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Comprehensive Review of Blockchain Applications in Fintech Companies

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Abstract. The application of blockchain technologies has been gaining popularity in the fintech industry and its effects on the performance of fintech companies have emerged as an important field of research in the domain of finance. Thus this paper comprehensively reviews recent literature on blockchain applications in fintech companies in order to understand how it can be designed and utilised to optimize fintech service delivery. The focus is on blockchain application literature related to fintech from the perspective of both Chinese and global fintech companies. The results show that explain the optimization of fintech company performance through the unique characteristics of blockchain and the features of blockchain-enabled smart contract application. Also, we found that blockchain technologies possess unique characteristics that can enhance fintech systems and processes. Furthermore, meta-analysis and conceptual papers are the most commonly employed methodological approaches in the literature. This review provides a foundation for future studies that can contribute to the development of more robust methodological systems to accurately measure and understand the dynamics of blockchain application in fintech. Otherwise, it provides valuable insights into the applications, benefits, and challenges of blockchain technology for fintech companies.

Keywords: Blockchain application, Fintech, Blockchain characteristics, Smart contracts

1. Introduction

Blockchain application in the fintech sector remains in a nascent stage as companies are beginning to recognise its potentials, engaging and designing fintech specific blockchain applications (Fernandez-Vazquez et al, 2019). However, the application of blockchain technologies has played a key role in the transformative growth of fintech, enabling traditional abstained financial services to fulfil its potentials and overcome challenges in operational reality due to the lack of supportive technological features/ infrastructures (Fosso Wamba et al, 2018). Moreover, it has received unrivalled support from the Chinese government and is recognized as a strategic priority in the MIC 2025 plan (TOI News, 2022). Thus, it is valuable to explore the applications, benefits, and challenges of blockchain technology in fintech companies. Specifically, the retailing banking sector in particular has been benefited by blockchain's distributed ledger technology to keeping and automating transactions with the elimination of human made errors, substantially reducing costs, wastage and inefficiencies due to the reliability of blockchain protocols as shown by the accelerated shift from the traditional "SWIFT" system toward the blockchain enabled "Ripple/ XRP" system (Qiu et al, 2019). The costly and time-consuming process of funds transfer especially cross-country funds transfer in traditional banking services have long been regarded as inconveniences amongst consumers, as well as representing a risky procedure amongst banks due to the possibility of money laundering and illicit financial acts (Aziani, 2018). The application of blockchain can help to verify the identity of end parties through KYC (know your customer) protocols, overcoming the costly procedure of due diligence as funds can be securely and immediately transferred on a blockchain as shown in the development of blockchains for banks in the Middle East and North Africa regions in Papadaki & Karamitsos' (2021) study.

The emergence of blockchain enabled cross border funds transfer systems such as Ripple and Ethereum has disrupted traditional retail banking systems, enabling real-time settlements and removing inefficient intermediaries to replace the traditionally slow international payment processing systems (Islam et al, 2022). According to the statistics from PYMNT's (2022) report, 37% of companies favour the use of blockchain enabled banking platforms to conduct cross border payments, as 50% of surveyed companies have used or would like to use blockchain enabled banking platforms in the future due to the provided security, speed, transparency and conveniences. The high scalability of blockchain banking protocols such as Ripple can facilitate up to 1,500 transactions per second with an average transaction settling time of 4 seconds, driving the interests of financial institutions and consumers to leverage clear benefits in terms of predictability and speed lacked in the traditional SWIFT system (Deng, 2020). Nonetheless, despite the increasing popularity for fintech companies to design blockchain enabled protocols made for cross country funds transfer, Qiu et al (2019) argues that there remains an ongoing debate over the use of blockchain facilitated payments to replace traditional fiat currencies due to high volatility of cryptocurrencies, a lack of regulation and last mile problem presented to verify the legitimate purposes of each transfer to eliminate illicit financial activities.

Computer scientist and cryptographer Nick Szabo gave rise to the etymology of smart contract technologies in 1994, referred to as a set of promises that are specified in digital formats, detailing the protocols in place within which the selected parties are eligible to perform on these promises (Schulpen, 2018). The development of smart contracts did not gather widespread applications until the emergence of the fintech sector and the technological infrastructure support facilitated in blockchain developments. The adoption of blockchain based smart contracts has radically reshaped traditional financial services and processes, enforcing the completion of pre-defined agreements in digital formats without the abundance of unnecessary inputs required from third parties, becoming a cornerstone for the current and future fintech industry (Rahim et al, 2019). According to Panisi (2017), the application of blockchain enabled smart contracts have enabled financial institutions to record accurate financial data in a real-life manner, enhancing the auditing and the effective transmission of data across banking accounts/ organisations. The Barclays bank illustrates a prime example on how smart contracts are used to automatically identify and record changes in ownership of funds and derivatives, automatically

executing a digital contract upon the satisfaction of predefined conditions for a derivative trade/ fund transfer, settling trades and transfers in an optimised manner without the need for negotiating, manual signing and documentation (Alkhajeh, 2020).

