The digital butterfly effect: unleashing the Islamic Banking industry in a post-pandemic era

Hadjer Boulila[1*]

[1] University of Tlemcen, Department of Economics, Tlemcen – 13000, Algeria
Corresponding author: b.hadjer94@gmail.com
ORCID 0000-0002-1115-6065

Widad Metadjer [2]

[2] Al-Maktoum College of Higher Education, Dundee, Scotland, United Kingdom.
ORCID 0009-0009-7636-7451

Ibrahim Elsayed[1]

[1] Durham University, Stockton Rd, Durham DH1 3LE, United Kingdom.
ORCID 0000-0003-1469-3808

Seyf Eddine Benbekhti[1]

[1] University of Tlemcen, Department of Economics, Tlemcen – 13000, Algeria
ORCID 0000-0001-8500-5123

Abstract

This study draws on the parallelism between digitalization and the complexity of the Islamic banking industry (IBs) in a post-pandemic era. It examines the digital Butterfly Effect on the Islamic banking industry to promote tech-driven IBs through an empirical lens. The study constructs a Fintech adoption index (FADi) and uses a Bayesian vector Auto-Regressive model, causality tests and impulse response functions for yearly data from 2008 to 2022 to examine the possible magnified effect of adopting Fintech by the Islamic banking industry in Malaysia. Key findings suggest that embracing Fintech by the IBs enhances the profitability of the banks, which is measured by the return on asset and return on equity. In addition, the study reports a ripple effect of FADi on the broader spectrum of the Malaysian economy. This indicates that Fintech fosters economic growth, household consumption, financial and insurance services, and corporate taxes. On the other hand, Fintech adoption helps reduce the unemployment rate. The findings contribute to the literature by investigating the IB as a system within financial chaos theory and the possible Butterfly Effect triggered by Fintech adoption.

Keywords: Fintech, digital butterfly effect, chaos theory, Islamic banking, Bayesian VAR

1. Introduction

It is fascinating how a delicate thing such as a butterfly's wing flap may have the strength to start a tornado somewhere in the world; this concept is known as the butterfly effect; it was first introduced in the 1960s when a meteorologist at MIT modeling weather patterns revealed that a tiny rounding modification in his input parameters caused in enormously diverse weather proceedings (Lorenz, 2000). Further, the butterfly effect is used in various areas, including science, finance, mathematics, and biology. To illustrate, seemingly very small events may lead to enormous changes to a process or situation. Applying this concept to the Islamic banking (IB) system through a digital lens suggests that implementing financial technology tools into the operational processes of the IBs could have a ripple effect on the various areas of the market, economy, and environment(Abakah et al., 2023; Khan et al., 2021; Rafiki & Nasution, 2021; Rahim et al., 2023). Due to the unique framework of the IB institutions and the integration of ethical elements into their business model, IBs are sensitive to external and internal changes that may occur over time(Nawaz, 2017).

Pinning down the trajectory of the Islamic banking industry in a post-COVID era is very sophisticated work. Practitioners and economists scrutinize the Islamic banking industry from various aspects, taking apart different external and internal variables and aiming to map the determinants of the future of this growing industry. However, taking it all holistically and looking into the complexity of the Islamic banking industry might be the solution that would fit the intricacy of the phenomena. The complexity of the economic system, the increasing interactions of heterogeneous variables in a globalized world, the domino effect of the preceding financial crisis, and consequently, the gigantic financial losses of banking and financial institutions during the last years have led to the emergence of a fuller approach to analyzing the economy (Arthur, 1999; Nowotny, 2003; Awrey, 2012; Arthur, 2014). Looking back to the dramatic consequences of the financial crashes, the global financial crisis of 2008 is on the list; the later crisis exposed the blind spots left underexamined by the traditional finance theory, exhibiting, unfortunately, the negligence of the *'uncertainty'* of markets and exposing the lack of transparency. This triggered a investors' mind-shift in the financial sphere; the public started to look for an alternative to the traditional financial system, where transparency became the top priority (Rabbani, 2020); the journey into looking for a "*trustworthy*" business model paved the way for innovations and the emergence of a thirsty tech-savvy community. The race to reach the untapped Fintech market led to the birth of several upgraded digital services in the financial industry (Gomber et al., 2018), that spurs the market with novel fancy terminologies, to name a few of the services relatively newly born, such as artificial intelligence, Reg-tech, blockchain, cryptocurrency, smart banking, smart contract, peer to peer lending and many other *"nerdy"* terms, very appealing to the relevant public.

The Islamic banking industry is not an exception to the trend; indeed, technological developments are lowering the barriers to entry for entrepreneurs who want to operate in the Islamic Fintech sector (Ali et al., 2019; Khan, 2015; Lutfi and Ismail, 2016; Marzban et al., 2014; Taha and Macias, 2014; Torabi, 2017; Wahjono and Marina, 2017), especially after the onset of the COVID-19 pandemic, which pushed the financial sector to innovate more to facilitate digital transactions and to reduce in-person financial contacts and formalities. The ability to transform bulky data into usable information, the availability of tick-by-tick data, and the transparency characteristic of a multitude of Fintech tools and services helped economists and practitioners to test the presence of fractal patterns or nonlinearity in markets. The digitalization of the financial systems and the uniqueness of the Shariah-compliant banking industry bring under one umbrella a complex framework that might have dramatic consequences on the full economic situation of the country or region. Indeed, the Fintech ecosystem exhibits nonlinear features, dynamic behaviour, and very complex inner methodologies, with the exponential growth of this market grows the magnitude of its effect on other areas of the economy (Jinasena et al., 2020; Muthukannan et al., 2020).

Considering that Malaysia has a well-developed financial system and is one of the hot hubs for Fintech and Islamic finance (Tun-pin et al., 2019; Ab Razak et al., 2020; Sallah and Tasnim, 2022; Zakariyah et al., 2022), the influence of Fintech adoption on the broader spectrum of the economy is certainly significant. Undeniably, finance being embedded in the quasi totality of daily life interactions, certainly, in countries with the majority of the Muslim population, the adoption of Islamic Fintech can be quantified. It therefore may permit measuring the effect of tech on the IBs industry. The degree of sensitivity of IBs could be seen through the lens of the Butterfly effect; incorporating the Fintech element into this framework permits the articulation of a digital butterfly effect for the IBs and measuring the extent of the Fintech adoption by IBs on economic development in Malaysia.

This study builds on chaos theory in finance and examines the digital butterfly effect of financial technology adoption in the Islamic banking industry. Drawing on the parallelism between the digitalization of the finance industry and the complexity of the Islamic financial sector in a post-pandemic world. To ensure a comprehensive understanding of this phenomenon, this study is guided by the following primary research question:

"*How does adopting Fintech in the Islamic banking sector create a digital butterfly effect that influences financial performance metrics and broader economic indicators?*".

Accordingly, this paper aims to provide a holistic understanding of how Fintech adoption transforms the Islamic banking landscape, not only by enhancing financial performance metrics such as Return on Assets (ROA) and Return on Equity (ROE) but also by generating significant ripple effects across the broader economy. This includes assessing impacts on GDP growth, unemployment rates, household consumption, and corporate tax revenue. Ultimately, the study seeks to establish and quantify the digital butterfly effect of Fintech integration within the Shariah-compliant financial ecosystem.

To the best of our knowledge, this study is the first attempt to investigate the possible digital butterfly effect from an Islamic Fintech perspective, where the literature has predominantly focused on the general effects of Fintech on conventional banking systems, overlooking the unique characteristics and requirements of Islamic banking. By addressing this gap, our study provides novel insights into how digital innovations interact with Shariah-compliant financial practices, potentially leading to significant and previously unexplored economic outcomes. Additionally, the originality of this research lies in its dual focus on technological innovation and Islamic finance principles. It extends the application of the butterfly effect to a new domain and enhances the understanding of Fintech's role in shaping the future of Islamic banking.

The rest of the paper comprises a literature review, methods and data, empirical results, discussion, and conclusion with final remarks and recommendations for policymakers.

2. Literature review

2.1. Fintech Industry and the Islamic Economics Perspective

The development of the Fintech industry is expanding globally, presenting substantial opportunities for new financial technology companies. This potential can be realized by offering diverse financial services and earning the respect and trust of their clients. A significant part of this industry focuses on serving Muslim populations, which supports the spread of Islamic Fintech. Islamic Fintech complies with Shari'ah principles and models, applying foundational Islamic financial and economic principles in its solutions (Rabbani et al., 2020). Technological advancements in the financial sector have raised the need to develop innovative Islamic financial solutions that endorse rapid evolution. The Islamic Fintech has to be deployed to achieve the major umbrella of Islamic economics beyond finance and banking (Oseni and Ali, 2019).

The emergence of Fintech has huge chances to promote and introduce Islamic financial products, solutions, and institutions in alignment with the advantages of technology. Generally, in Islamic principles, every transaction is permissible unless prohibited solutions, products, or structures are engaged (Atiyah *et al.*, 2024). Therefore, as a pure concept, Fintech is Shari'ah compliant until an impermissible action or product is involved financially or operationally. According to Hasan et al. (2020), Shari'ah compliance is paramount in the potential integration of Fintech with Islamic finance. Islamic Fintech firms have made significant efforts to ensure their business models adhere to Shari'ah requirements by following universally applicable Shari'ah standards and undergoing regulatory audits. Fintech has opened the opportunities for Islamic finance and banking to go digital, which is privileging access to its services and facilities by employing advancing technologies, for instance, blockchain, machine learning (ML), and Artificial intelligence (AI) (Rabbani et al., 2020).

