

Volume 2, Issue 3

Research Article

Date of Submission: 10 June, 2026

Date of Acceptance: 07 July, 2026

Date of Publication: 15 July, 2026

The Impact of Digital Technologies on the Development of the Banknote Industry

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Citation: Lipkin, A. (2026). The Impact of Digital Technologies on the Development of the Banknote Industry. *Lett Econ Res Updates*, 2(3), 01-09.

Abstract

It's clear that digital technologies such as blockchain and generative AI will have a significant impact on the development of the securities and banknote printing industry. But will this impact be disruptive and destructive, or will it provide an evolutionary boost to the industry's development?

Blockchain

Trends in the use of blockchain technology indicate that digital funds or digital proof of identity, qualifications, rights, and permissions, securely stored in electronic wallets, will become the foundation of the next generation of not only government and financial, but also any other digital infrastructure.

Hybrid technologies will not only ensure the seamless integration of a printed document with secure digital data, but will also facilitate digital and visual verification of the presence of digital assets or the legitimacy of delegated authority.

The blockchain modernization of central bank cash will be a fateful event for the banknote industry, and banknote companies have the potential to bring this moment closer. To achieve this, it is necessary to develop a working prototype of a hybrid banknote based on the formulated technical requirements, as an offline value transfer mechanism for digital CBDCs, and propose this solution to central banks. Of course, in parallel with this, it is necessary to adapt our own production capacities to hybrid technologies, which will significantly reduce the cost of producing hybrid banknotes.

Ultimately, central banks developing their own CBDCs will begin to look for a manufacturer capable of modernizing their banknotes for a small price difference. If the banknote company partnering with the central bank fails to offer such a solution, the central bank will turn to another manufacturer, leading to a redistribution of the banknote market.

Generative AI

To be or not to be of Generative AI — that's the question facing every banknote designer today. How useful is GenAI for banknote design, and can it make a designer's job easier? Does AI-powered image generation affect the security of central bank cash?

Introduction

Today, counterfeiters' capabilities have reached such a professional level that even a forensic expert finds it incredibly difficult to detect a modern counterfeit without specialized equipment. Therefore, from the standpoint of simple visual verification by the user, further competition between the banknote industry and counterfeiters is becoming meaningless.

The average user can't physically tell the difference between a counterfeit banknote and genuine central bank cash. And because people are accustomed to visual verification, they rarely use modern authentication methods.

An evolution in the security of central bank cash and securities is needed that is not tied to the technological development of banknote printing technologies and/or the multiplication of printing security features. This evolution must provide every user with the ability to instantly authenticate a banknote at any time. This requires not only developing a convenient, fast, and virtually unnoticeable verification process for the user, but also engaging the entire country's population in regularly conducting such verifications.

Modernizing central bank cash and securities using blockchain technology is the optimal solution to this problem, allowing the country's population to not only instantly verify the authenticity of each banknote, but also conduct digital transactions with automated authentication in the background.

Moreover, reliable tracking of hybrid banknotes at every stage of intra-bank circulation will significantly expand the usual range of counterfeit checks through innovative legitimacy checks, protecting against any illegal actions with the banknote (from theft/robbery) and from financial fraud (from money laundering and bribery).

Hybrid Banknotes/Securities

Hybrid technologies are based on a traditional banknote or security, which is produced using a wide range of printing methods, banknote technologies and printing security features applied to a paper/polymer base.

A Hybrid Banknote/Security is a banknote or security that utilizes blockchain technology, has its own electronic wallet, and interacts with it using specialized software, while utilizing various technologies for interacting with the digital payment network:

By receiving and interpreting a radio signal with a private and/or public key from RFID/NFC chips embedded in a paper/polymer base.



Hybrid Banknote Using Contactless RFID/NFC Technologies

By scanning and recognizing machine-readable codes printed on paper/polymer with a private and/or public key.



Hybrid Banknote Using Machine-Readable Code Recognition Technology

Availability of Contactless RFID/NFC Technologies

Today, the introduction of microchips and electronic components into a paper/polymer base entails certain problems and difficulties both at the stage of production of hybrid banknotes/securities and during use.

The microchip has a certain thickness, exceeding that of the paper/polymer base, yet the microchip casing is quite fragile. During paper and/or polymer film production, the microchip casing can withstand the stresses generated. During offset printing, when the printed sheet with embedded microcircuits passes between the rollers of the offset printing machine, the microcircuit housing is also capable of withstanding excessive mechanical pressure.