The application of blockchain enabled smart contracts in the fintech sector is also common across investment banking firms, the design of smart contracts can help to reduce operational costs and risks as recurring/ syndicated payments are automatically repaid upon reaching the settlement date (Panisi, 2017). The completion of a trade, event or condition such as goods and services being produced and delivered to the end customer can trigger the execution of fund transfers from the customer/ client to the product/ service provider, facilitating automated recurring payment transfers in a highly reliably and secured manner (Borgogno, 2019). Smart contracts are also found to accelerate the application process for financial services including mortgages, insurance and loan applications, fintech companies such as Berbix, AML solutions and Onfido provide digital identity systems to validate the legitimacy and credentials of people, substantially reducing the occurrence of fraudulent identities and identity theft to optimise the due diligence process of financial service applications (Wolfond, 2017). The application of blockchain technologies have undoubtedly revamped the fintech industry in dynamic ways, overcoming traditional barriers and limitations of financial services with optimised operational time, cost and accuracy in financial service delivery. However, blockchain application in the fintech sector remains in a nascent stage as companies are beginning to recognise its potentials, engaging and designing fintech specific blockchain applications that will likely continue its disruption on traditional financial services in the foreseeable future (Fernandez-Vazquez et al, 2019).

In order to understand in order to understand how it can be designed and utilised to optimize fintech service delivery, this paper thoroughly reviews recent literature, specifically looking at its unique characteristics and smart contract functions that contribute to improved performance. The study also evaluates various methodologies and research scopes used to measure blockchain's impact on fintech markets, both from a global and Chinese perspective. Additionally, the article discusses current research trends and challenges, while also proposing potential avenues for future research in the field of blockchain and fintech.

2. Literature Review

2.1. Review of Blockchain Characteristics and Application in Fintech

Blockchain is a major technological advancement that has emerged as a key research field amongst both academicians and practitioners in recent years, revolutionizing traditional supply chain processes (Ajwani-Ramchandani et al, 2021) and inflicts major impacts on industries that have long relied on human intermediaries (Bhardwaj & Kaushik, 2018). The origins of blockchain are widely associated to the introduction of Bitcoin by Satoshi Nakamoto in October 2008, combining cryptology with public distributed ledger technologies to create a digital currency under a peer-to-peer network. According to Xu et als' (2019) systematic review of blockchain, a common definition of blockchain is widely accepted as a decentralized, distributed public ledger technology to record transactions over a network of blocks (computers), whereby previous records cannot be altered retroactively without the alteration of all previous blocks and the consensus of the network. Gorkhali & Shrestha (2020) further expanded on this definition of blockchain and argued that blockchain technologies essentially represent a distributed database that stores data in highly secured and immutable blocks.

A major research theme amongst blockchain related studies has been conducted to identify the key characteristics of blockchain, as Viriyasitavat & Hoonsopon (2019) argues that the effective application of blockchain technologies in different industries remain a practical issue due to the lack of consensus and understanding over its unique characteristics. According to Xinyi et als' (2018) technical analysis of blockchain characteristics model as shown in figure 1 below, they key characteristics of blockchain is categorized into five unique features. Under the anonymity feature, an adversary in the network

system is unable to distinguish a particular actor from their real identity, facilitating a privacy preservation method that protects users from identity and privacy related problems as shown in the findings of Andola et als' (2021) blockchain based e-cash protocol. The majority of blockchains offer anonymity by pseudonymity methods, as each blockchain addresses are only identifiable via public key codes that contains no private information about the identity of the user, enabling a zero-knowledge proof system where verification is performed without disclosing personal data (Jivanyan, 2019). The anonymity feature of blockchain is also highly debated amongst scholars as anonymization would ease illegal transactions where law enforcement bodies would not be able to identify the culprits, in contrast to traditional financial services where all fund transfers can be traced with clear information of each user (Rahardja et al, 2021).

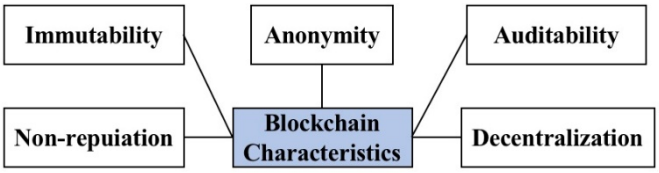

Fig. 1: Blockchain characteristics model (Xinyi et al, 2018)

Under the auditability feature, Xinyi et al (2018) argues that blockchains enable users to make effective decisions based on the past data stored in the blockchain as opposed to making decisions based on random samples, this facilitates greater auditability with highly transparent data that can be accessed by the public. Additionally, Li (2017) founded that the application of blockchain technologies have eliminated traditional problems in accounting and auditing services, the nature of public blockchains offer accessibility and clear visibility of all stored records, removing the opportunity for malicious actors to reverse engineer financial documents. Nonetheless, despite the enhanced auditability supported by transparency of recorded data, Li (2017) raised the apparent concerns over auditing analytics as there is a substantial volume of data recorded in blockchains, hence making it difficult to perform data analytics of financial records. Another study conducted by Gokoglan et al (2022) founded that the key impacts of blockchain technologies in auditing services are related to the reduced costs of monitoring and control on financial data, benefiting from the strong reliability, transparency and timeliness of data stored and accessible on blockchain networks.