First, blockchain technology has enormous potential to improve Islamic Fintech by increasing openness, security, and efficiency in financial operations. Blockchain can assure compliance in Islamic finance, which runs on Shari'ah rules emphasising ethical behaviour and the prohibition of interest, by creating immutable and transparent transaction records. Smart contracts, a major blockchain element, may automate and execute agreements based on specified criteria without middlemen, lowering costs and enhancing efficiency. Furthermore, blockchain can improve cross-border transaction efficiency and inclusion by making financial services accessible to underbanked people. The technology's capacity to offer a secure and transparent ledger of transactions is consistent with the ethical criteria of Islamic finance, promoting increased trust and confidence among stakeholders.

Generally, blockchain technology is not against the Shari'ah principles (Abu-Bakar, 2018); it shapes an art of cryptography that enhances the operational process of the transaction, provides tracking options that empower transparency, and works efficiently. It can be used in the Islamic Fintech platforms to ease access to funding, facilitate financial transactions (Hasan *et al.*, 2020), Zakah collection and philanthropic financial activities (Abojeib and Habib, 2021), waqf, and Halal economy (Tieman

and Darun, 2017). Moreover, Smart contracts within blockchain require data on funding and transaction orders, including digital operational structures. These contracts are automatically issued based on client requests and are fully automated (Rabbani et al., 2020). However, smart contracts lack legal recognition or regulatory approval in many Islamic banking jurisdictions, posing a significant barrier to widespread adoption. To realize their potential in Islamic Fintech, appropriate legal frameworks and regulatory guidelines must be developed to align technological advancements with Shari'ah principles (Mat Rahim et al., 2018).

In addition, the recent promotion of smart contracts has been linked to cryptocurrencies like Ethereum and Bitcoin (Vujičić, 2018). The primary issue with these cryptocurrencies is the lack of official recognition in Islamic countries where Islamic law is the main source of legislation. Scholars have varied opinions on the permissibility of using cryptocurrencies. Abu-Bakar (2018) categorizes cryptocurrencies into permitted, prohibited, and those based on religious belief, with the last group focusing on developing Islamic cryptocurrencies supported by traditional currencies like the Dinar and Dirham. However, one of the significant challenges facing Islamic Fintech is the development of regulatory frameworks that support steady and lawful industry growth (Firmansyah and Anwar, 2019). Additionally, there is a shortage of skilled professionals with finance and Shari'ah law expertise, which poses another major challenge. Despite the rapid rise of Fintech, the levels of awareness, trust, and expertise among the general population remain relatively low, potentially hindering the industry's expansion

Also, Digital gold trading tools and apps have gained popularity as they offer a convenient and secure way for individuals to buy, sell, and trade gold online. For these tools to be Shari'ah compliant, several conditions must be met, such as Ownership and Possession, where the buyer must take immediate possession of the gold, physically or constructively, after the transaction. This ensures that the trade does not involve deferred delivery, which is not permissible., Certainty and transparency are where the transaction terms must be clear and transparent, including the gold's weight, purity, and price. Any ambiguity (gharar) in the transaction terms must be avoided. Finally, avoiding interest (riba) is important as the transaction must not involve interest-based financing. If the platform provides financing options, they must comply with Islamic financing principles, such as profit-sharing (mudarabah) or cost-plus financing (murabahah). By adhering to these principles, digital gold trading tools can be structured to comply with Shari'ah, providing Muslims with a permissible means to invest in gold digitally (Yahaya, 2023).

Furthermore, the Fintech sector institutions' development and operating technologies, along with the Shari'ah-related discussions, still hold much attention. Given their extensive effect on many aspects of our lives, it is critical to create machine learning (ML) algorithms that are accurate but also just and equitable. As machine learning (ML) technology becomes more integrated into banking, healthcare, and employment decision-making processes, the demand for fairness and impartiality grows (Mehrabi *et al.*, 2021). Ensuring these algorithms do not reinforce current prejudices or create new discrimination is critical for building confidence and encouraging equal results. This includes establishing strong data governance policies, constantly monitoring and auditing algorithmic judgements, and including ethical concerns in designing and deploying ML systems (Pessach and Shmueli, 2022).

The ML algorithms are designed to learn automatically from the inputs to the system (Chouldechova and Roth, 2020). Therefore, biases, discrimination, and unfairness may be caused by biases in the feeding or missing data. Some measures in the data can unbalance the data set and turn it into bias. Those measures can be related to disparate impact, demography, equality, awareness, and equalisation (Pessach and Shmueli, 2022). Hence, it is essential to run the data before entering it into the machine to prevent such biases from being created by altering the dataset's characteristics so that the distributions for both advantages and disadvantaged groups become identical, making it more difficult for the algorithm to distinguish between them.

On the other side, Grover and Roy believe that Intelligence-driven Fintech solutions have the potential to address financial exclusion and enhance access to financial services, particularly for the poor. AI-driven algorithms and machine learning technologies enhance financial services' efficiency, accuracy, and usability, allowing financial institutions to meet marginalised communities' needs better. It creates self-sustaining and reproducible solutions by leveraging the interdependent link between sustainable development, human advancement, and economic empowerment (Salampasis and Mention, 2018). However, applying Fintech, particularly AI and ML, in finance brings potential risks and considerations for protecting financial consumers and investors. These technologies can amplify vulnerabilities due to their complexity, dynamic adaptability, and level of autonomy. The lack of explainability in Fintech models' operations could lead to systemic and pro-cyclical market risks and potential misalignment with existing financial oversight and internal regulatory and governance frameworks, challenging the technology-neutral approach adopted in policymaking (Benlala, 2023).

Within the range of the promises of technological emergence, there are still a lot of gaps that need to be bridged legally and in accounting. Many accountability measures have been proposed to promote responsible AI development, design, and deployment (Henriksen *et al.,* 2021). Accountability is a concept that gathers the desire for good governance and need to act with transparency, fairness, and justice (Bovens, 2010). The lack of accountability in such advanced technology involved in financial decision-making may create a "black box problem" that will result in more complicated, complex, and aggregated situations that will directly link to substantial effects on the markets (Fletcher and Le, 2021). Due to these concerns, the advantages of AI need to be carefully balanced against the specific risks that come with its proliferation in the markets (Fletcher and Le, 2021).

Several accountability methods have been suggested and implemented in the past few decades to guarantee that AI is designed, developed, and used responsibly. These procedures seek to address AI technology's ethical, legal, and societal concerns while encouraging openness, justice, and responsibility (Bovens, 2010). One of the key issues in AI accountability is determining who is responsible for AI system choices. Depending on the nature of the choice and the level of human engagement in the AI's operation, accountability may lie on AI system creators, operators, or users. Regulators and politicians are attempting to find a fair and transparent way to allocate this obligation (Bovens, 2010).

Uzougbo *et al.* (2024) highlighted that tackling the ethical concerns, which are related to no transparency in the decision-making process, advantage-giving selections to the users, discrimination, and non-fairness, necessitates a comprehensive strategy involving cooperation among technologists, policymakers, ethicists, and other stakeholders. Integrating ethical considerations into developing and deploying AI systems can help guarantee their use is fair, transparent, and accountable. The accountability process can occur accordingly after building a standard and certification system that runs the necessary test on the system before certifying it as a safe system for wide use in the financial sectors (Henriksen *et al.,* 2021). Following of the creation of such grounds, a manual of explanation should be designed for the users, developers, policymakers, and operators; this manual should aim to elaborate the system fairly and transparently by giving clear and enough explanation on every step of the system (Henriksen *et al.,* 2021, and Uzougbo *et al.,* 2024). Applying a system of accountability that includes all the parties involved will result in a risk-mitigating mechanism.

2.2. Ripple effects and Chaos theory: the dynamics of the Islamic banking industry

"When delicateness meets strength", the latter statement represents the quintessence of the Butterfly effect from a financial perspective. Even miniature decisions might have profound consequences in the increasingly interconnected markets. Indeed, a tiny increase in interest rate by the central bank can have a ripple effect on many fragments of the economy, starting from the financial and banking sectors to the labour market, influencing the competitiveness with alternative and Islamic banks, investment proportions, business creation, job offers, employment and economic growth (Murinde, 1996; Murinde & Ryan, 2003; Pagano, 1993). This magnified effect, famous by the term of the Butterfly effect, is part of the chaos theory (Klioutchnikov et al., 2017). Chaos theory is a branch of mathematics that deals with complicated and nonlinear systems that exhibit unexpected or potentially unexpected future behaviour. According to Biswas et al. (2018), chaos theory is a statistical field of research that posits that seemingly arbitrary nonlinear animated systems are predicted from a small number of simple equations. According to Devaney and Alligood (1989), a minor modification can have a large impact. Chaos theory argues that even deterministic systems governed by known rules and equations can lead to extremely unexpected results over time. This notion has applications in various domains, including physics, biology, weather forecasting, and economics (Klioutchnikov *et al.*, 2017).

