

# IMPACT OF ARTIFICIAL INTELLIGENCE APPLICATIONS IN REDUCING FRAUD DIAMOND IN COMMERCIAL BANKS: A GOVERNANCE CONTEXT

Arwa Hussein Amoush \*

\* Accounting Department, Faculty of Business, Al-Zaytoonah University of Jordan, Amman, Jordan

Contact details: Accounting Department, Faculty of Business, Al-Zaytoonah University of Jordan, P. O. Box 130, Amman 11733, Jordan



## Abstract

**How to cite this paper:** Amoush, A. H. (2025). Impact of artificial intelligence applications in reducing fraud diamond in commercial banks: A governance context [Special issue]. *Journal of Governance and Regulation*, 14(4), 332–341.  
<https://doi.org/10.22495/jgrv14i4siart10>

Copyright © 2025 The Author

This work is licensed under a Creative Commons Attribution 4.0 International License (CC BY 4.0).  
<https://creativecommons.org/licenses/by/4.0/>

**ISSN Print:** 2220-9352  
**ISSN Online:** 2306-6784

**Received:** 28.11.2024  
**Revised:** 30.04.2025; 30.05.2025; 31.10.2025  
**Accepted:** 25.11.2025

**JEL Classification:** C45, G21, M42, O33  
**DOI:** 10.22495/jgrv14i4siart10

This study investigates the impact of artificial intelligence (AI) applications, specifically deep learning, neural networks, and machine learning, on reducing fraud in Jordanian commercial banks, using the fraud diamond framework. The study looks at the growing threat of financial fraud, which has evolved with digital banking and increased technological sophistication. A descriptive-analytical approach was used, with data collected via an electronic questionnaire distributed to 216 employees from various departments of Jordanian commercial banks. After removing invalid responses, 190 valid questionnaires were analyzed with SPSS software. The findings show that AI applications have a statistically significant impact on reducing all four dimensions of the fraud diamond: pressure, opportunity, rationalization, and capability. Machine learning had the greatest impact of all AI dimensions, followed by neural networks and deep learning. The study emphasizes banks' growing interest in using AI for fraud detection and recommends the implementation of more advanced AI tools to improve operational efficiency and financial security. The study provides practical and theoretical insights for banking professionals, policymakers, and academic researchers working on financial fraud prevention in the digital age.

**Keywords:** Artificial Intelligence (AI), Jordanian Commercial Banks, Deep Learning, Neural Networks, Machine Learning, Fraud Diamond

**Authors' individual contribution:** The Author is responsible for all the contributions to the paper according to CRediT (Contributor Roles Taxonomy) standards.

**Declaration of conflicting interests:** The Author declares that there is no conflict of interest.

**Acknowledgements:** The Author thanks Justice Mundonde and Ezekiel Chitombo for their support and contributions to this study.

## 1. INTRODUCTION

The world has recently seen an upsetting growth in fraud diamond operations, economic crimes, and the persistence of financial crashes and commercial disruptions (Shiyyab et al., 2023). The most significant factor contributing to the emergence of new fraudulent practices, such as economic and fraud diamond, credit card fraud, and securities fraud, has been the decline of the worldwide economy as a result of the implications of COVID-19

and controversial events (Anastasi et al., 2021). The proliferation and diversification of fraud cases are accelerated by the growing need for electronic operations and activities. Even if the benefits that companies have been able to reap from integrating technology and digital methods into their workplaces have grown, so too have the hazards associated with these innovations (Al Otaibi & Mohamed, 2024).

Using technology and tools that are appropriate with the current state of affairs and aid in tracking

and overseeing operations on a continuous basis has become necessary for organizations, and banking institutions in particular, as a result of the increasing significance of digital innovation in the commercial environment (Basri & Almutairi, 2023). This has raised the significance of applying methods powered by artificial intelligence (AI), given the numerous benefits they offer, including time savings, speed, and accuracy in data analysis, and the extraction of clear insights and opinions with regard to the operations and activities performed by the bank (Salameh & Lutfi, 2021).

The application of AI technology has evolved throughout time, as seen by the fight against and prevention of financial fraud, which involves ongoing knowledge, data, task, and activity inspection, as well as an assessment of the veracity and integrity of money-related information (Okur et al., 2021).

Multiple goals stem from the main objective of this research, which is to show the effects subjected on using applications for AI in all its dimensions (deep learning, neural networks, as well as machine learning) on minimizing fraud diamond in Jordanian commercial banks. Highlighting the role that deep learning, neural networks, in addition to machine learning, have all played in decreasing fraud diamond in Jordanian commercial banks.

Risks are seen as an essential component of organizational work in general, and because of the nature of their operations, banks are among the companies most exposed to risks. Furthermore, because banks are seen as a key pillar and axis of the state's economy, the effects of these risks go beyond the operation and survival of the bank to include the financial stability and economic reality of the state's financial and economic sector. Owing to the unique nature of their operations, banks are always vulnerable to several types of fraud and operational hacking (Anastasi et al., 2021). The growth of advances in technology and the rise in electronic banking transactions have led to an increase in both the scope and severity of fraud cases. This has made it more difficult for them to identify, encounter, and conflict instances of fraud and safeguard the bank compared to the repercussions. Banks are now able to see the benefits of AI in the banking industry, including lower operational costs, enhanced productivity, higher profitability, risk management and anticipation, and fraud and deception detection (Dastres & Soori, 2021; Shaban & Omoush, 2025).

Thus, the purpose of this research is to investigate whether AI can effectively reduce the incidence of fraud diamond in Jordanian commercial banks. This study's fundamental problem is summarized by aiming to answer the following query:

*RQ1: Is there an effect of AI applications (deep learning, neural networks, and machine learning) in reducing fraud diamond in Jordanian commercial banks?*

This is the main question. Several additional inquiries flow from this main question is as listed below:

*RQ2: Is there an effect of deep learning in reducing fraud diamond in Jordanian commercial banks?*

*RQ3: Is there an effect of neural networks in reducing fraud diamond in Jordanian commercial banks?*

*RQ3: Is there an effect of machine learning in reducing fraud diamond in Jordanian commercial banks?*

These inquiries seek to assess the impact that different AI systems play in preventing fraud, with a particular emphasis on the complex problems that fraud diamond poses to the financial industry.

Consequently, creating a conceptual framework to describe the effects of AI and how to prevent fraud in Jordanian commercial banks is where the research's significance is based. The examination of research factors, such as deep learning, neural networks, as well as machine learning, is covered under this approach, and how such applications may influence corporate models and procedures. Along with how to make efficient use of these technologies for reducing the incidence of fraud diamond and guaranteeing the security of financial activities within Jordanian commercial banks.

