requires careful management to ensure a smooth transition and mitigate the negative impact on employment. Strategies such as retraining and upskilling programs can help individuals adapt to the changing job landscape.

Ethical Considerations: The utilization of autonomous AIs brings forth significant ethical considerations. Questions regarding the moral status of machines, their decision-making processes, and the potential risks they pose to humans and other morally relevant entities emerge. It is vital to ensure the safety, transparency, and ethical standards of autonomous AI systems in order to build trust and mitigate potential harm. The establishment of ethical guidelines and regulations is necessary to address issues such as bias, privacy, accountability, and responsible AI use. Furthermore, when autonomous AI has the ability to engage in contracts and use financial services, the capabilities of these AI systems are dramatically augmented. It is essential to conduct more research on the boundaries and limitations of such arrangements, as the potential drawbacks of financially and economically capable autonomous AI agents could be catastrophic if not properly regulated.

Economic Inequality: The integration of autonomous AIs into economic institutions has the potential to exacerbate economic inequality. If the benefits of autonomous AI adoption primarily concentrate in the hands of a few individuals or organizations, it can widen the gap between the rich and the poor. Ensuring equitable distribution of benefits and addressing socioeconomic disparities is essential to harness the potential of autonomous AIs for inclusive growth and societal well-being.

*Data Privacy and Security***:** Autonomous AIs rely on vast amounts of data for learning and decision-making. This raises concerns about data privacy and security. Economic institutions must establish robust data protection measures to safeguard sensitive information and prevent unauthorized access or misuse. Blockchain technology, with its decentralized and transparent nature, can offer potential solutions to enhance data privacy and security in the context of autonomous AI systems.

Regulatory and Legal Challenges: The integration of autonomous AIs into economic institutions poses regulatory and legal challenges. Current laws and regulations may not adequately address the unique aspects and implications of autonomous AI technologies. New frameworks need to be developed to address issues such as liability, accountability, intellectual property rights, and governance of AI systems. Collaborative efforts between policymakers, industry stake-holders, and researchers are necessary to establish a regulatory environment that fosters innovation while ensuring ethical and responsible AI use.

Overcoming these hurdles indeed necessitates a multidisciplinary approach that merges technological advancements with ethical considerations, policy interventions, and multi-

stakeholder collaborations. Addressing these challenges proactively is key to maximizing the potential of autonomous AI within economic institutions while concurrently mitigating the associated risks.

5. Conclusion

In conclusion, our exploration into the intersection of AI and Blockchain technologies has revealed significant potential for the advancement of autonomous AI agents. We have identified the constraints faced by these agents, particularly their limited access to economic and financial institutions, which hinders their ability to independently achieve predefined objectives. However, we propose that Blockchain technology, as an institutional technology, can provide a solution to this challenge by creating digital-native economic and financial institutions. Our study has shown that AI agents can theoretically and practically interact with these Blockchain-based institutions through the management of private keys. This interaction extends their capabilities, allowing them to form and participate in contracts and agreements, and to utilize financial services autonomously. This potential for autonomy could lead to a significant increase in the deployment of AI agents, thereby augmenting human productivity.

While the debate on whether AI will replace or augment human capabilities continues, our study suggests a future where AI and humans coexist and collaborate. In this future, AI agents, empowered by Blockchain technology, can perform tasks independently, while humans focus on tasks requiring unique human intelligence. This symbiotic relationship could lead to greater efficiency and productivity in various sectors, including finance, commerce, and supply chain management. Despite the potential benefits, the integration of AI and Blockchain technologies also raises important questions and challenges that need to be addressed. These challenges encompass various dimensions including economic factors, societal impact, regulatory constraints, privacy considerations, and the ethical implications of autonomous AI entities. Consequently, we strongly advocate for continued and extensive research in these critical areas.

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