Chaos theory has been applied in the financial sector to understand market behaviour and price movements, most notably in the stock market and banking setting. The complexity of the system and the multitude of parties in the banking sector raise the unpredictability of the system and its consequences (Klioutchnikov et al., 2017; Murinde, 1996). Furthermore, the shift in the operational and regulatory environment (Khambata, 2000), based on market expectations and projections, is producing additional upheaval. As a result, every micro-event in the market, capital market, regulation, systemic operations, systems, or any other relevant subject might result in cascading effects and rapid market shifts.

Due to the complexity of the economic systems and globalization, the chaos theory, from the point of view of manageability and determinateness, proved to be an efficient theory that permits taking all the correlated fragments of the economy into consideration. Debnath (2022) demonstrated that pure deterministic models are unlikely to produce realistic data forecasts because monetary and financial systems are unpredictable due to human interactions. At the same time, chaos theory may play

an important role in developing models of how economies run and adding unpredictable events caused by external occurrences such as COVID-19 (Spulbar and Minea, 2020). Using this theory in finance aids in spotting irregular nonlinear behaviour caused by new emergencies (such as technology) or a shift in goals, such as from efficient to moral (Debnath, 2022).

Thinking of an Islamic bank as a centre of Chaos theory, conceptualising a possible articulation of the Chaos theory and involving a butterfly effect in the market, the following figure can be proposed:

Expecting the unexpected is at the heart of the chaos theory, taking the Islamic bank system, which operates within an uncertain environment known as the market. The market has many other players that may influence the IB of interest. The IB may have different approaches to its operational methodologies based on different elements, such as its own characteristics and internal variables, the interactions with other banks and financial institutions, the market metrics, etc.. (Klioutchnikov et al., 2017; Mandelbrot & Richard, 2004). Considering its position in the market, the Islamic Bank's initial condition is sensitive to the variables that might influence the Bank's decisions and operations and, therefore, its new or unexpected position in the market. Considering the random characteristics of some elements of the markets and the essence of chaos and order, the IB system can go through chaos and order in many cycles. The theoretical foundation is summarized in the following Figure 1.

Figure 1. Foundation of the financial Chaos: looking into an Islamic banking system
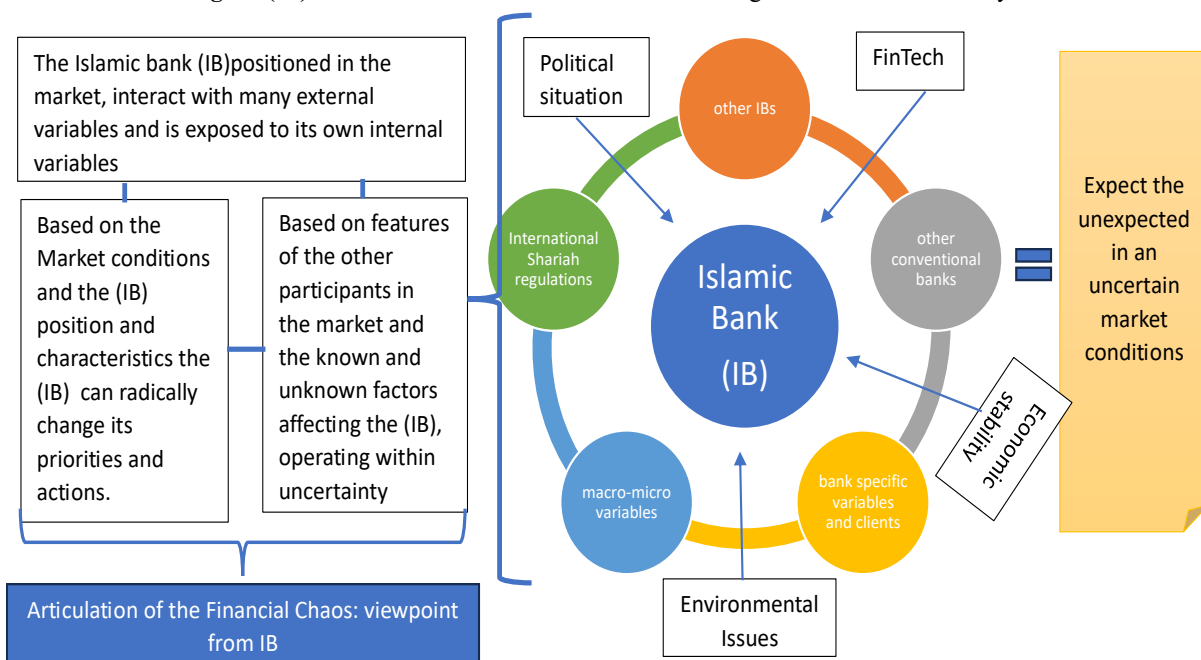
Source: by the author based on klioutchnikov et al. (2017)

2.2. Unlocking the Islamic banking industry in a post-pandemic era: evidence from Fintech adoption:

The use of technology in the finance and banking sectors has developed a sense of competition between different institutions. The institution that offers its clients a great experience and relies on cost-efficiency, speed, and competitive advantages most likes to be the most popular and have more clients. The emergence of technology will most probably force the banking sector to offer reduced-cost services.

Fintech firms and institutions are focusing on offering new alternative ways to transfer money domestically and internationally, save money, and finance the needs of life (Kou *et al.,* 2021). According to (Leong & Sung, 2018) Fintech, services are more about payments, advisory services, and compliance. Haddad and Hornuf (2019) and World Bank (2020) listed more than nine categories to which Fintech is contributing, among which are financial and non-financial. All those categories with different uses by one way or another are positively impacting the economic growth and developing the infrastructures (Song & Appiah-Otoo, 2022).

The technological revolution is one element that cannot be ignored when shaping the new face of the Islamic banking (IB) sectors. The IB industry's exposure to Fintech tools and digitalization of the sericitisation processes put the IB operational and regulatory framework in a more sensitive position (Hassan et al., 2020). On the one hand, the tech revolution will probably enhance IB's efficiency and profitability; delivering shariah-cost effective products more quickly is certainly one of the many positive aspects of Fintech adoptions (Abdeljawad et al., 2022). On the other hand, Simplicity and efficiency may be obtained, but uncertainty will occur, as in the case of Bitcoin and cryptocurrencies (Lahmiri et al., 2018). Moreover, technology gives Islamic banking a great chance to expand if the IBs fulfil their huge responsibility to educate the public about Islamic banking and its services.

However, the Fintech industry and technology-based finance still lack regulatory frameworks to facilitate and legalise their existence. As some countries are trying to form new regulations for tech adoption, there are regulatory limitations on the Fintech firms that increase different risks (Lee and Shin, 2018). Aysan and Unal (2023) highlighted that the lack of regulations may cause regulatory non-compliance and instability. Furthermore, it may reflect the level of liquidity and fund access. Al-Natoor (2023) referred to the inadequate awareness of Fintech and Islamic Fintech (IsFin) as one of the development constraints of the industry.

The era of digitalisation and the acceleration of technology solutions and tools have resulted in the deployment of technology into financial services. Other studies highlighted the rise in the frequency of downloading and using financial applications during the lockdown because COVID-19 spread by up to 32% daily. This percentage differs from one country to another according to the readiness and the level of development in a country's infrastructure.

After COVID-19, the number of Fintech start-ups has jumped to record more than 20.000 start-ups worldwide (Statista, 2022). Those firms worldwide are making massive investments to reach $238.9 US Billion dollars (Figure 2). Islamic Fintech (IsFin) firms are taking a huge segment of the Fintech industry, with a market size of USD 49 Billion in the Organisation of Islamic Cooperation (OIC) countries (Global Islamic Fintech Report, 2021).

Figure 2. Total Value of Investments into Fintech Companies Worldwide
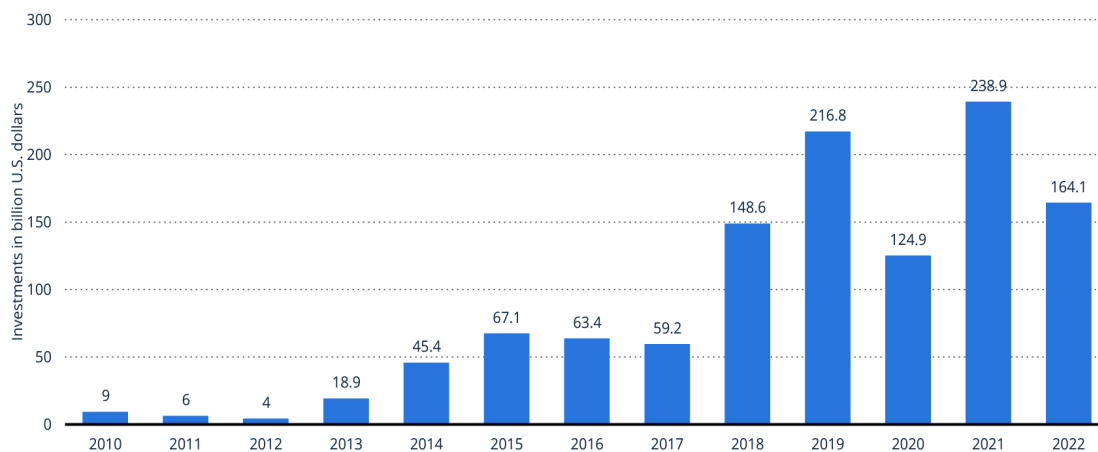
Source: Statista Fintech Report (2022)

As Islamic finance (IF) and Islamic banking (IB) are significant components of the financial systems, the rise of financial solutions that comply with shari'ah is rising with the developments witnessed in the financial markets. The calls for IsFins applications started to take a serious turn with the dire necessity to be founded. In times of financial hardships, IF and Islamic financial institutions are establishing a steady ground that helps them to face the challenges of the time because of the genuineness of the IF solutions.

