Review

Technology

The Roles of Technology in Anti-Money Laundering

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In the context of globalization, the intensified complexity and covertness of money laundering have undermined the effectiveness of traditional anti-money laundering measures. Meanwhile, emerging technologies are bringing new opportunities as well as challenges to anti-money laundering efforts. This article seeks to explore the roles of technology in anti-money laundering, focusing on analyzing the applications, benefits, and challenges of big data, artificial intelligence, blockchain, and biometric technologies in this area. The study finds that these technologies can significantly enhance the financial institutions' capability to monitor and identify money laundering acts, despite the issues, such as data privacy and security, technological complexities, and legislative gaps, encountered in their application. It also proposes suggestions about how to fully leverage technology to combat money laundering, including strengthening data security mechanisms, promoting multi-agency collaboration, improving the framework of legislation and regulations, and increasing anti-money laundering education for the public.

Keywords: Anti-Money Laundering; Application of Technology; Big Data; Artificial Intelligence; Blockchain; Biometrics

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MONEY laundering, a form of financial crime, poses severe threats to the stability of a country's financial system, damaging the reputation and normal operation of financial institutions, disrupting the order of financial markets, and impairing the effects of the state's macroeconomic policies (Sun & Zhao, 2022; Tiwari et al., 2020). Moreover, it can undermine social stability and national security by instigating other criminal acts and providing financial support for major crimes like terrorism and corruption. In the context of globalization and the attendant expansion in the scale and frequency of international capital flows, cross-border money laundering has become increasingly complicated and less easy to detect (Ren, 2024). Money launderers capitalize on the differences in financial regulations between countries and territories to transfer and launder illegally gained wealth across the globe, significantly increasing regulatory challenges.

To safeguard financial security, social stability, and the healthy growth of the economy, all nations have strengthened their anti-money laundering (AML) efforts. Yet, with increased sophistication of money laundering techniques, traditional AML measures have become less effective despite their deterrent effect on a certain scale. Luckily, the expedited development of information technology (IT) has opened up new opportunities for AML endeavors. The application of advanced technologies, such as big data, artificial intelligence (AI), and blockchain, can significantly enhance the monitoring and detection capabilities of AML agencies. On the other hand, technological advancements are equally utilized by money launderers, resulting in a surge of new criminal devices, such as online money laundering and money laundering through virtual currencies. This makes AML work increasingly technologically demanding.

In this context, it is of vital significance to explore the roles of technology in improving AMT's efficiency and results. This study is a literature review of global research on technology-assisted AML, seeking to encapsulate the applications of emerging technologies, including big data, artificial intelligence, blockchain, and biometric technologies, in AML, as well as their challenges for financial institutions and regulatory agencies.

Basic Facts about Money Laundering and AML

What is Money Laundering?

Criminal activities, such as smuggling, drug trafficking, and fraud, as well as those more hidden ones like corruption, bribery, and insider trading, can all bring the criminals huge numbers of assets. Money laundering is the practice of engaging in financial transactions to "legalize" these illegally acquired assets by concealing their sources and destinations in order for the criminals to "safely" use them.

A money laundering scheme typically involves three basic processes: placement, layering, and integration (Force, 1999). "Placement" is the initial process in which money launderers introduce the illegally earned money into the financial system by creating a multitude of bank accounts or purchasing financial instruments such as checks and money orders. The "layering" process entails a series of intricate transactions aimed at obscuring the origins of the money, including the repeated buying and selling of those instruments and utilizing bank accounts across the world for wire transfers. The purpose of this process is to confuse the trail of the money, making it difficult to trace its original sources. In the "integration" process, the money, after going through a slew of treatments in the preceding processes, returns to the economic system with legal identities in the form of real estate, luxury goods, commercial investment, etc.

Traditional AML Measures and Limitations

Money laundering can occur almost anywhere in the world, as it is the intrinsic element in every for-profit crime (Force, 1999). To address this acute challenge, the international community has introduced a series of measures to combat money laundering. The governments of various countries have strengthened financial regulation, requiring their financial institutions to establish stringent customer-identification procedures [e.g., Know Your Customer (KYC) and Customer Due Diligence (CDD)], build surveillance systems for suspicious transactions, and report suspicious transactions detected. Furthermore, since 1988, they have actively promoted AML legislation and issued a wide range of AML policies and regulations for preventing and fighting money laundering. Furthermore, international AML cooperation has been heightened. The Financial Action Task Force (FATF), established at the 1989 G7 Summit in Paris, has been committed to formulating internationally unified AML standards and combating cross-border money laundering by means of international intelligence sharing and joint operations.