However, when applying Intaglio, the pressure generated is much higher, which destroys the microchip casing. This rules out the use of Intaglio as a possible printing security method for hybrid banknotes/securities, making them an easy target for counterfeiters.

Excessively high mechanical loads at each stage of the production of hybrid banknotes/securities give rise to the problem of possible manufacturing defects in microchips, which can lead to partial or complete loss of information, and, consequently, to the loss of the private key.

Similarly, the reliability of microchips and electronic components, and therefore the security of private key storage, is affected by aggressive external factors:

- Exposure to moisture and aggressive environments;
- Exposure to powerful electromagnetic pulses or fields;
- Exposure to various types of radiation;
- Mechanical impacts, etc.

Furthermore, due to the wide potential for fraudulent activity against RFID/NFC chips (interception, copying, or duplication of information), it is recommended that they be used only for personalized hybrid documents. This means that contactless technologies cannot be used for the production of cash and bearer securities.

The key to preventing such digital fraud is the development of contactless technologies that can establish continuous, direct communication with the server storing the digital data of the hybrid document.

However, even the presence of a constant direct connection to the server doesn't mean that the instant verification by the User will become a rudiment. After all, in this case, counterfeiters would have the opportunity to create counterfeits by focusing their efforts on meticulously replicating the appearance and simulating a connection to the server.

The security of private key storage, due to potential manufacturing defects, aggressive external influences, and the possibility of fraudulent actions against RFID/NFC chips, requires mandatory instant verification for each deal, which, in turn, creates problems for the use of hybrid banknotes/securities based on RFID/NFC technology:

- Total control will significantly complicate and lengthen the transaction process, which will create certain inconveniences at hypermarket checkouts and bank branches that handle large amounts of cash.
- Due to total control of every cash transaction, anonymity will be completely lost.
- The need for a user device or additional equipment, internet access, and electricity will limit autonomy and make instant digital verification impossible during war, natural or man-made disasters, pandemics, and in remote areas.

Therefore, RFID/NFC technologies are still on the technological horizon. Their full implementation will require advances in chip manufacturing technologies, flexible LCD displays, electronic components, and power supplies, as well as the development of contactless technologies themselves.

Availability of Machine-Readable Code Technology

Hybrid banknotes and securities based on machine-readable code technology are produced exclusively using banknote printing technology. Thanks to blockchain technology, the electronic wallets of these documents will securely store digital funds or digital proof of identity, qualifications, rights, and permissions.

Interaction with an electronic wallet occurs through scanning and recognition by software of machine-readable codes with a private and/or public key, printed on a paper/polymer document. The machine-readable code with the public key is publicly available and is used for instant verification, while the machine-readable code with the private key is protected by comprehensive protection against unauthorized reading and is used to carry out digital transactions or change digital confirmation.

The highest level of security for hybrid banknotes/securities created using machine-readable code technology is achieved through the use of printing technologies, polymer substrates, and the complete absence of any electronic components or microchips in the production process, thereby eliminating the issue of physical security:

- No issues protecting electronic components from aggressive external factors;
- No issues related to the reliability of microcircuits;
- No issues with possible manufacturing defects or failure of electronic components;
- No security issues related to hacking contactless RFID/NFC technologies.

Machine-readable code technologies transform hybrid banknotes/securities into "cold," highly secure printed versions of



Blockchain-Based Certificates



Blockchain-Based Banknotes

Cryptobanknotes

Cryptobanknotes are banknotes upgraded with blockchain technology that use machine-readable code technology to interact with their own electronic wallet.

CBDC Cash is the emission of central bank cryptobanknotes of all denominations [2].

There are two types of cryptobanknotes, depending on whether they have access to their own e-wallet:

- **CryptoNOTE** is a type of cryptobanknote that has full access to its own e-wallet. CryptoNOTEs are fully functional and can be used to obtain cash of the highest denomination.
- **CryptoBILL** is a type of cryptobanknote that lacks full access to its own e-wallet. While CryptoBILLS lack full functionality, they offer the maximum possible lifespan and can be

CryptoBILL



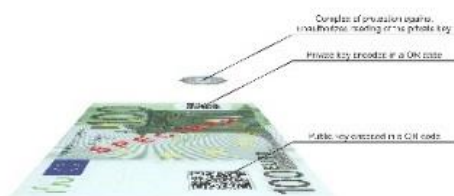


Key Differences Between CryptoNOTE and CryptoBILL

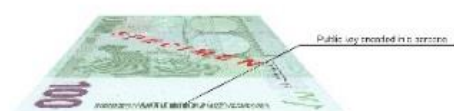
Methods of Encoding Machine-Readable Codes

Various machine-readable codes can be used to encode the private and/or public key: alphanumeric, linear, and two-dimensional barcodes. Moreover, the public key must be duplicated in different encoding systems on the front and back of the hybrid banknote/security.