Regarding financial inclusion, Baber (2020) noted that those countries where Islamic finance and banking are more popular are more financially included than other countries. Furthermore, the establishment of IBs and IF solutions is providing an

environment for developing businesswomen and female empowerment (Guo et al., 2021). However, conventional financial institutions are still more technologically advanced.

3. Methodology

This study lies at the heart of deciphering the multifaceted impact, namely the "digital butterfly effect" in the Islamic banking sector—a nuanced exploration of the profound shifts precipitated by digital interventions on IBs and economic development in Malaysia, particularly in a post-pandemic scenario (Figure 3).

Figure 3. Conceptual Framework for the Digital Butterfly Effect on Islamic Banking and the Broader Economy
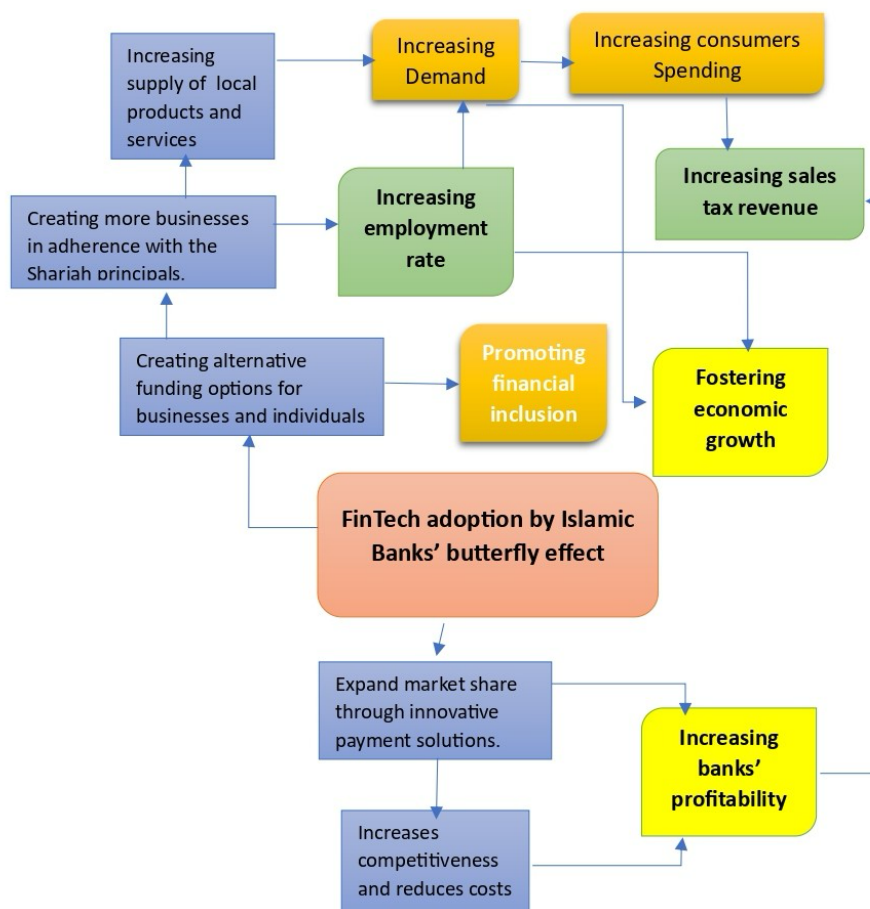
Source: Authors' elaboration

The digital butterfly effect, when contextualized within Islamic banking, can catalyze noticeable transformations. These are not limited solely to the operations of Islamic banks but also affect the broader economic landscape, as depicted in Figure (03). Drawing a parallel to the deterministic yet chaotic system advanced in Lorenz's Butterfly Effect, one might conceptualize how a subtle flutter of a butterfly's wing in Islamic banking becomes instrumental, creating a ripple effect via advanced Fintech integrations. This effect ripples outward, infiltrating the larger economic framework and potentially influencing key macroeconomic determinants. This influence encompasses GDP growth trajectories and employment equilibria and significantly contributes to fostering enhanced financial inclusion across the broader economic spectrum. On the household front, the butterfly effect signals a paradigm shift in personal financial management. Families and individuals might experience

more personalized banking services, better investment advice tailored to Shariah-compliant products, and enhanced digital security, making online transactions safer.

3.1. Variables selection and data collection

To achieve a rich and multi-layered empirical analysis, this study exploits different variables organized into four pillars: Fintech, Islamic banking metrics, economic factors, and the financial sector, presented and described in Table 1. In addition, the study examines data for 2008-2022, which encompasses pre-pandemic, during a pandemic and post-pandemic era, where a dummy variable represents the COVID-19 pandemic crisis.

Table 1. Variables description

Category	Variable	Description	Source
Fintech	*FADi*	Fintech Adoption Index	Calculated using PCA
Islamic Banking Metrics	*ROA*	Return on Assets for Islamic Banking	S&P global, Capital IQ
	ROE	Return on Equity for Islamic Banking	S&P global, Capital IQ
Economic Indicators	*GDP*	Gross Domestic Product	Bank Negara Malaysia
	Unemp	Unemployment Rate	Asian Development Bank
	consumption	Household Consumption	
	Induryt	Industry's Share to GDP	
Financial Sector	*F&I*	Financial and Insurance Services	Asian Development Bank
	Corp_Tax	Corporate Tax Rate	Capital IQ

Source: Authors' elaboration

3.2. Construction FADi Using Principal Component Analysis (PCA)

Principal Component Analysis (PCA) is a statistical methodology used to convert original variables into a new set of variables, termed principal components, which capture the maximum variance from the original variables while being orthogonal to each other (Jolliffe, 2002). Given its capability to diminish dimensionality without compromising significant information, PCA serves as a pertinent tool for constructing the Fintech Adoption Index *FADi*

Components for *FADi* and Their Corresponding Fintech Pillars:

Fintech's multidimensional nature is represented by several core pillars: money alternatives, capital intermediation, Investech (Huong et al., 2021). Each of these pillars captures a range of services and innovations transforming the financial landscape. The components chosen are situated within these broader categories as follows:

E-money (Money Alternatives): E-money exemplifies the innovations under the money alternatives pillar. It transcends traditional transaction modes, encompassing cryptocurrency and external bank payment systems (Dahlberg et al., 2015).

ATM (Capital Intermediation Pillar): ATMs resonate with capital intermediation, given their critical role in facilitating physical access to digitalized banking services (Legowo et al., 2021).

Mobile Banking (Capital Intermediation and Investec Pillar): Mobile banking, a primary part of digital banking, aligns with capital intermediation. Additionally, the ever-expanding suite of services offered through mobile banking apps also intersects with investech, especially when considering functionalities like investment apps and financial intelligence (Tam & Oliveira, 2017). The computation of FADi, utilizing the PCA methodology, proceeds through various stages, as presented in Figure 4.

Figure 4. Steps of PCA
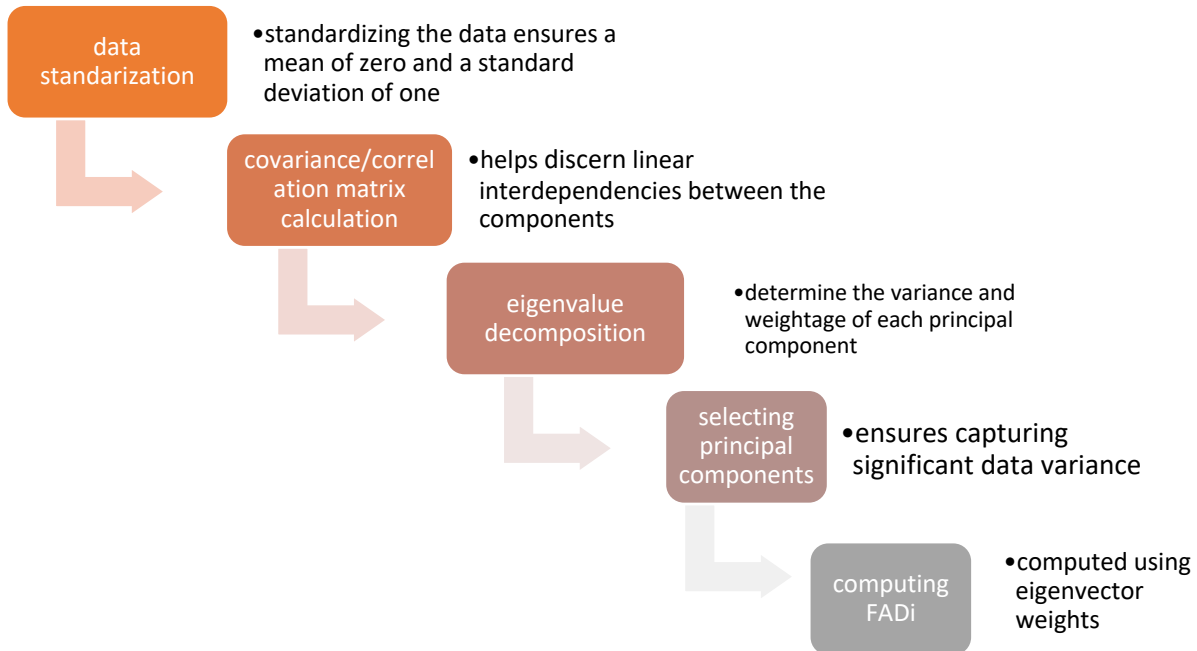
Source: Author's elaboration on Jaadi (2021)