Nevertheless, these AML actions are not without limitations. There remain divides in AML legislation and practices between nations, which compromises the efficiency of international cooperation in AML, despite the efforts of international agencies like the FATF to promote such cooperation. At the same time, the effectiveness of AML regulations is controversial. Some researchers argued that AML regulations could reduce money laundering by increasing its cost (e.g., Barone & Schneider, 2018). On the other hand, certain studies suggest that the deterrent effect of AML regulations is insignificant and that the cost of their enforcement is high (e.g., Huang, 2015). Additionally, with the emergence of new money laundering methods, such as money laundering through virtual currencies and internet technology-assisted money laundering, AML is undergoing unprecedented difficulties. Gerbrands et al.'s study (2022) reveals the complications faced by AML policies. It finds that while the EU's Fourth Anti-Money Laundering Directive (AML-IV) 2015 strengthened AML action, the money laundering networks in Europe significantly expanded after the implementation of AML-IV to involve more individuals, businesses, and countries, presenting more diverse crimes.

Roles of Technology in AML

There is a growing consensus in the AML community that heightening the application of technology is a workable solution to the complexities of AML. In 2020, the FATF conducted a large-scale survey on the application of technology in AML, polling global AML and counter-terrorist financing (CTF) agencies, financial institutions, and technology developers. The survey results reveal that the use of technology has significantly enhanced the outcomes of AML efforts while also proving advantageous in elevating risk management capability, reducing the cost, improving auditability, and optimizing staffing in AML (Wang, 2022). This section is devoted to an analysis of specific roles of different technologies in AML.

Big Data

Financial globalization and digital technology advancement have resulted in the proliferation of financial data, alongside the emergence of new methods of crime. Traditional AML and fraud detection methods (such as the monitoring of rule-based transactions) have proven inefficient and have high false detection rates when dealing with massive datasets and novel criminal techniques (Jiang, 2024). For instance, most traditional AML systems operate on a "storing-then-processing" model, with which the bank first gathers data (such as customer personal details, account information, and transaction data) from various information systems and subsequently cleans, orders, and analyzes

the data. This cumbersome data processing workflow makes real-time monitoring and prompt detection of suspicious transactions hardly possible (Gui, 2024). Additionally, due to differences in operation rules and the database system architecture, there are no uniform formats of data shared by banks, leading to data "silos" in the industry (Ba et al., 2020). Money launderers may take advantage of this defect to perform money laundering by creating multiple accounts and conducting cross-bank transfers and cross-border payments, making their financial transactions less easy to trace and thereby managing to evade regulatory oversight.

The advent of big data technology has generated new possibilities for addressing these problems. First, big data technology can help improve the efficiency of data collection and processing in AML, aiding financial institutions and regulatory agencies in extracting valuable information from colossal amounts of complex data and creating customer and funds network profiles. Hidden money laundering acts can be identified by analyzing customer transaction behavior, associated accounts, and fund flows via data analytics and mining (Gui, 2024). Second, through setting monitoring targets or keywords, big data technology enables real-time surveillance of targeted activities, including counter services, online payments, and mobile payments (Fu, 2023); automated detection of suspicious transactions like repeated transfers of large sums of money and nighttime transactions; and provision of early warnings for potential money laundering manipulations. Third, big data technology can assist with the construction of the money laundering risk rating model, which can automatically generate ratings of money laundering likelihood in customers based on multiple information sources, including transaction records, credit history, and more. Financial institutions can administer different risk control measures to customers with varied risk levels, adjusting the strength of due diligence and transaction limits. This leveled risk management approach not only improves the efficiency of AML but also optimizes customers' experiences as non-money-laundering actors.

AI Technology

The proliferation of digital financial data has laid the groundwork for the application of AI in AML. This is because financial data, which encompasses vast amounts of transaction and customer information, are the basic materials necessitated in AI's model training, pattern recognition, and anomaly detection. Based on large volumes of financial data and big data-enabled data processing capabilities, AI technology can play an active role in AML.