The significance of this research stems from the enormous interest AI within organizations generally has attracted, and the advantages that are being gained from applying its technologies and tools to a variety of fields, particularly banking work, and from how it addresses fraud diamond, which is one of the most significant crimes that jeopardizes the economic health of commercial banks.

The goal of the research is to produce a scientific contribution that will serve as a resource for scholars and individuals interested in studying the topic of AI, along with its effects in decreasing the incidence of fraud diamond in commercial banks. This will contribute significantly to our understanding of the field and help shape the laws and regulations that are required to improve transparency and security in the banking industry.

This research is divided into the following parts. Section 2 reviews the theoretical framework of the study variables and presents previous studies and the development of hypotheses, and the study model. Section 3 explains the methodology used in the research. Section 4 presents the analytical results of the study tool and hypothesis testing, Section 5 discusses the results reached, and Section 6 presents the research conclusion.

## 2. LITERATURE REVIEW

Artificial intelligence technology is defined by its capacity to create programs that mimic human brains and abilities, enabling computers to execute a range of tasks involving comprehension, interpretation, reasoning, and possibly movement, along with carrying out different life abilities (Salameh & Lutfi, 2021). Since events suggest that nations that invest in implementing AI in their businesses will be an important driver of growth and succeed at generating information for the banking sector, AI is regarded as one of the most significant technological developments of the 21st century (Al-Araj et al., 2022). Banking institutions can use AI to their benefit in order to gain an edge over their competitors, increase their effectiveness, and consistently develop (Aziz & Andriansyah, 2023). Additionally, while preserving customer and bank security, it advances consumer knowledge, which quickens transactions and improves audit accuracy (Haddad, 2021).

One of the many objectives of AI is to allow machines to process data at the same time; this approach is comparable to how people solve issues (Al Omari & Al-Nimer, 2024). In addition, AI develops

the tools required to create and utilize information as well as store and analyze knowledge. In a practical way (Salameh & Lutfi, 2021). Furthermore, the goal of AI is to allocate scientific and practical knowledge as efficiently as possible, which helps to overcome issues with damage, scarcity, and forgetting (Ismail et al., 2023). Machines can function more intelligently and effectively in a range of jobs and obstacles by developing software that can carry out behaviors akin to human intelligence (Anastasi et al., 2021). The following are some of the most essential uses of AI:

- **Deep learning:** In a number of industries, particularly banking, deep learning is being utilized more and more to improve safety and fraud prevention (Mienye & Jere, 2024). Studies conducted in Jordanian commercial banks have demonstrated the enormous impact that AI, which includes deep learning techniques and security systems, can have on attempts to avoid fraud. These innovations aid in effectively predicting possible fraudulent transactions and learning from vast datasets (Wang et al., 2023).

- **Neural networks:** Neural networks are an attempt to create computer technologies that function in a manner similar to that of the human brain (Alzyoud et al., 2022). The capacity of these networks to learn through constant training and store that knowledge sets them apart (Juma et al., 2022). The neural network understands trends and knowledge by analyzing past data and drawing on prior experiences, leading to the ideal solution to the situation at hand (Shiyyab et al., 2023).

- **Machine learning:** A subset of AI is machine learning. It entails automating and enhancing computers' ability to learn from their previous work with no real programming or assistance from humans. Creating machine learning algorithms with various data and data-dependent methods is how this is accomplished, as well as the kind of job that will be carried out automatically (Ali et al., 2024). The computer's capacity to adjust according to shifts in information and the external environment is one of the benefits of machine learning (Bader et al., 2024). This capability makes it easier to improve analysis and forecasting efficiency and accuracy, as well as to make judgments more quickly and precisely. In addition, machine learning can identify trends as well as variations that are hard to find with conventional techniques, saving time and effort when processing and analyzing large amounts of data (Salameh & Lutfi, 2021).

Because of AI's precision, intelligence, and potency in preventing money laundering, businesses and financial institutions all over the world have turned to these apps to fight the laundering of cash (Chondough & Chondough, 2022). Consequently, the definition of financial fraud is the use of deception, manipulation, or fraud to obtain direct or indirect economic advantages for the offender or to enable others to do so, which ultimately causes financial harm to the victim (Saleh et al., 2022). In contrast, the Central Bank of Jordan (2023) views it as the act of using deceit to obtain an unjustified benefit through either direct or indirect procedures, alongside the ultimate goal of causing financial losses in order to obtain financial benefits for the criminal or to facilitate this for others.

According to Chen and Han (2023), financial fraud is a type of financial crime that seeks to influence and defraud financial activities and transactions by taking advantage of weaknesses in

systems of banking and economic operations in order to get money illegally or steal sensitive data. It generates financial losses and seeks to further personal benefit at the cost of others, clients, or organizations, eroding trust in the system. Banking and the economy as a whole (Shih et al., 2024) require banks to implement robust security measures to identify and thwart fraud in their data, including: two-factor authentication, keeping an eye on questionable activities, and utilizing methods of data analysis to spot unusual patterns and fraudulent activity. Additionally, banks must advise and counsel customers on how to safeguard their banking information and prevent falling victim to financial fraud (Bader et al., 2024).

Because of the goal of those who commit financial fraud to create new strategies and tactics that enable them to carry out immoral crimes without being readily discovered by regulatory authorities, financial fraud takes many different forms. Technological advancement has made it harder to detect fraud because it is now becoming harder to identify and follow illegal activity. It has also led to the rise of new financial fraud techniques, including email fraud, electronic identity theft, Internet fraud, and interfering with assets using information tools and advanced technology (Al-Own et al., 2023)

Employee fraud is a form of financial fraud in which workers purposefully make mistakes in accounting records in order to hide the theft of company assets and use them for personal gain (Omar et al., 2016). In order to achieve illegal gains, whether in the manner of taking advantage of the company's funds, exaggerating earnings, or hiding losses, administrative bodies within the organization commit intentional mistakes with the accounting books by influencing financial data and thus providing an inaccurate view of the company's financial status (Avortri & Aghanyo, 2020). Fraud involving the misappropriation, improper use, and theft of assets is one of the types of fraud that poses the greatest threat to organizations. It involves the abuse, misuse, and theft of assets, and those responsible are typically employees rather than management. The fraud begins with small and undetectable amounts, and that from in order to collect money illegally, the organization may be charged money in exchange for bogus services or products that were never received, misappropriate physical assets, seize intellectual property, or seize receipts. The capacity of the fraudsters to conceal their activities using obfuscating methods makes it challenging to identify this kind of fraud (Siahaan et al., 2019; Utomo & Mawardi, 2024). By purposefully deleting certain quantities, influencing costs, or applying accounting principles incorrectly, incorrect financial reporting refers to the intentional manipulation of financial statements with the goal of misleading consumers of reports on finances and increasing the cost of the business's stock in order in order to accomplish incorrect financial results.