3.3. Building the VAR model

The evolution of Islamic banking, influenced by the flutter of digitalization, merits a thorough investigation. Thus, it is paramount to opt for an approach that acknowledges the constrained dimensions of our dataset. The Bayesian VAR methodology emerges as an appropriate choice (Figure 5). It offers a holistic platform that judiciously melds prior information into the analytical process, allowing it to navigate the constraints of a smaller sample size while maintaining the precision of inferences (Tsagkanos et al., 2022).

Building upon insights from Ciccarelli & Rebucci (2003) and Tsagkanos et al. (2022), let the VAR model:
$Y_t = X_t\beta + \varepsilon_t \dots (1)$

In this context
- Y_t is a $n \times 1$ vector of endogenous variables namely, the digital attributes within Islamic banking.
- ε_t is a $n \times 1$ vector of error terms that explains the random disturbances, identically and normally distributed with variance - covariance matrix Σ, $\varepsilon_t \sim$ IIN $(0, \Sigma)$.
- X_t is a matrix $n \times nk$ and represents the set of independent variables.
- β is $nk \times 1$ and represents the coefficients that assess the relationship between variables.

The Bayesian structure, involving both prior and posterior distributions of the parameters $p(\beta, \Sigma)$ unfolds as:

$$L\langle Y \mid \beta, \Sigma \rangle \emptyset |\Sigma|^{-\mathbb{T}_2} \exp \left\{ -\frac{1}{2} \sum_t (Y_t - X_t\beta)' \Sigma^{-1}(Y_t - X_t\beta) \right\} \dots (2)$$

$$p\langle \beta, \Sigma \mid Y \rangle = \frac{p(\beta, \Sigma) LY|\beta, \Sigma}{p(Y)} \sigma p(\beta, \Sigma) L\langle Y \mid \beta, \Sigma \rangle \dots (3)$$

By analyzing $p\langle \beta, \Sigma \mid Y \rangle$, the study extracts marginal posterior distributions based on the data, $p\langle \Sigma \mid Y \rangle$ and $p\langle \beta \mid Y \rangle$ can be obtained by segregating β and Σ from $p\langle \beta, \Sigma \mid Y \rangle$ respectively.

The parameters' posterior distribution combines the prior distribution with the likelihood function derived from the data. Bayes' theorem is used to update the prior beliefs with the observed data, resulting in the posterior distribution.

In addition, aligning with our focus on the digital nuances in Islamic banking, this study leverages the Minnesota prior, championed by Litterman (1986). This prior is particularly useful in small sample sizes as it introduces shrinkage, which helps obtain more stable estimates by pulling them towards a prior mean, often assumed to be zero for simplicity.

Figure 5. The benefits of Bayesian VAR
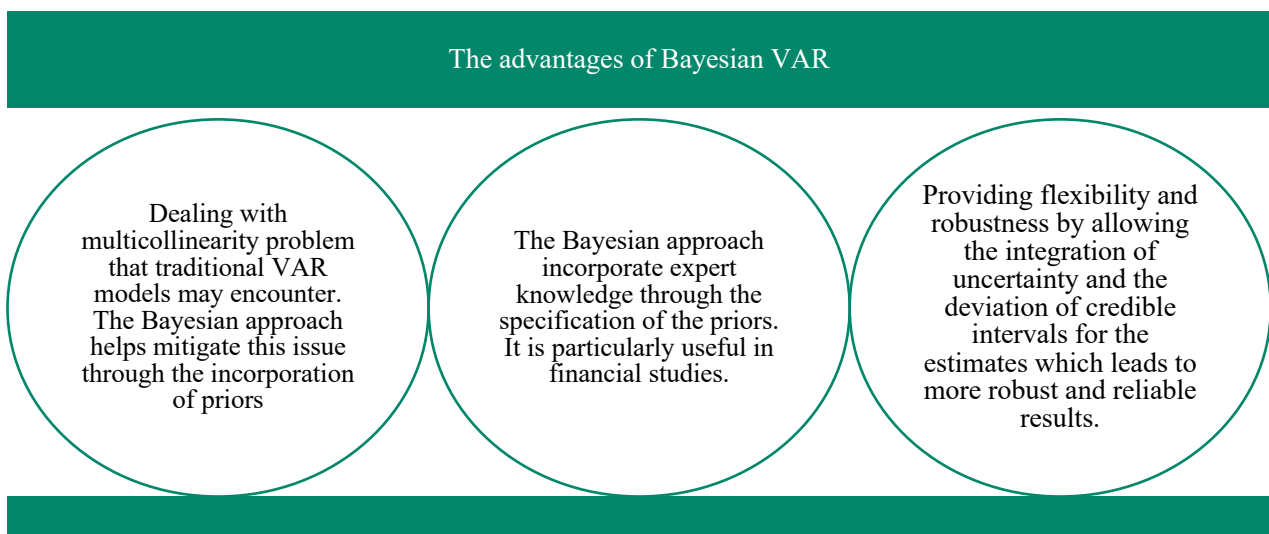
Source: Authors' elaboration

4. Results
4.1. Unit root test

To assess the stationarity properties of the variables under study, we have used the Augmented Dickey-Fuller (ADF) test commonly used in the literature. This test aims to determine whether a variable follows a unit root process, indicating its stationarity (at levels (I(0)) or non-stationarity (require differencing to achieve stationarity (I(1)) (Paparoditis & Politis, 2018).

Table 2. ADF unit root test results

Variables	ADF without Constant & Trend		
	Level	1st difference	Decision
FADi	0.9962	0.0320	I (1)
ROA	0.0001	0.0001	I (0)
ROE	0.0491	0.0014	I (0)
F&I	0.8760	0.0011	I (1)
GDP	0.8667	0.0004	I (1)
Unemp	0.8799	0.0004	I (1)
Consumption	1.0000	0.0457	I (1)
Corp_Tax	0.9184	0.0027	I (1)
Industry	0.0098	0.0000	I (0)

Source: Authors' elaboration

The Augmented Dickey-Fuller (ADF) test results through the p-values indicate the significance levels presented in Table 2, where ROA, ROE, and Industry are stationary at levels (I(0)), while FADi, F&I, GDP, Unemployment, Consumption, and

Corp_Tax are (I(1)) and necessitate one-time differencing to achieve stationarity. Given the mix of I(0) and I(1) variables, appropriate modeling strategies should be considered to ensure robust and meaningful econometric results.

4.2. Johansen cointegration test

The Johansen cointegration test is a multivariate extension of the unit root tests. It is specifically designed to determine the cointegration relationships in a system of equations. It evaluates the presence of cointegrated vectors that indicate long-term equilibrium relationships among the variables (Dwyer, 2015). The trace statistics and corresponding probabilities are used to determine the number of cointegration relationships. In this case, Table 3 reveals the absence of significant cointegration vectors at the 5% level, suggesting that the variables do not share a long-term equilibrium relationship.

Table 3. Johansen cointegration results

Johansen test			
Hypothesized	**Eigenvalue**	**Trace statistics**	**Probabilities**
None	0.915789	97.7128	0.0531
At most one	0.887433	52.1503	0.2998
At most two	0.234877	24.7823	0.2147
At most three	0.788580	31.2032	0.5030

Source: Authors' elaboration

4.3. Bayesian VAR estimation

Bayesian Vector Autoregression (BVAR) estimation combines prior information with observed data to estimate model parameters and their posterior distributions (Miranda-Agrippino & Ricco, 2019). This approach is particularly useful for addressing the dense parameterization of VAR models through informative priors that impose shrinkage on coefficients (Kuschnig & Vashold, 2019). Bayesian VAR estimation, considering the prior information and the specific characteristics of the data, revealed different insights into the relationships and dynamics among the study's variables, as summarized in Table 4.