First off, AI-powered big data technology has the potential to process unstructured data (such as text, images, and audio) and draw valuable information from them, thereby strengthening financial institutions' capability of identifying the customers' transaction patterns and monitoring their behaviors. For instance, natural language processing (NLP) can be used to analyze inter-customer and customer-financial institution communication records (such as transaction notes and chat logs), identify keywords or abnormal behavioral patterns pointing to money laundering, and uncover hidden clues of money laundering acts (Tsapa, 2023; Han et al., 2020).

Furthermore, AI-powered Robotic Process Automation (RPA) has exhibited significant effects in enhancing the efficiency of AML work. RPA, a form of digital labor force, automates the workflows of financial institutions by employing computer software-driven robots (Chen, 2024). RPA plays a crucial role in the processes of KYC and transaction monitoring in AML. It can perform standardized, repetitive, and complicated tasks such as searching blacklists, gathering information on high-risk political figures, screening suspicious transactions, and producing reports on these transactions. In traditional AML manipulations, manual handling of these tasks has a high incidence of errors, such as incorrect data entry and omission of critical information. The application of RPA can substantially reduce human involvement in these tasks, thereby improving the quality and accuracy of AML data.

Also, machine learning algorithms can be used to predict potential money laundering acts. Algorithm-based AI models can establish patterns and features of money laundering behaviors using vast amounts of historical data and recognize money laundering transaction patterns based on those of previous cases (Tsapa, 2023). Moreover, AI models can spot anomalous traces among the data, which is hardly viable with the traditional rule-based system (Chen, 2024). The predictive role of AI models helps reduce money laundering incidents by enabling financial institutions to take preventive actions.

Additionally, with technologies like machine learning and cloud computing, AI-powered detection models can be continually updated and optimized to better suit the practical needs of AML work. Machine learning models can automatically modify their algorithm parameters by continuously learning new money laundering patterns, adjusting to ever-changing money laundering behaviors (Han et al., 2020). At the same time, cloud computing supports AI models' large-scale data processing and constant updating with its potent data storage capability and computational power (Agorbia-Atta & Atalor, 2024). The limitless update capability of AI-enabled models is vital to AML, for it can enhance the accuracy and adaptability of the models, reducing detection errors, while also enabling financial institutions to adapt to renewed requirements from regulatory agencies.

Blockchain Technology

Blockchain technology, brought by the rise of cryptocurrencies like Bitcoin, is a decentralized database mechanism that allows transparent information sharing within a business network (Shao et al., 2018). It has been applied to the distributed ledger technology (DLT) in the financial sector, a technology used to record, store, and synchronize data across multiple nodes (computers) within a network (Wang, 2022). Unlike the traditional method of using centralized ledgers, with which data are stored on a single central server, DLT distributes data across various nodes in the network, with each node keeping a complete copy of the ledger and with consistency and security of the data being guaranteed via consensus mechanisms. The blockchain is one of the devices for implementing DLT. Due to the blockchain's features as decentralized, tampering-resistant, traceable, transparent, and highly secure, blockchain technology can successfully address those issues with traditional AML practices, such as information silos, data security risks, and difficulty recognizing customer

identities.

The decentralized nature of the blockchain can be leveraged to create a system for verifying customer identities to break down the barriers of information silos and facilitate efficient sharing and verification of customer information (Thommandru & Chakka, 2023; Anti-Money Laundering Research Group of the People's Bank of China, 2020). Using the consortium chain (a type of blockchain network that balances openness with control), for instance, a group of financial institutions can store customer identity information and transaction records on the blockchain for cross-institutional information sharing and verification. This approach not only enhances the efficiency and accuracy of customer identity verification systems but also helps financial institutions reduce their compliance costs (Hua & Wang, 2020).

The blockchain, as a traceable ledger, is an effective device for monitoring and tracking suspicious transactions (Jiang et al., 2024). Using smart contracts and data analytics, financial institutions can monitor transactions in real time, with suspicious transactions being automatically identified and reported (Liao, 2019). For instance, when a warning against a dubious transaction is issued by a member of the consortium chain, the entire network will automatically initiate the identification function, and the warning issuer can draw on information from other members of the consortium chain to verify the legitimacy of the transaction.