The variations in financial fraud kinds indicate the variations in the intents and justifications behind these crimes. One of the most crucial analytical tools for understanding fraud's motivations and causes, as well as for spotting control system flaws, is the fraud triangle model created by scientist Cressey (1953). This model helps focus efforts on stopping fraud by reducing opportunities, strengthening control, and identifying the causes of motivations behind fraud.

According to this concept, a criminal's motivation and justification for his actions, as well as any unreported financial issues, are significant contributing factors to the crime (Al-Taie & Fakhri, 2019). Based to the fraud diamond model, the following are the driving forces behind financial fraud (Chukwuekwu, 2024).

### 2.1. Pressures and motivations

These encompass a range of elements influencing workers. Statement on Auditing Standards (SAS) Regulation No. 99 states that workers are subject to a variety of stresses in both their personal and professional lives (Auditing Standards Board [ASB], 2002). These pressures could come from the drive to succeed and make money, as well as the desire for a quick promotion. As management recognizes, these motivations may lead certain workers to turn to fraudulent activities in an effort to fulfill their demands or reach their objectives (Firdaus et al., 2022). Fraud typically occurs when someone is unable to control their financial debts and feels it is difficult to ask for assistance or to discuss their predicament with others. Pressures from the workplace or from personal relationships can also lead to fraud. A person's drive for more could be the driving force for deception. The impulse to conduct additional fraud may grow if the crime is committed covertly. Fraudulent behavior is typically motivated by internal factors. Fraud cases may rise as a result of institutional pressures, abuse of staff in their official position within the company, official cover, or offered legal protection. This is a reference to the employee abusing his legal immunity or the protection afforded by his political party membership in other potential instances of fraud and manipulation (Isahak et al., 2023).

### 2.2. Opportunity

When internal controls are lax and simple for workers and employees to breach, there may be a chance for fraud. Therefore, since the likelihood of fraud is directly correlated with the quality of this system, it is the duty of the bank's leadership and important supervisors to create an effective internal control system. It is evident that the incidence of fraudulent activities and the efficacy of internal control systems are inversely correlated; in other words, the more robust and stringent the system, the less room there is for fraud and manipulation (Chukwuekwu, 2024). As a result, the system for internal control is considered to be an important component in lowering the likelihood that fraud would occur. A lack of internal controls appears to have been the root cause of 35% of the fraud incidents documented (Chukwuekwu, 2024).

### 2.3. Justifications (rationalization)

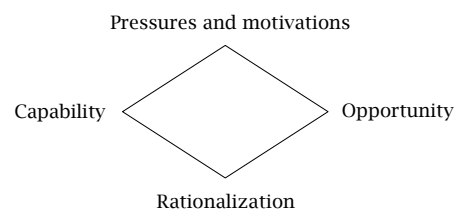
A lot of con artists utilize justification techniques to shield their employment crimes from scrutiny. They tell themselves that things were not as bad as they look and that they were carrying out their duties and expectations in line with the organization's goals for its success. When the company succeeds, some employees look for financial compensation; if this is not received, they turn to other ways to get money. Because the reasons for these behaviors are frequently

complicated and based on a variety of personal factors, it should be underlined that each employee presents a set of arguments for their choices (Chukwuekwu, 2024).

### 2.4. Capability

All three elements of fraud now include capability as well. Opportunity is the gateway to fraud, and people are drawn to it by pressure and rationalization. The capacity to spot an opportunity and seize it on a regular basis is one of the factors contributing to fraud. Chances and pressure together might help people create acceptable excuses, but pressure alone can also drive people to look for chances. But unless there was a genuine ability to commit fraud, none of these characteristics by themselves result in fraud (Dahir, 2025).

Figure 1. Fraud diamond



Source: Authors' elaboration based on Wolfe and Hermanson (2004).

Employing a solid and efficient system of internal controls, assessing risk indicates associated with employee behavior, working conditions, and wages, putting strict policies and procedures in place to verify and inspection economic records and information, safeguarding the business's cash and assets, depending on an unbiased outside auditor to identify and avoid any fraud in the preparation of financial reports, implementing openness regarding financial reporting processes, enhancing ethical culture, and encouraging staff to uphold professional ethical standards are all effective ways to detect and combat financial fraud, regardless of the type, justifications, and motivations. Thanks to its capacities in data processing, analysis of patterns, as well as abnormal behavior detection, as well as offering processes that enhance fraud detection and decrease manipulation or counterfeiting of economic information and statistics in the bank, AI can also play a crucial and beneficial part in decreasing fraud diamond in banks while strengthening safety and trust in the financial system.

Alzyoud et al. (2022) study focused on the operational and service delivery inefficiencies that Jordanian commercial banks experienced, which raised costs and caused customer discontent. The study discovered that the banks' service efficiency was greatly enhanced by the application of AI in the areas of fraud detection, risk assessments, and automation of repetitive jobs. AI helped banks increase overall operational performance, decrease human mistake rates, and streamline procedures, all of which led to higher customer satisfaction and better banking services.

Another report by Qasaimeh and Jaradeh (2022) tackled the problem raised by the fact that Jordanian commercial banks were unable to implement adequate cyber governance, making them open to internal fraud and cyberattacks. This study

investigated how improving fraud detection and fortifying cybersecurity protocols could support the governance framework through the use of AI applications like expert systems and neural networks. Banks were able to improve overall governance and fraud prevention efforts by incorporating AI into their governance policies, which allowed them to better spot abnormalities, monitor transactions, and protect their systems from cyber-attacks.

The fraud diamond theory, which looks at elements like pressure, opportunity, rationalization, and capability in fraudsters, was combined with AI in Firdaus et al. (2022) to address the growing issue of internet transaction fraud in the banking industry. AI was used to analyze human psychological triggers in online transactions to predict and identify fraudulent activities. Banks were able to detect fraud more quickly and correctly by combining behavioral analysis and machine learning, which greatly decreased the risk of internal and external fraud.