Table 4. Bayesian VAR estimation results

Bayesian VAR estimates									
	FADi	**ROA**	**ROE**	**F&I**	**GDP**	**Unemp**	**consmp**	**Corptax**	**Industry**
FADi	1.016722	4.94E-05	0.003679	0.001422	0.004755	-0.000140	0.001407	0.001407	0.076450
	(0.09788)	(0.00036)	(0.02709)	(0.03968)	(0.04913)	(0.00891)	(0.03118)	(0.0311)	(0.80882)
Covid	0.483969	-0.002782	0.014304	0.005479	0.208194	0.021233	-0.027352	0.097115	0.613084
	(0.03493)	(0.00248)	(0.18861)	(0.14615)	(0.02625)	(0.08128)	(0.48128)	(0.06214)	(5.63034)
R²	0.929318	0.873896	0.98146	0.837394	0.975514	0.862051	0.987545	0.957491	0.887066

Source: Authors' elaboration

Results underscore the digital butterfly effect, where minor digital shifts can lead to significant economic transformations. The Fintech adoption index (FADi) is a catalyst in this framework, showing significant effects across banking and macroeconomic landscapes. With every flutter in FADi, there's a significant positive sway in both Islamic banking metrics,

ROA and ROE, emblematic of the transformative power of Fintech in reshaping financial outcomes. On the macroeconomic front, FADi positively impacts GDP, household consumption, and corporate tax while also hurting the unemployment rate.

While the ripples on ROA (4.94E-05) and Unemployment (0.000140) are almost imperceptible, suggesting these sectors may be insulated from immediate digital shifts, the industry sector feels a more pronounced wave (0.076450). This substantial influence, tempered by a higher standard error, mirrors the vast potential of the digital revolution, albeit with uncertainties.

Additionally, the R2 highest values, 0.98146, underscore its substantial explanatory power for most variables.

4.4. Bayesian Impulse Response function

Impulse response functions (IRFs) provide a valuable mechanism to comprehend the dynamic interplay among variables in a system, especially when considering how a shock in one variable might propagate and influence others over subsequent periods. Just as the butterfly effect underscores the sensitivity and interdependence of complex systems, our Bayesian IRFs demonstrate how small disturbances in one area of the economy can affect significantly various sectors.

The next **Figure 6** offers an interesting glimpse into the digital "butterfly effect" initiated by Fintech adoption. At the flap of FADi wings, a significant positive response merges across different economic pillars, starting with Islamic banking (ROA and ROE), GDP growth, and financial and insurance services hinting at enhanced financial inclusivity, household consumption and corporate tax; however, the same flutter drive to a negative response of unemployment rate probably due to shifting skill requirements. Additionally, the stabilization of the industry's contribution to GDP by a growth of 0.16 at t=10 paints a picture of an evolving economic landscape adapting to its new digital era.

4.5. Granger causality Wald tests

Given the nature of the digital butterfly effect, it is essential to determine if changes in FADi genuinely precede changes in these metrics or if it's merely coincidental using the Granger causality test to strengthen and complement the previous results by examining the causal relationship among the variables. By assessing the Wald test, we can determine whether one variable can be said to Granger and cause another (Shukur & Mantalos, 2000).
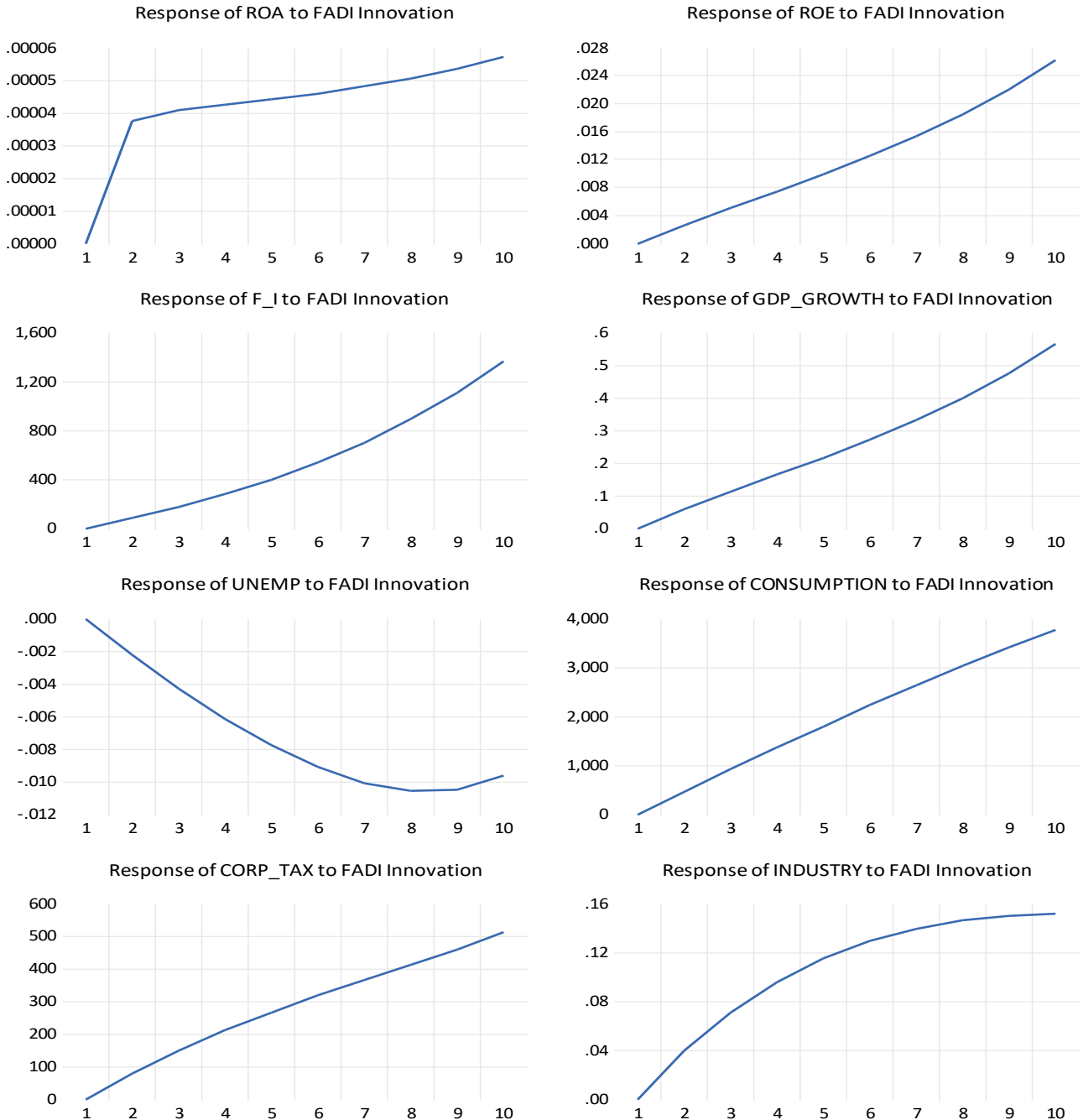
Table 7 summarizes the Granger causality test results, indicating the causal relationships between FADi and other key variables. The p-values suggest the significance of these relationships. For instance, there is a bidirectional causal relationship between FADi and both ROA and ROE, indicating that not only does Fintech adoption drive changes in financial profitability, but changes in these profitability metrics can also impact the rate of Fintech adoption. The table also shows causal relationships between FADi and GDP, unemployment, household consumption, and corporate tax, underscoring the extensive influence of Fintech adoption on economic indicators.

Figure 6. Bayesian ERF

Response to Cholesky One S.D. (no d.f. adjustment) Innovations

Source: Authors' elaboration

Table 7. Granger causality test results

Variable		p-value	Decision
The causal relationship between FADi and Islamic banking			
FADi ROA	ROA FADi	0.0309 0.0482	Bidirectional causal relationship between FADi and both ROA and ROE. This means that not only (FADi) drive changes in financial profitability (ROA) and equity returns (ROE) but shifts in these financial metrics can also influence the rate of Fintech adoption.
FADi ROE	ROE FADi	0.0225 0.0125	
The causal relationship between FADi and economic and financial variables			
FADi	GDP Unemployment Consumption Industry F&I services Corp Tax	0.0375 0.0285 0.0110 0.8935 0.0259 0.0488	Causal relationships exist between FADi and GDP, Employment, Consumption, F&I services and corporate taxes illustrating how digital financial innovations shape economic health, consumer behaviors, and the dynamics of the finance sector. Intriguingly, FADi does not show a causal relationship with the industry's share to GDP,

Source: Authors' analysis based on data processing

5. Discussion

In the evolving digital butterfly effect, results revealed that innovations in the Fintech adoption index (FADi) have considerable influence across various sectors. The positive trajectories observed for metrics such as ROA, ROE, GDP Growth, and Financial & Insurance Services underline Fintech's potential to supercharge the economy.