With the immutability of the blockchain, no transaction records can be altered or deleted once generated, which guarantees the existence of reliable evidence for auditing in AML efforts. Furthermore, blockchain technology ensures the record of the complete process of each transaction, helping financial institutions track the flow of funds and identify potential money laundering acts (Thommandru & Chakka, 2023). This technology is effective in monitoring cross-border transactions and intricate flows of funds, and particularly so in thwarting money launderers in their attempt to transfer illegally gained financial assets through virtual currencies or other channels (Jiang et al., 2024). In addition, blockchain technology offers regulatory agencies more transparent access to data, enabling them to obtain transaction data in real time from financial institutions' blockchain platforms (Anti-Money Laundering Research Group of the People's Bank of China, 2020).

Biometric Technology

Biometric technology is defined as the use of individually distinctive physiological and behavioral traits for authentication purposes. Fingerprint, facial, iris, and voice recognition are all examples of biometric technology (Ji et al., 2023). Biometric technology is effective in addressing the gaps in the traditional identity verification mechanism, such as the inability to spot fake identities or misused identities. For instance, facial recognition can be used in scenarios like bank account opening and transaction verification to ensure that the actor is the actual customer. Biometric technology-based identity verification devices also aid financial institutions in implementing CDD and AML regulations to meet compliance requirements.

In the actual AML work, biometric technology is integrated with other technologies, such as big data and machine learning, to augment the strength of monitoring and advance warning. Financial institutions combine biometric data (on fingerprints, faces, voices, etc.) with transaction data (on transaction sums, times, locations, etc.) to build an all-encompassing identity verification and transaction monitoring system. As a result, the system not only records the sum and time of a transaction but also simultaneously verifies the customer's biometric features when it occurs. This connection enables financial institutions to verify in real time whether the transaction was enacted by the account holder, facilitating prevention of identity misuse (Ji et al., 2023). Furthermore, the combination of biometric technology with other technologies is not just to verify each individual transaction but also to warn about potential money laundering activities, based on the long-term monitoring of customers' transaction behaviors. For instance, financial institutions use facial recognition to record the customer's transactions at different times and identify, with the assistance of big data technology, changes in their transaction patterns. When a customer conducts abnormally frequent large transactions or repeatedly changes transaction locations in a certain period, the system can analyze these changes to estimate the possibility of money laundering (Utkina, 2023). In addition, biometric technology can also be integrated into the management of external data (such as tax records, business records, and judicial data) to further heighten AML outcomes. For example, financial institutions can share data with tax departments to match customers' biometric information with their tax records to ensure their transactions are legitimate and authentic. The system will issue an alert, suggesting the possibility of money laundering or other financial crime, when it detects discrepancies between a customer's identity details and tax records (Zhao & Tian, 2021).

Challenges in the Application of Technology to AML

Despite the benefits of technology to AML work, there exist significant issues in its application processes. First, the most severe challenge is about data privacy and security in AML. AML efforts involve sensitive customer information. While the use of technology improves the efficiency of information collection and processing in AML, it also increases the risks of breaching customers' privacy. For instance, blockchain technology can facilitate information sharing; on the other hand, its decentralized nature can lead to higher transparency of customer information, which may be utilized by financial crime perpetrators in their attempt to access personal information of bank customers, increasing difficulties for AML work (Hua & Wang, 2020). Moreover, amid the expansion of data and increase in complexity of technology, deficits in data protection may result in the exploitation of customer data by financial criminals for money laundering purposes.

Second, the limitations of technology can possibly impair AML outcomes. While big data and AI can enhance the efficiency and accuracy of monitoring in AML, these technologies may cause misjudgments when the quality of data applied is subpar. For instance, incomplete, inaccurate, and inconsistent data may compromise the model's training results and prediction performance (Jiang, 2024). Furthermore, algorithmic bias and inadequate model explainability are pronounced issues in the

application of technology in AML. While AI and machine learning models are capable of processing huge volumes of data and identifying intricate transaction patterns, they have a lower capacity to explain their decision-making processes, which may lead to misjudgments in AML-associated regulation.