The goal of the study by Almustafa et al. (2023) was to enhance the fraud detection and credit risk management procedures in Jordanian commercial banking institutions, since the previous approaches were laborious and error-prone. Banks have been able to increase the precision of credit evaluations, anticipate market risks more accurately, and stop fraud by incorporating AI technology like machine learning and predictive analytics. The study by Shen (2024) demonstrated how AI-driven solutions greatly enhanced financial forecasting, risk validation, and overall operational efficiency in banks. This, in turn, led to increased financial performance and the avoidance of fraud.

This study looked into how AI may help lower the frequency of cybercrimes in Jordanian banks in response to a study by Salameh and Lutfi (2021) that emphasized the growing threat of these incidents. Through the use of AI technology, banks were able to identify and stop cyber attacks in real time, including expert systems, neural networks, and genetic algorithms. Large amounts of transaction data were evaluated by AI systems to find anomalies, which helped banks react more quickly to possible cybercrime activity. This greatly enhanced cybersecurity and decreased the number of fraud events (Salameh & Lutfi, 2021; Al Omoush et al., 2025).

The application of AI to help cybersecurity measures in combating fraud in Jordanian commercial banks was the subject of a study conducted by Tariq et al (2024). The National Institute of Standards and Technology (NIST) cybersecurity framework was utilized to gather information from 173 information technology administrators. The study showed that by employing biometric technologies, multi-factor authentication, and online transaction monitoring, AI-based cybersecurity solutions, especially in the detection function, were crucial in reducing fraud. The outcomes demonstrated how well AI works to support fraud protection measures in the banking industry.

In a study conducted by Odufisan et al. (2025) to explore the potential of AI technologies, namely machine learning and deep learning, in detecting and preventing fraud in Nigeria, it was concluded that by leveraging AI's continuous learning capabilities, organizations can adapt to new fraud situations and types. The study revealed that increased efficiency, improved accuracy, and proactive risk mitigation are among the most significant benefits of using AI in fraud detection.

A study by Harry and Khan (2024) provided evidence of the increasing reliance on advanced technologies such as machine learning and big data analytics in the banking sector, as these technologies provide strong and effective protection against all forms of advanced threats.

In a study by Sekar (2025), which aimed to clarify the importance of integrating AI with cloud data engineering to create effective fraud detection systems, it was found that the combination of advanced machine learning models, powerful cloud infrastructure, and real-time data processing capabilities has revolutionized how organizations detect and prevent fraudulent activity. As fraud methods continue to evolve, the adaptability and intelligence of these systems prove critical to maintaining effective defense mechanisms.

Previous studies have revealed the importance and role of AI and its various technologies in reducing fraud cases despite their development. They have also contributed to mitigating the risks proactively resulting from them. This study comes to focuses on the elements of fraud, which are: pressures and motives, opportunity, justifications (rationalization), and capability to try to prove the ability of AI technologies to mitigate these elements, and thus reduce fraud. Based on previous studies, the following hypotheses were formulated:

*H1: There is no statistically significant effect at a significant level ( $0.05 \geq \alpha$ ) of AI applications in its dimensions (deep learning, neural networks, machine learning) in reducing fraud diamond in Jordanian commercial banks.*

The following supporting hypotheses flow from this main hypothesis:

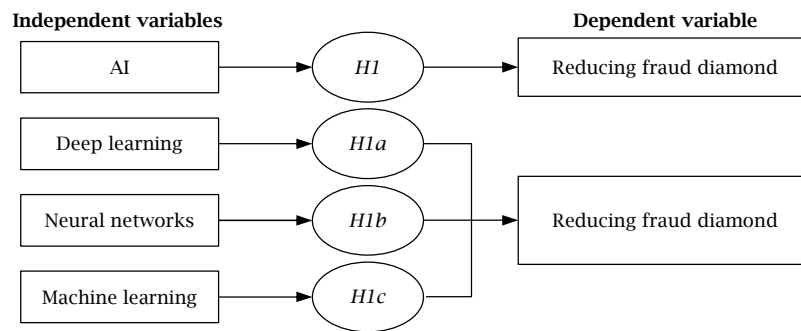
*H1a: There is no statistically significant effect at a significant level ( $0.05 \geq \alpha$ ) of deep learning in reducing fraud diamond in Jordanian commercial banks.*

*H1b: There is no statistically significant effect at a significance level ( $0.05 \geq \alpha$ ) of neural networks in reducing fraud diamond in Jordanian commercial banks.*

*H1c: There is no statistically significant effect at a significant level ( $0.05 \geq \alpha$ ) of machine learning in reducing fraud diamond in Jordanian commercial banks.*

The relationship between AI technologies (deep learning, neural networks, and machine learning) and reducing fraud elements is translated through the following figure, which represents the study model.

Figure 2. Study model



Source: Authors' elaboration.

### 3. RESEARCH METHODOLOGY

A questionnaire was designed to measure the research variables and confirm the correlations between them. The researcher was unable to use the interview method with some members of the study sample due to the nature of their work and the size of the tasks assigned to them. The descriptive analytical approach was employed in this study to describe and analyze the phenomena under investigation, and an inductive approach was also used through a review of the literature and previous studies. Up to the end of 2023, 12 banks — all commercial banks listed on the Amman Stock Exchange — were the target. Branch managers, customer service, financial department employees, loan employees, and information and software systems were the categories from which the research sample was chosen. After distributing 216 electronic

questionnaires, collecting 198 questionnaires, and excluding eight owing to answer similarity, the total number of completed questionnaires was 190, which may be statistically analyzed with the use of SPSS software.

The questionnaire was designed to gather quantitative data by using a five-point Likert scale to indicate the degree of agreement or disagreement with the offered statements and paragraphs. Five levels are: Strongly agree = 5, Agree = 4, Neutral = 3, disagree = 2, Strongly disagree = 1 are included in the scale. This scale aids in the accurate and efficient analysis of data, allowing for the accurate and reliable evaluation of the outcomes and the provision of insightful information. It facilitates the interpretation and analysis of the information gathered from the study sample participants' responses. The following Eq. (1) was applied.

$$\text{Materiality} = \frac{\text{The upper limit of the scale} - \text{The lower limit of the scale}}{\text{Number of scales}} = \frac{1 - 5}{3} = 1.33 \quad (1)$$

A five-point Likert scale was used to estimate the level of interest and practice of banks in the research variables, where the levels were classified as follows:

- High level: Ranging between 3.66 and 5.00.
- Medium level: Ranging between 2.33 and 3.66.
- Low level: Ranging between 1 and 2.33.

#### 3.1. Cronbach's alpha coefficient test

This study employed a descriptive-analytical method to investigate the role of AI applications in reducing fraud diamond in Jordanian commercial banks. A structured questionnaire was distributed electronically to bank employees across various departments. The collected data were analyzed using SPSS software.