Notably, these patterns suggest that increased Fintech integration might push the Islamic banking sector to another level, where ROA, a metric signifying the ability of assets to generate profits, exhibited an immediate surge with heightened FADi. This suggests that Fintech integrations, ranging from digital banking platforms to AI-driven financial tools, can optimize asset utility, enhancing profitability. ROE, on the other hand, gauges the profitability of shareholders' equity. Its positive response to FADi indicates that as Islamic banks adopt more Fintech solutions, they can generate higher returns on the capital invested by shareholders. These results agreed with the outcomes of the previous literature (Monika et al., 2021; Sidaoui et al., 2022; Siska, 2022). In addition, The effectiveness of Fintech adoption in promoting GDP growth finds validation in works by (Paparoditis & Politis, 2018) and (Yoon et al., 2023), who proposed a symbiotic relationship between digital finance innovations and macroeconomic resilience. Additionally, corporate tax revenue witnesses a positive uptick, possibly due to increased digital transactions. The continuous growth observed in the Financial and Insurance Services sector underscores Fintech's role in fostering greater financial inclusivity and streamlining services, propelling the sector to new heights, which aligns with (He et al., 2017). Additionally, households appear to benefit from the proliferation of Fintech solutions, experiencing heightened consumption, possibly due to enhanced access to diverse financial products and platforms.

Moreover, an encouraging sign was the decline in unemployment with the emergence of Fintech adoption. Contrary to concerns about digital transformation leading to job erosion (Ben Romdhane et al., 2023), our findings hint at Fintech's potential to forge new employment avenues. The tech sector, rife with innovations, seems to be emerging as a crucible for diverse job opportunities, assuaging fears tied to automation and rapid technological advancements.

On the other side, the pandemic ushered in an era marked by both chaos and digital evolution. As global economies grappled with disruptions, an intensified pivot towards digital solutions arose, with the Islamic Banking sector no exception. This shift underscores the potency of the "Digital Butterfly Effect". Our findings vividly illustrate this, revealing how Islamic Banking, underpinned by Fintech, exhibited resilience amidst adversity, with marked improvements in performance metrics such as ROA and ROE, which agreed with the findings (Aini et al., 2022; Karim et al., 2022). Furthermore, after the widespread job losses during the pandemic, the sector's digital metamorphosis seems to have unveiled a spectrum of new employment avenues in the

post-pandemic era. As we navigate the post-pandemic landscape, it's evident that the synergy between Fintech and Islamic Banking is about surviving challenges and harnessing them as catalysts for transformative growth and resilience.

Therefore, businesses, regulators, and educators should pivot towards embracing Fintech innovations and harnessing their potential to drive resilience and growth in an interconnected economy.

6. Implications: Theory & practice

The findings have implications for theory and practice. The theoretical consequences contribute to the literature on conceptualising the Islamic banking activity as a system at the heart of chaos theory in finance that moves from chaos to order frequently due to the uncertainty of the market conditions. Hence, the Butterfly Effect can be diagnosed in this research through considering the effect of tiny external or internal initial events that may occur in the market (Lorenz, 2000), and the influence of such novelties on various operational and regulatory activities of the IBs. When IBs adopt Fintech tools, bank-specific profitability metrics such as return on assets and equity are increased, improving the IB system's placement in the market.

The practical implications are emphasised via two different points. Firstly, by offering a practical way to understand the complexity of the Islamic banking system, how the conceptualizing of the chaos theory and the butterfly effect of the Fintech adoption by the IBs where results underscore the "Digital Butterfly Effect," emphasizing how minor shifts in Fintech adoption can have cascading impacts across the economic landscape. This study draws initial outcomes to build informed decision making, in being proactive when assessing and implementing risk mitigating strategies and operational methodology in the banking industry because market is uncertain, and organization should expect the unexpected.

Secondly, looking into the digital Butterfly Effect, and considering the globalization and interconnectedness of markets, policymakers would be able to implement forecasting models to predict to a certain confidence level the outcomes that a given event might have on the larger scale of the local and international markets. The fintech adoption index, for instance, had a positive effect on economic growth and reduced the unemployment rate. Hence, despite Fintech not being directly implemented to foster employability in Malaysia, it has an indirect effect on the job market for a tech-savvy youth community, for instance.

7. Conclusion

In this context, the study examines the digital butterfly effect on the Islamic banking industry to promote tech-driven IBs through an empirical lens; the study constructs a Fintech adoption index (FADi) and uses a Bayesian vector Auto-Regressive model, causality tests and impulse response functions, for yearly data from 2008 to 2022, to examine the possible magnified effect of the adoption of Fintech by the Islamic banking industry in Malaysia. The findings highlight the role of Fintech in the Malaysian economy, which goes beyond the financial sector. The research's outputs argue that at the flap of FADi wings, a significant positive response merges across different economic pillars, starting with Islamic banking (ROA and ROE), GDP growth, financial and insurance services hinting at enhanced financial inclusivity, household consumption and corporate tax, however, the same flutter drive to a negative response of unemployment rate probably due to shifting skill requirements.

The study empirically contributes to the existing literature by investigating the Islamic banking system at the heart of the chaos theory; fintech adoption creates a non-linear response of different sectors of the Malaysian economy, which is emphasized in the transformative impacts of fintech tools. Our study's results highlight that the effects of fintech adoption are unpredictable and not always straightforward. Hence, our findings shed light on the fuller picture and give a holistic viewpoint to policymakers and stakeholders to embrace the inherent uncertainty of technological advancement in the financial industry. Policymakers and scholars within the field must thoroughly explore the complex impact of Fintech adoption on the economy, ensuring meticulous attention to all relevant details and involved stakeholders and sectors. A particular area requiring in-depth analysis is the role of fintech in enhancing transparency and fairness and fostering greater equity. Such a decentralized system integrated with an effective RegTech framework for efficient governance could promote an inclusive financial system.

References

Abakah, E. J. A., Tiwari, A. K., Ghosh, S., & Doğan, B. (2023). Dynamic effect of Bitcoin, Fintech and artificial intelligence stocks on eco-friendly assets, Islamic stocks and conventional financial markets: Another look using quantile-based approaches. *Technological Forecasting and Social Change*, *192*, 122566.

Abdeljawad, I., Hashem, S. Q., & Rashid, M. (2022). Fintech and Islamic Financial Institutions: Applications and Challenges. *Fintech in Islamic Financial Institutions: Scope, Challenges, and Implications in Islamic Finance*, 193-222.

Abojeib, M., & Habib, F. (2021). Blockchain for Islamic social responsibility institutions. In *Research anthology on blockchain technology in business, healthcare, education, and government* (pp. 1114-1128). IGI Global.

Abu-Bakar, M. M. (2018). Shariah analysis of bitcoin, cryptocurrency, and blockchain. *Shariah Analysis in Light of Fatwas and Scholars' Opinions*, 14-19.

Aini, I., Nasution, A. M., Kurniawan, F., & Lubis, R. H. (2022). Fintech opportunities and challenges in the Sharia banking

industry in pandemic times. *Al-Masharif: Jurnal Ilmu Ekonomi dan Keislaman*, *10*(2), 143-157.

Al-Jamili, O. (2019). Smart Contracts, Their Reality and Their Relationship to Virtual Currencies. In *International Islamic Jurisprudence Assembly conference Dubai, Dubai, Islamic Affairs & Charitable Activities Department & Government of Dubai.*

Asif, S. (2018). The halal and haram aspect of cryptocurrencies in Islam. *Journal of Islamic Banking and Finance*, *35*(2), 91-101.

Atiyah, G. A., Manap, N. A., Ibrahim, A. I., & Rahman, A. (2024). Legitimacy of Smart Contracts from the Perspective of Islamic Law: A Case Study of Blockchain Transactions. *Al-Istinbath: Jurnal Hukum Islam*, *9*(1), 155-192.

Benlala, M. A. (2023). Exploring Risks and Issues Related to Policy Making and Regulation in FinTech. Perspectives of Law and Public Administration, 12(2), 249-255.

Ben Romdhane, Y., Kammoun, S., & Loukil, S. (2023). The impact of Fintech on inflation and unemployment: the case of Asia. *Arab Gulf Journal of Scientific Research*.

Bovens M. (2010) Two Concepts of Accountability: Accountability as a Virtue and as a Mechanism. *West European politics. Vol. 33, No. 5*, 946–967.

Charles, W. E. (2015). Bitcoin in Islamic banking and finance. *Journal of Islamic Banking and Finance*, *3*(1), 1-11.

Chouldechova, A., & Roth, A. (2020). A snapshot of the frontiers of fairness in machine learning. *Communications of the ACM*, *63*(5), 82-89.

Ciccarelli, M. M., & Rebucci, M. A. (2003). Bayesian VARs: A survey of the recent literature with an application to the European Monetary System.

Dahlberg, T., Guo, J., & Ondrus, J. (2015). A critical review of mobile payment research. *Electronic commerce research and applications*, *14*(5), 265-284.

De la Mano, M., & Padilla, J. (2018). Big tech banking. *Journal of Competition Law & Economics*, *14*(4), 494-526.

Dwyer, G. P. (2015). The Johansen tests for cointegration. *White Paper*, *516*.

Evans, C., (2015). Bitcoin in Islamic Banking and Finance. *Journal of Islamic Banking and Finance*. Vol. 3, No. 1, pp. 1-11.

Firmansyah, E. A., & Anwar, M. (2019, January). Islamic financial technology (FINTECH): its challenges and prospect. In *Achieving and Sustaining SDGs 2018 Conference: Harnessing the Power of Frontier Technology to Achieve the Sustainable Development Goals (ASSDG 2018)* (pp. 52-58). Atlantis Press.