Features of the technological process of production of CBDC CryptoNOTES with a face value of 100 EURO



Features of the technological process of production of CBDC CryptoNOTES with a face value of 100 EURO. Turnover of CBDC CryptoNOTE



The public key is used for instant verification and can be represented by any machine-readable code. The private key can be encoded using either standard machine-readable code or specially developed machine-readable code for use only with customized software.

Generative AI

In 2024, during the design process for a cryptobanknote, the need to use Generative AI arose [3]. This interesting experience allowed us to evaluate the potential of Artificial Intelligence for central bank cash design and identify the advantages and disadvantages of using GenAI.



Obverse of the 100 Maroon ODUWA Cryptobanknote



Reverse of the 100 Maroon ODUWA Cryptobanknote

The design of the 100 Maroon ODUWA Cryptobanknote is dedicated to the history of the Maroons' struggle for freedom in Jamaica in the 18th century.

There are virtually no graphic materials depicting the Maroons' confrontation with their Spanish and, later, British oppressors. Therefore, a decision was made to utilize the image generation capabilities of Artificial Intelligence.

At the same time, the goal was to preserve the historical identity of each image as much as possible. Therefore, photographs of museum exhibits from that era and region were used to highlight historically significant details of each image, such as 18th-century weapons.

Rare archival photographs of maroons and African slaves were used to train the AI. During image generation, the AI's main problem became apparent: a complete lack of understanding of the design and operation principles of any mechanical devices, particularly weapons, as well as a lack of understanding of the evolutionary characteristics of the

stages of development of these devices.

However, despite the problems and difficulties encountered during weapon generation, the AI performed quite well in landscape generation. The Caribbean Sea and the sandy shore of Jamaica, as well as the medieval fort, were rendered almost perfectly.

Thanks to AI-powered photo processing software, a bust of Queen Nanny, erected in honor of this vibrant Jamaican national hero, has been brought to life.



Bust of Nanny of the Maroons



AI-Generated Image of Nanny of the Maroons

A comparison of AI-generated images of Queen Nanny with the images used on current Bank of Jamaica banknotes clearly demonstrates the potential of Generative AI.



Obverse of the 2012 Jamaican 500 Dollar Banknote



Obverse of the 2022 Jamaican 500 Dollar Banknote

At the same time, it's clear that current AI capabilities for banknote design are still quite weak. It's absolutely impossible to generate fully finished security graphic elements for banknote designs, such as engravings, using AI.

However, GenAI can already be used today to generate raw graphic materials. However, one must be aware that there will be a significant gap between the AI-generated image and the finished graphic element suitable for use in banknote design, a process that requires the manual work of a banknote designer. Only after this significant refinement will it be possible to further process the graphic element using specialized software and transform it into a security graphic.

It's important to understand that using AI-generated images does not reduce the security of banknotes. Each generated image will subsequently be processed into a full-fledged engraving or security graphic element using specialized software, which guarantees adequate protection against partial and/or complete counterfeiting, both for traditional photographs or slides and for AI-generated images. At the same time, it's necessary to regularly purge AI-generated sessions to prevent public access to working materials.

Conclusion

The banknote industry must stop whispering the spell or mantra "Cash is king" and looking at the approaching digital future with panicked horror. The key to the digital future of the banknote industry is already in the hands of banknote companies – the main thing is to start actively using it.

Blockchain technology will pave the way for digital evolution not only for central bank cash but for the entire spectrum of documents and securities. Banknote companies need to modernize their production facilities and adapt their entire product range to hybrid technologies. This should begin now. The company that first realizes this will gain the largest share of the hybrid banknote market in the future. Ultimately, it is hybrid technologies that will pave the way for the digitalization of the banknote industry.

Regarding Generative AI, unfortunately, at this stage of development it will not greatly simplify the task for a banknote designer. However, GenAI is capable of significantly expanding the imagination and horizons of possibilities of a designer right now.

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