To ensure the reliability of the measurement tool, a Cronbach's alpha test was conducted to evaluate the internal consistency of the items used to assess the study variables. The results are shown in Table 1.

Table 1. Internal consistency coefficient test

No.	Dimensions	Alpha value
1	Deep learning	0.851
2	Neural networks	0.858
3	Machine learning	0.881
	AI	0.929
	Reducing fraud diamond	0.901
	Search tool	0.931

Source: Authors' elaboration using SPSS software.

All values are more than 0.70 since the values of Cronbach's alpha for the dimensions of AI varied from 0.851–0.881, the independent variable (AI) had a value of 0.929, the dependent variable, *Reducing fraud diamond*, had a value of 0.901, and the research tool's alpha value was 0.931. This indicates the reliability of the study tool and its potential use in statistical analysis.

#### 3.2. Multicollinearity test

This test indicates that if the correlation value is greater than 0.80, there is an issue with multicollinearity. The following table shows the correlation matrix of AI dimensions.

Table 2. Correlation matrix of AI dimensions

Dimensions	Deep learning	Neural networks	Machine learning
Deep learning	1.000		
Neural networks	0.645**	1.000	
Machine learning	0.609**	0.552**	1.000

Note: \*\* indicates that the correlation is statistically significant at the 1% level ( $p < 0.01$ ).

Source: Authors' elaboration using SPSS software.

The correlation coefficient between *Deep learning* and *Neural networks* is 0.645, which is less than 0.80, meaning that there is not a multi-linear relationship between the variables. Since the correlation coefficients between expert systems

and *Machine learning* and *Neural networks* and *Machine learning* also emerged (0.609 and 0.552, respectively), all the numbers are less than 0.80. This implies that there is no problem with high multicollinearity (Gujarati, 2003). The variance inflation factor (VIF) and tolerance tests were conducted to confirm the previous result.

**Table 3.** Results of the test of the VIF and the permissible variance

Dimensions	VIF	Tolerance
Deep learning	2.150	0.465
Neural networks	2.604	0.384
Machine learning	2.147	0.466

Source: Authors' elaboration using SPSS software.

According to the results of the multiple linear correlation analysis, the VIF of *Deep learning* reached 2.150 and tolerance 0.465, and the VIF of *Machine learning* reached 2.147 and tolerance 0.466,

while the VIF of *Neural networks* reached 2.604 and tolerance 0.384. This confirms that there is no problem with a multi-linear correlation between the variables because the tolerance value must range between 0.1-1, and the VIF values must lie between 1-10.

## 4. RESULTS

### 4.1. Description of research variables

The relative importance of the independent variable was high, as the arithmetic average was 3.764. *Deep learning* took first rank with an average of 3.921 with high relative importance, while *Neural networks* took last rank with an average of 3.521 and medium relative relevance. The arithmetic average of the *Reducing fraud diamond* was 3.756, and a high relative importance.

**Table 4.** Arithmetic averages and materiality for dimensions of AI

No.	Dimensions	Arithmetic average	Standard deviation	Rank	Materiality
1	Deep learning	3.921	0.133	1	High
2	Neural networks	3.521	0.147	3	Medium
3	Machine learning	3.851	0.210	2	High
AI		3.764	0.217	-	High
	Reducing fraud diamond	3.756	0.210	-	High

Source: Authors' elaboration using SPSS software.

### 4.2. Hypothesis testing

Table 5 shows that there is a statistically significant relationship between the variable AI and the variable *Reducing fraud diamond*, as 59.4% of the variance in

*Reducing fraud diamond* can be explained by applications of AI combined. There is a significant impact of all applications of AI (*Deep learning*, *Machine learning*, *Neural networks*) in *Reducing fraud diamond*.

**Table 5.** Regression analysis of AI's effect on *Reducing fraud diamond*

Dependent variable	Model summary		Analysis of variance (ANOVA)			Coefficients				
	Correlation coefficient R	Coefficient of determination R <sup>2</sup>	Calculated F-value	Df	Sig F*	Independent variables	B	Std. error	Calculated T	Sig t*
Reducing fraud diamond	0.771	0.594	199.289	3	0.000	Deep learning	0.171	0.052	3.288	0.000
						Neural network	0.248	0.040	6.200	0.000
						Machine learning	0.441	0.057	7.737	0.000

Note: \* The effect is statistically significant at the level ( $\alpha \leq 0.05$ ).

Source: Authors' elaboration using SPSS software.

Therefore, we reject the main hypothesis and accept the alternative hypothesis. There is a statistically significant effect at a significant level ( $0.05 \geq \alpha$ ) of AI applications in its dimensions (*Deep learning*, *Neural networks*, *Machine learning*) in *Reducing fraud diamond* in Jordanian commercial banks.

Referring to the values of the regression coefficients in Table 5, it is clear that *Deep learning* is directly related to *Reducing fraud diamond*, as the value of the coefficient B reached 0.171, and this value is considered significant, as the calculated T-value reached 3.288 at the significance level (Sig. t = 0.000), which is less than 0.05, and this indicates the existence of a significant effect of *Deep learning* in *Reducing fraud diamond*.

Also, it is clear that *Neural networks* is directly related to *Reducing fraud diamond*, as the value of the coefficient B reached 0.248, and this value is considered significant, as the calculated T-value reached 6.200 at the significance level (Sig. t = 0.000),

which is less than 0.05, and this indicates the existence of a significant effect of *Neural networks* in *Reducing fraud diamond*.

In addition, it is clear that *Machine learning* is directly related to *Reducing fraud diamond*, as the value of the coefficient B reached 0.441, and this value is considered significant, as the calculated T-value reached 7.737 at the significance level (Sig. t = 0.000), which is less than 0.05, and this indicates the existence of a significant effect of *Machine learning* in *Reducing fraud diamond*.

## 5. DISCUSSION

The growing interest of Jordanian commercial banks in AI and its advanced applications reflects the strategic shift in the banking sector towards adopting modern digital technologies to address contemporary challenges. This interest comes in the context of banks' efforts to enhance their operational efficiency and improve the customer

experience. AI technologies enable more accurate analysis of big data and faster, smarter decision-making. The focus on deep learning is particularly significant because it enables these banks to develop advanced predictive models capable of detecting complex patterns in financial data, enhancing their ability to combat sophisticated fraud. Machine learning plays a pivotal role in automating routine banking operations and improving credit risk assessment, contributing to reduced costs and increased accuracy.