Firmansyah, H. B., & Ramdani, A. L. (2018, May). The role of Islamic financial technology (Fintech) start-up in improving financial inclusion in Indonesia case: Angsur. In *3rd international conference of integrated intellectual community (ICONIC)*.

Fletcher, G. G. S., & Le, M. M. (2021). The future of AI accountability in the financial markets. *Vand. J. Ent. & Tech. L.*, *24*, 289.

Grover, M., & Roy, S. Empowering Financial Inclusion: Leveraging Fintech and AI Innovations for Underserved Communities. *DTC Journal of Computational Intelligence, Vol-3, Issue-1.*

Hasan, R., Hassan, M. K., & Aliyu, S. (2020). Fintech and Islamic finance: Literature review and research agenda. *International Journal of Islamic Economics and Finance (IJIEF)*, *3*(1), 75-94.

Hassan, M. K., Rabbani, M. R., & Ali, M. A. M. (2020). Challenges for the Islamic Finance and banking in post COVID era and the role of Fintech. *Journal of Economic Cooperation & Development*, *41*(3), 93-116.

He, M. D., Leckow, M. R. B., Haksar, M. V., Griffoli, M. T. M., Jenkinson, N., Kashima, M. M., Khiaonarong, T., Rochon, M. C., & Tourpe, H. (2017). *Fintech and financial services: Initial considerations*. International Monetary Fund.

Henriksen, A., Enni, S., & Bechmann, A. (2021, July). Situated accountability: Ethical principles, certification standards, and explanation methods in applied AI. In Proceedings of the 2021 AAAI/ACM Conference on AI, Ethics, and Society (pp. 574-585).

Huong, A., Puah, C.-H., & Chong, M.-T. (2021). Embrace Fintech in ASEAN: A perception through Fintech adoption index. *Research in World Economy*, *12*(1), 1.

Jaadi, Z. (2021). A step-by-step explanation of principal component analysis (PCA). *Retrieved June*, *7*(2021), 470.

Jolliffe, I. T. (2002). *Principal component analysis for special types of data*. Springer.

Karim, S., Naeem, M. A., & Abaji, E. E. (2022). Is Islamic Fintech coherent with Islamic banking? A stakeholder's perspective during COVID-19. *Heliyon*, *8*(9).

Khambata, D. (2000). Impact of foreign investment on the volatility and growth of emerging stock markets. *Multinational Business Review*, *8*(1), 50-50.

Khan, S., Hassan, M. K., Rabbani, M. R., & Atif, M. (2021). An artificial intelligence-based Islamic Fintech model on Qardh-Al-Hasan for COVID 19 affected SMEs. *Islamic perspective for sustainable financial system*, 234-249.

Klioutchnikov, I., Sigova, M., & Beizerov, N. (2017). Chaos Theory in Finance. *Procedia Computer Science*, *119*, 368-375. https://doi.org/https://doi.org/10.1016/j.procs.2017.11.196

Kuderer, N. M., Choueiri, T. K., Shah, D. P., Shyr, Y., Rubinstein, S. M., Rivera, D. R., Shete, S., Hsu, C.-Y., Desai, A., & de Lima Lopes, G. (2020). Clinical impact of COVID-19 on patients with cancer (CCC19): a cohort study. *The Lancet*, *395*(10241), 1907-1918.

Lahmiri, S., Bekiros, S., & Salvi, A. (2018). Long-range memory, distributional variation and randomness of bitcoin volatility. *Chaos, Solitons & Fractals*, *107*, 43-48.

Legowo, M. B., Subanidja, S., & Sorongan, F. A. (2021). Fintech and bank: Past, present, and future. *Jurnal Teknik Komputer AMIK BSI*, *7*(1), 94-99.

Leong, K., & Sung, A. (2018). Fintech (Financial Technology): What is it and how to use technologies to create business value in Fintech way? *International Journal of Innovation, Management and Technology*, *9*(2), 74-78.

Lorenz, E. (2000). The butterfly effect. *World Scientific Series on Nonlinear Science Series A*, *39*, 91-94.

Mandelbrot, B., & Richard, L. (2004). The (mis) behavior of markets. A basic book.

Mat Rahim, S. R., Mohamad, Z. Z., Abu Bakar, J., Mohsin, F. H., & Md Isa, N. (2018). Artificial intelligence, smart contract and islamic finance. *Asian Social Science*, *14*(2), 145.

Mehrabi, N., Morstatter, F., Saxena, N., Lerman, K., & Galstyan, A. (2021). A survey on bias and fairness in machine learning. *ACM computing surveys (CSUR)*, *54*(6), 1-35.

Mohtar, J. 2020). Use Blockchain technology to certify halal products: New straits times. *NST Online*. URL: https://www.nst.com.my/opinion/columnists/2020/12/651806/use-blockchain-technology-certify-halal-products. Accessed: July 17, 2024.

Monika, A., Azam, A. N., & Teguh, S. I. (2021). The Impact of Fintech Development to Profitability of Islamic Bank. *International Journal of Research and Review*, *8*(1), 250-258.

Murinde, V. (1996). Financial markets and endogenous growth. *Financial Development and Economic Growth, New York: Routledge*, 94-114.

Murinde, V., & Ryan, C. (2003). The Implications of WTO and GATS for the Banking Sector in Africa. *World economy*, *26*(2), 181-207.

Nawaz, T. (2017). Conventional vs. Islamic banks in dual-banking systems: business model, outlay stratagems and economic performance. *International Journal of Business Governance and Ethics*, *12*(4), 330-348.

Oseni, U. A., & Ali, S. N. (2019). Fintech in Islamic finance. In *Fintech in Islamic finance* (pp. 3-14). Routledge.

Pagano, M. (1993). Financial markets and growth: An overview. *European economic review*, *37*(2-3), 613-622.

Paparoditis, E., & Politis, D. N. (2018). The asymptotic size and power of the augmented Dickey–Fuller test for a unit root. *Econometric Reviews*, *37*(9), 955-973.

Pessach, D., & Shmueli, E. (2022). A review on fairness in machine learning. *ACM Computing Surveys (CSUR)*, *55*(3), 1-44.

Polas, M. R. H., Muhibbullah, M., & Bhattacharjee, A. (2020). Is bitcoin halal or haram in the Islamic banking and finance? An overview. *Journal of Economics, Business and Market Research*, *1*(2), 96-104.

Rabbani, M. R., Khan, S., & Thalassinos, E. I. (2020). Fintech, blockchain and Islamic finance: An extensive literature review.

Rafiki, A., & Nasution, A. (2021). Islamic Financial Technology (Fintech) applications in Indonesia. *Artificial Intelligence and Islamic Finance: Practical Applications for Financial Risk Management*, 91.

Rahim, N. F., Bakri, M. H., Fianto, B. A., Zainal, N., & Hussein Al Shami, S. A. (2023). Measurement and structural modelling on factors of Islamic Fintech adoption among millennials in Malaysia. *Journal of Islamic Marketing*, *14*(6), 1463-1487.

Salampasis, D., & Mention, A. L. (2018). Fintech: Harnessing innovation for financial inclusion. In *Handbook of blockchain, digital finance, and inclusion, volume 2* (pp. 451-461). Academic Press.

Shukur, G., & Mantalos, P. (2000). A simple investigation of the Granger-causality test in integrated-cointegrated VAR systems. *Journal of Applied Statistics*, *27*(8), 1021-1031.

Sidaoui, M., Ben Bouheni, F., Arslankhuyag, Z., & Mian, S. (2022). Fintech and Islamic banking growth: new evidence. *The Journal of Risk Finance*, *23*(5), 535-557.

Siska, E. (2022). Financial Technology (Fintech) and its impact on financial performance of Islamic banking. *ARBITRASE: Journal of Economics and Accounting*, *2*(3), 102= 108-102= 108.

Song, N., & Appiah-Otoo, I. (2022). The impact of Fintech on economic growth: Evidence from China. *Sustainability*, *14*(10), 6211.

Tam, C., & Oliveira, T. (2017). Literature review of mobile banking and individual performance. *International Journal of Bank Marketing*, *35*(7), 1044-1067.

Tieman, M., & Darun, M. R. (2017). Leveraging blockchain technology for halal supply chains. *ICR Journal*, *8*(4), 547-550.

Tsagkanos, A., Argyropoulou, D., & Androulakis, G. (2022). Asymmetric economic effects via the dependence structure of green bonds and financial stress index. *The Journal of Economic Asymmetries*, *26*, e00264.

Uzougbo, N. S., Ikegwu, C. G., & Adewusi, A. O. (2024). Legal accountability and ethical considerations of AI in financial services. *GSC Advanced Research and Reviews*, *19*(2), 130-142.

Vujičić, D., Jagodić, D., & Ranđić, S. (2018, March). Blockchain technology, bitcoin, and Ethereum: A brief overview. In *2018 17th international symposium infoteh-jahorina (infoteh)* (pp. 1-6). IEEE.

Yoon, S. S., Lee, H., & Oh, I. (2023). Differential Impact of Fintech and GDP on Bank Performance: Global Evidence. *Journal of Risk and Financial Management*, *16*(7), 304.