Third, due to the sophistication and specialism of technology, as well as its high frequency of updating, financial institutions need to continually and heavily invest in technological research and development, system upgrading and maintenance, and staff training, which mean the high cost of technology-driven AML. Yet, small and medium-sized financial institutions, with limited financial and technical power, may not be able to apply advanced, AML-supportive technologies, resulting in unbalanced development of AML (Hua & Wang, 2020).

Fourth, the gaps in legislation and regulations have presented difficulties in the application of technology to AML. The new technological advancements may go beyond the existing framework of legislation, leading to regulation vacuums. For instance, the rise of cryptocurrencies has generated new channels for money laundering; yet, the formulation and implementation of relevant legislation and regulations have been delayed, leaving financial institutions inadequate legal backing in tackling money laundering through cryptocurrencies. Additionally, discrepancies in AML regulations between countries and territories add further complications to the AML compliance procedures of multinational financial institutions in their use of technology.

Lastly, technological advances also help financial criminals increase their capacity to conceal money laundering acts via technological means, such as circumventing monitoring by adopting cryptocurrency transactions or confusing online transactions (Wang, 2022), which intensifies the difficulty of AML. This requires financial institutions and regulatory agencies to continuously upgrade their technological tools to combat increasingly sophisticated money laundering manipulations.

To sum up, issues like data security risks, delayed legislation, technological complexities, algorithmic bias, and misuse of technology for unlawful purposes are posing serious threats to AML outcomes. Financial institutions, regulatory agencies, technology developers, and legislative bodies must collaborate to tackle these issues jointly. To ensure AML's effectiveness and justice, it is important to make full use of the benefits of technology while also modifying relevant legislation and regulations and strengthening data protection.

Conclusions and Discussions

This study explores the roles of technology in AML, focusing on analyzing the applications, benefits, and challenges of big data, AI, blockchain, and biometric technologies in this area. In the context of economic globalization, these emergent technologies present new opportunities for AML work with their extraordinary capabilities to enhance the efficiency of monitoring and the accuracy of identifying money laundering acts. Specifically, big data technology supports AML with its potent capacity for data collection and processing; AI technology strengthens AML actors' ability to detect complex money laundering behaviors by pattern recognition and predictive analytics; the blockchain, with its decentralized, immutable, and traceable nature, is effective in addressing issues like information silos; and biometric technology enables precise identity verification in AML. In response to the challenges in the application of technology to AML, the study puts forward the following suggestions: (i) Financial institutions, in collaboration with regulatory agencies, should establish robust data security mechanisms to safeguard the customers' personal information in their AML work. For example, encryption technologies can be employed for the purpose of safe storage and transmission of sensitive data, and stringent access controls and audit mechanisms should be executed to prevent data breaches. (ii) Financial institutions should make legitimate use of technology in AML based on their business scales and needs. Small and medium-sized financial institutions can reduce AML costs through joint procurement, technology sharing, and other means, while strengthening cooperation with large financial institutions and high-tech companies to improve their capability of applying technology to AML. In addition, financial institutions across the board need to increase mutual information sharing to improve the overall monitoring results in AML. (iii) The legislative bodies should accelerate the formulation and improvement of legislation and regulations on the application of emerging technologies to bridge regulatory gaps in AML. Regulatory agencies need to collaborate with other government departments (such as taxation, customs, and judicial authorities) in combating money laundering. (iv) It is also important to raise AML awareness in the popular public. AML publicity and education campaigns can heighten public understanding of the harm of money laundering while also fostering their vigilance against this crime. Regulatory agencies should encourage public involvement in AML, such as reporting suspicious financial activity in a timely manner.

The limitations of the study should be acknowledged. There may be certain discrepancies between the research findings of the study and the actual circumstances of technological applications in AML because it is an investigation based on literature review without involving field research. Moreover, the article is mainly about the general roles of emerging technologies in AML without delving into their specific outcomes and cost-effectiveness. Future studies should focus on empirical research to provide more credible evidence on the effects of advanced technologies on AML outcomes. Additionally, interdisciplinary research, which integrates law, economics, computer science, and other disciplines, is warranted for exploring more comprehensive solutions to money laundering in the digital era.■

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