Natural language processing occupies a special place in this digital transformation, representing a vital bridge between technical systems and human users. With this technology, banks can improve their interactions with customers across digital channels, such as developing intelligent virtual assistants capable of understanding complex queries and responding in natural language. Natural language processing also enables sentiment analysis from customer comments and reviews, providing banks with valuable insights into customer expectations and satisfaction levels. This integration of various dimensions of AI reflects Jordanian banks' vision for building smarter and more secure banking systems, while preserving the human aspect of banking transactions. This focus also demonstrates the Jordanian banking sector's awareness of the importance of digital transformation in enhancing its competitiveness and responding to customer demands in the era of the digital economy.

The growing interest of Jordanian commercial banks in mitigating fraud indicates a strategic shift in financial risk management as they seek to address the security challenges of the digital banking environment. This trend also reflects a deep awareness of the growing risks of cybercrime and the evolution of fraud methods. This focus also demonstrates the Jordanian banking sector's commitment to strengthening trust with customers and investors and preserving the reputation of the banking and financial system.

AI is showing a significant positive impact in combating financial fraud by analyzing big data and identifying abnormal patterns in real time. Jordanian banks use AI algorithms to monitor suspicious transactions, reducing the chances of fraudulent operations. This also contributes to enhancing cybersecurity by detecting hacking or phishing attempts. These technologies enable banks to adapt to evolving fraudulent methods, enhancing customer confidence and maintaining the stability of the banking sector. Additionally, AI improves the efficiency of internal audit processes, reducing operational costs associated with fraud.

Deep learning is one of the most effective AI tools for fraud detection, helping analyze massive amounts of data to identify hidden patterns and monitor unusual customer behavior. It also helps analyze images and signatures to detect fraud in banking documents. These models become more accurate over time thanks to continuous learning from new data, making them a vital tool for banks in combating sophisticated financial fraud.

Natural language plays an important role in analyzing text and voice conversations between customers and banks to detect suspicious content and identify phishing or fraud attempts on social media. Customer complaints are also analyzed to detect any inconsistencies or unusual patterns that may indicate fraudulent activity. Additionally, it

contributes to the development of intelligent virtual assistants capable of recognizing suspicious tone of voice or phrases during customer interactions, enhancing security and providing a smoother customer experience.

Machine learning improves the efficiency of fraud detection systems by analyzing historical data and predicting suspicious transactions based on past patterns. Jordanian banks use machine learning models to classify risks and identify accounts or transactions that require manual review. This technology also helps automatically update fraud detection rules to keep pace with new methods.

The study recommends that Jordanian commercial banks enhance collaboration with academic institutions and research centers to develop specialized AI models for detecting financial fraud, with a focus on local challenges, and invest in specialized training programs for bank employees to enable them to understand and operate AI systems efficiently. Hybrid systems that combine deep learning and natural language processing techniques must also be developed to analyze unusual behavior across various banking channels.

Jordanian banks also need to modernize their technological infrastructure to support advanced AI systems, with a focus on real-time data processing. They also need to enact specific banking legislation regulating the use of AI in combating fraud, while establishing an ethical framework governing data collection and analysis. Customer awareness programs should also be developed about the risks of electronic fraud and how to identify suspicious attempts. It also recommends establishing a specialized unit in each bank to monitor the performance of AI systems and continuously update them, while conducting periodic tests to ensure their effectiveness in combating new fraud methods.

Future research can improve knowledge in a number of areas, even though this study shows how well AI applications — deep learning, neural networks, and machine learning — reduce fraud in Jordanian commercial banks. First, longitudinal research could evaluate AI systems' long-term efficacy and flexibility in rejecting changing fraud tactics. Second, future research might look into integrating additional AI technologies like blockchain-based fraud detection, natural language processing, and genetic algorithms. Comparative studies between traditional banks and fintech companies can also highlight issues and solutions unique to a given industry. Furthermore, broadening the research to incorporate cross-national analyses in the Middle East or other emerging economies could aid in determining the cultural and legal elements affecting the use of AI in fraud prevention.

## 6. CONCLUSION

The research aimed to investigate the impact of AI applications, specifically in the areas of deep learning, neural networks, and machine learning, on reducing fraud in Jordanian commercial banks. The study utilized SPSS software to analyze the data, applying various statistical techniques, including the Cronbach's alpha coefficient test, correlation analysis, multicollinearity tests, and stepwise regression analysis.

The results of the descriptive analysis revealed a significant increase in the adoption of AI applications by Jordanian commercial banks.

Moreover, the study found a statistically significant effect of AI applications, across all dimensions (deep learning, neural networks, and machine learning), on reducing financial fraud.

Additionally, the analysis indicated a growing interest among Jordanian commercial banks in mitigating financial fraud. The research recommended that banks should further explore and adopt other AI technologies, such as intelligent agents, genetic algorithms, and advanced deep learning methods, to enhance operational efficiency and further reduce the risk of financial fraud.

The study represents a framework of reference for researchers in the field of financial security and banking technology, providing an applied model for how to employ AI technologies in emerging banking environments. It also opens new avenues for research in the field of integrating intelligent

systems with behavioral risk management, and can be built upon to develop more specialized models for detecting fraud patterns specific to each banking context.

This study faced some limitations that should be taken into account in subsequent research, the most important of which is the difficulty of using the interview method to collect data from the study sample members, and the fact that not all sample members responded to the study tool.

Research calls for a comprehensive approach that combines technical development, employee awareness, and regulatory policy changes to maximize the potential of AI in combating financial fraud, while emphasizing the importance of balancing technological innovation with data privacy protection.

## REFERENCES

- Al Omari, B., & Al-Nimer, M. (2024). Harnessing artificial intelligence to strengthen financial reporting quality in developing economies: A mediated model with internal controls in Jordanian banks. *Journal of Infrastructure, Policy and Development*, 8(8), 1–32. <https://doi.org/10.24294/jipd.v8i8.5806>
- Al Omoush, K., Lassala, C., & Ribeiro-Navarrete, S. (2025). The role of digital business transformation in frugal innovation and SMEs' resilience in emerging markets. *International Journal of Emerging Markets*, 20(1), 366–386. <https://doi.org/10.1108/IJOEM-12-2022-1937>
- Al Otaibi, D., & Mohamed, E. (2024). The role of digital auditing in enhancing the efficiency of detecting error and financial fraud. *Arab Journal of Literature and Humanities*, 8(32), 633–658. <https://doi.org/10.21608/ajahs.2024.365890>
- Al-Araj, R., Haddad, H., Shehadeh, M., Hasan, E., & Nawaiseh, M. (2022). The effect of artificial intelligence on service quality and customer satisfaction in Jordanian banking sector. *WSEAS Transactions on Business and Economics*, 19(12), 1929–1947. <https://doi.org/10.37394/23207.2022.19.173>
- Ali, S., Allaymoun, M., Al Astal, A., & Saleh, R. (2024). Detecting and preventing fraud in financial transactions: A case study on big data analysis at Kareem Exchange Company. In A. Hamdan, B. Alareeni, & R. Khamis (Eds.), *Digital technology and changing roles in managerial and financial accounting: Theoretical knowledge and practical application* (Vol. 36, pp. 305–317). Emerald Publishing Limited. <https://doi.org/10.1108/S1479-351220240000036028>
- Almustafa, E., Assaf, A., & Allahham, M. (2023). Implementation of artificial intelligence for financial process innovation of commercial banks. *Journal of Social and Environmental Management*, 17(9), 1–17. <https://www.researchgate.net/publication/373918604>
- Al-Own, B., Saidat, Z., Kasem, J., & Qasaimeh, G. (2023). Impact of digital payment systems and blockchain on economic growth. In *2023 International Conference on Business Analytics for Technology and Security (ICBATS)* (pp. 1–5). Institute of Electrical and Electronics Engineers (IEEE). <https://doi.org/10.1109/ICBATS57792.2023.10111140>
- Al-Taie, B., & Fakhri, H. (2019). The role of industry specialization of audit companies in detecting fraud in the financial statement. *Journal of Economics and Administrative Sciences*, 25(114), 575–602. <https://doi.org/10.33095/jeas.v25i114.1751>
- Alzyoud, S., Al-Naimi, A., & Al-Gasaymeh, A. (2022). The impact of artificial intelligence on the efficiency of banking service: Evidence from Jordanian commercial banks. *Journal of Southwest Jiaotong University*, 57(6), 699–704. <https://doi.org/10.35741/issn.0258-2724.57.6.62>
- Anastasi, S., Madonna, M., & Monica, L. (2021). Implications of embedded artificial intelligence-machine learning on safety of machinery. *Procedia Computer Science*, 180, 338–343. <https://doi.org/10.1016/j.procs.2021.01.171>
- Auditing Standards Board (ASB). (2002). *Consideration of fraud in a financial statement audit*. [https://www.iaa.si/Dokumenti/IIA\\_mesecni\\_sestanki/2012/120919/sas\\_no\\_99.pdf](https://www.iaa.si/Dokumenti/IIA_mesecni_sestanki/2012/120919/sas_no_99.pdf)
- Avortri, C., & Agbanyo, R. (2020). Determinants of management fraud in the banking sector of Ghana: The perspective of the diamond fraud theory. *Journal of Financial Crime*, 28(1), 142–155. <https://doi.org/10.1108/JFC-06-2020-0102>
- Aziz, L. A. R., & Andriansyah, Y. (2023). The role of artificial intelligence in modern banking: An exploration of AI-driven approaches for enhanced fraud prevention, risk management, and regulatory compliance. *Reviews of Contemporary Business Analytics*, 6(1), 110–132. <https://www.researchgate.net/publication/373489510>
- Bader, A., Abu Hajar, Y., Weshah, S., & Almasri, B. (2024). Predicting risk of and motives behind fraud in financial statements of Jordanian industrial firms using hexagon theory. *Journal of Risk and Financial Management*, 17(3), 1–27, Article 120. <https://doi.org/10.3390/jrfm17030120>
- Basri, W., & Almutairi, A. (2023). Enhancing financial self-efficacy through artificial intelligence (AI) in banking sector. *International Journal of Cyber Criminology*, 17(2), 284–311. <https://cybercrimejournal.com/menuscrypt/index.php/cybercrimejournal/article/view/251>
- Central Bank of Jordan. (2023). *Guide to combating financial fraud in the national payments system*. [https://www.cbj.gov.jo/ebv4.0/root\\_storage/en/eb\\_list\\_page/guidelines\\_on\\_combating\\_financial\\_fraud\\_within\\_the\\_national\\_payment\\_system-0.pdf](https://www.cbj.gov.jo/ebv4.0/root_storage/en/eb_list_page/guidelines_on_combating_financial_fraud_within_the_national_payment_system-0.pdf)
- Chen, Z., & Han, D. (2023). Detecting corporate financial fraud via two-stage mapping in joint temporal and financial feature domain. *Expert Systems with Applications*, 217, Article 119559. <https://doi.org/10.1016/j.eswa.2023.119559>

- Chondough, S., & Chondough, J. (2022). The moderating role of intellectual capital on the relationship between artificial intelligence and employee performance of the commercial banks in Nigeria. *Cross-Cultural Management Journal*, 24(2), 115-119. [https://seaopenresearch.eu/Journals/articles/CMJ2022\\_I2\\_4.pdf](https://seaopenresearch.eu/Journals/articles/CMJ2022_I2_4.pdf)
- Chukwuekwu, O. (2024). Fraud and performance of listed deposit money banks in Nigeria: Exploring the combined effects of fraud triangle and fraud diamond theories. *Journal of Business and Econometrics Studies*, 1(3), 1-8. <https://doi.org/10.61440/JBES.2024.v1.27>
- Cressey, D. R. (1953). *Other people's money: A study in the social psychology of embezzlement*. Free Press.
- Dahir, M. (2025). Prevalence of fraud in private sector of Somalia: Case Mogadishu business firms. *Asian Journal of Public Administration and Law*, 7(1), 10-22. <https://www.researchgate.net/publication/390122563>
- Dastres, R., & Soori, M. (2021). Artificial neural network systems. *International Journal of Imaging and Robotics*, 21(2), 13-25. <https://www.researchgate.net/publication/350486076>
- Firdaus, R., Xue, Y., Gang, L., & Sibte Ali, M. (2022). Artificial intelligence and human psychology in online transaction fraud. *Frontiers in Psychology*, 13, Article 947234. <https://doi.org/10.3389/fpsyg.2022.947234>
- Gujarati, D. N. (2003). *Basic econometrics* (4th ed.). McGraw-Hill
- Haddad, H. (2021). The effect of artificial intelligence on the AIS excellence in Jordanian banks. *Montenegrin Journal of Economics*, 17(4), 155-166. <https://doi.org/10.14254/1800-5845/2021.17-4.14>
- Harry, A., & Khan, A. (2024). Leveraging artificial intelligence and big data: A comprehensive examination of workforce performance enhancement, fraud detection in the petroleum and banking sectors, healthcare innovations, and ethical considerations in information management systems. *Multidisciplinary Journal of Science*, 3(5), 638-647. <https://media.neliti.com/media/publications/592403-leveraging-artificial-intelligence-and-b-95675f3c.pdf>
- Isahak, M., Roslan, N., Tahrim, N., Zawari, S., Najib, W., & Lajuni, N. (2023). Factors influencing fraudulent in financial reporting using fraud triangle theory in Malaysia: A conceptual paper. *International Journal of Academic Research in Business and Social Sciences*, 13(6), 1350-1361. <https://doi.org/10.6007/IJARBS/v13-i6/17291>
- Ismail, A. R., Ali, M. S., Alattar, K., Hasan, M., & Durrani, F. (2023). The role of artificial intelligence techniques in the digital transformation of Jordanian banking system. In B. A. M. Alareeni & I. Elgedawy (Eds.), *Artificial intelligence (AI) and finance* (pp. 72-82). Springer. [https://doi.org/10.1007/978-3-031-39158-3\\_7](https://doi.org/10.1007/978-3-031-39158-3_7)
- Juma, H. I., Raja, R. R., & Zaman, M. R. (2022). *Credit card fraud and bankruptcy detection using machine learning* [Doctoral dissertation, East West University]. <http://dspace.ewubd.edu:8080/handle/123456789/3837>
- Mienye, I., & Jere, N. (2024). Deep learning for credit card fraud detection: A review of algorithms, challenges, and solutions. *IEEE Access*, 4, 1-18. <https://doi.org/10.1109/ACCESS.2024.3426955>
- Odufisan, O., Abhulimen, O., & Ogunti, E. (2025). Harnessing artificial intelligence and machine learning for fraud detection and prevention in Nigeria. *Journal of Economic Criminology*, 7, Article 100127. <https://doi.org/10.1016/j.jeconc.2025.100127>
- Okur, M., Zengin-Karaibrahimoglu, Y., & Taşkın, D. (2021). From conventional methods to contemporary neural network approaches: Financial fraud detection. In K. T. Çaliyurt (Ed.), *Ethics and sustainability in accounting and finance* (Vol 3, pp. 215-228). Springer. [https://doi.org/10.1007/978-981-33-6636-7\\_11](https://doi.org/10.1007/978-981-33-6636-7_11)
- Omar, M., Nawawi, A., & Puteh Salin, A. (2016). The causes, impact and prevention of employee fraud: A case study of an automotive company. *Journal of Financial Crime*, 23(4), 1012-1027. <https://doi.org/10.1108/JFC-04-2015-0020>
- Qasaimeh, G., & Jaradeh, H. E. (2022). The impact of artificial intelligence on the effective applying of cyber governance in Jordanian commercial banks. *International Journal of Technology Innovation and Management*, 2(1), 68-86. <https://doi.org/10.54489/ijtim.v2i1.61>
- Salameh, R., & Lutfi, K. (2021). The role of artificial intelligence on limiting Jordanian commercial banks cybercrimes. *Accounting*, 7(5), 1147-1156. <https://doi.org/10.5267/j.ac.2021.2.024>
- Saleh, I., Marei, Y., Ayoush, M., & Afifa, M. M. A. (2022). Big data analytics and financial reporting quality: Qualitative evidence from Canada. *Journal of Financial Reporting and Accounting*, 21, 83-104. <https://doi.org/10.1108/JFRA-12-2021-0489>
- Sekar, R. (2025). Enhancing fraud detection through AI-driven cloud data engineering. *Management*, 16(2), 420-431. [https://doi.org/10.34218/IJITMIS\\_16\\_02\\_027](https://doi.org/10.34218/IJITMIS_16_02_027)
- Shaban, O. S., & Omoush, A. (2025). AI-driven financial transparency and corporate governance: Enhancing accounting practices with evidence from Jordan. *Sustainability*, 17(9), Article 3818. <https://doi.org/10.3390/su17093818>
- Shen, Q. (2024). AI-driven financial risk management systems: Enhancing predictive capabilities and operational efficiency. *Applied & Computational Engineering*, 69, 134-139. <https://doi.org/10.54254/2755-2721/69/20241494>
- Shih, Y. C., Dai, T. S., Chen, Y. P., Ti, Y. W., Wang, W. H., & Kuo, Y. (2024). Fund transfer fraud detection: Analyzing irregular transactions and customer relationships with self-attention and graph neural networks. *Expert Systems with Applications*, 259, Article 125211. <https://doi.org/10.1016/j.eswa.2024.125211>
- Shiyyab, F., Alzoubi, A., Obidat, Q., & Alshurafat, H. (2023). The impact of artificial intelligence disclosure on financial performance. *International Journal of Financial Studies*, 11(3), Article 115. <https://doi.org/10.3390/ijfs11030115>
- Siahaan, M., Umar, H., & Purba, R. B. (2019). Fraud star drives to asset misappropriation moderated by internal controls. *Journal of Southwest Jiaotong University*, 54(4), 1-10. <https://www.researchgate.net/profile/Rahima-Purba/publication/336208599>
- Tariq, E., Akour, I., Al-Shanableh, N., Alquqa, E., Alzboun, N., Al-Hawary, S., & Alshurideh, M. (2024). How cybersecurity influences fraud prevention: An empirical study on Jordanian commercial banks. *International Journal of Data and Network Science*, 8(1), 69-76. <https://doi.org/10.5267/j.ijdns.2023.10.016>
- Utomo, S. T., & Mawardi, W. (2024). The impact of ownership structure and company size on corporate financial fraud: An empirical study of manufacturing companies. *Corporate Law & Governance Review*, 6(4), 74-85. <https://doi.org/10.22495/clgrv6i4p7>
- Wang, H., Zheng, J., Carvajal-Roca, I., Chen, L., & Bai, M. (2023). Financial fraud detection based on deep learning: Towards large-scale pre-training transformer models. In H. Wang, X. Han, M. Liu, G. Cheng, Y. Liu, & N. Zhang (Eds.), *Knowledge graph and semantic computing: Knowledge graph empowers artificial general intelligence* (pp. 163-177). Springer. [https://doi.org/10.1007/978-981-99-7224-1\\_13](https://doi.org/10.1007/978-981-99-7224-1_13)
- Wolfe, D. T., & Hermanson, D. R. (2004). The fraud diamond: Considering the four elements of fraud. *The CPA Journal*, 74(12), 38-42. <https://digitalcommons.kennesaw.edu/cgi/viewcontent.cgi?article=2546&context=facpubs>