Under the decentralization feature, Xinyi et al (2018) argues that even though companies or individuals can uitlise private blockchains under a centralized network, public blockchains are commonly decentralized as it facilitates a trustless environment where network actors are not required to know or trust other network actors. All network actors own a copy of the exact same data records through a distributed ledger system, whereby any altered data will be automatically rejected by other members of the network to improve data reconciliation processes (Bodo et al, 2020). The capability to add on top of existing data enables network actors to exchange data without traditional data silos, as al updates with new data are performed in real time manner that is recorded for all other network actors. Glaser (2017) challenges that traditional centralized models of financial systems have been limited by the over reliance on specific actors, contributing to systemic failures and the inability to provide promised services due to poor decision making on resource allocation, corruption and insufficient incentives for effective financial service delivery. The unique decentralization of blockchain is summerised in areas of network/ hardware resources, solution components, data, control, fault tolerance, security and performance in comparison to traditional centralized and distributed models of the financial system as shown in table 1 (Amazon, 2021).

Table 1: A comparison of decentralized, distributed and centralized systems (Amazon, 2021)

	Centralized	Distributed	Decentralized
Network/hardware resources	Maintained & controlled by single entity in a centralized location	Spread across multiple data centres & geographies; owned by network provider	Resources are owned & shared by network members; difficult to maintain since no one owns it
Solution components	Maintained & controlled by central entity	Maintained & controlled by solution provider	Each member has exact same copy of distributed ledger
Data	Maintained & controlled by central entity	Typically owned & managed by customer	Only added through group consensus
Control	Controlled by central entity	Typically, a shared responsibility between network provider, solution provider & customer	No one owns the data & everyone owns the data
Single Point of Failure	Yes	No	No
Fault tolerance	Low	High	Extremely high
Security	Maintained & controlled by central entity	Typically, a shared responsibility between network provider, solution provider & customer	Increases as # of network members increase
Performance	Maintained & controlled by central entity	Increases as network/hardware resources scale up and out	Decreases as # of network members increase
Example	ERP system	Cloud computing	Blockchain

Under the non-repudiation feature, Xinyi et al (2018) argues that that non-repudiation of information substantially increases the security of data, as the use of advanced security technologies such as digital signatures, identity authentication and time stamping are found to aid the verification of transactions. According to Fang et al (2020), blockchain network actors cannot deny the transactions of other actors in a public blockchain, as the non-repudiation feature of blockchain aids the collection, maintenance, provision and verification of undeniable evidence transmitted between the transmitter and the receiver. In comparison to traditional financial models that requires the services of third parties for due diligence needs, the information sent across a blockchain network cannot be denied by the receiver and the receiver cannot claim to have not received a particular message/ transaction across the blockchain (Wang et al, 2021). This reduces ambiguity as all transactions on a blockchain network can be verified, especially with the support of advanced technologies such as digital signatures and smart contracts where transactions are automated given the satisfaction of predefined conditions and verification of receiver identity as shown in Sun et al's (2020) study on non-repudiation storage, access control and verification of insurance data based on blockchain applications in POFS technologies.

Under the immutability feature of blockchain, Xinyi et al (2018) argues that this is the underlying reason why blockchain technology applications have revolutionized traditional processes, being able to remain a permanent, indelible and unalterable system that provides strong trust as recorded data/ history of transactions cannot be amended. The immutability feature of blockchain provides integrity in recorded data, especially in auditing processes where the presented data stored on blockchains can be trusted by stakeholders, ensuring that no data has been tampered and only reliable/ accurate data are recorded (Hofmann et al, 2017). A study conducted by Landerreche & Stevens (2018) found a positive correlation between blockchain immutability and the reduced time, cost and resources required for financial data related operations, directly contributing to the simplification of auditing efforts whilst achieving optimized efficiency and fraud prevention. The combination of cryptography and blockchain's hashing process technology enables all transactions to be timestamped and embedded into blocks, secured through a hashing process with cryptography to corporate the hashing of previous

blocks, causing blockchains to be immutable in nature (Monrat et al, 2019).

The application of blockchain technologies in the fintech sector remains an emerging research field of great importance due to the drastic growth of fintech and the increased understanding on the application of blockchain technologies (Xu et al, 2019). According to Renduchintala et als' (2022) study, the willingness to apply of blockchain technologies amongst fintech companies have drastically increased during the post pandemic era, as the capability of blockchain to increase trust, reduces the need for inefficient and costly intermediaries, overcoming counterparty risks and substantially decreasing settlement times with streamlined services. However, despite increasing recognition over the potential benefits of blockchain application in fintech, the highly diverse and dynamic nature of fintech services/ products raise apparent challenges to developing standardized guidelines for effective blockchain application, as many fintech companies have been unable to incorporate blockchain technologies with optimized values as shown in the large numbers of failed blockchain technology application in Malaysian fintech companies (Nor et al, 2021). There is an apparent research gap over the practical design and application of blockchain technologies in fintech companies (Renduchintala et al, 2022), representing strong research importance to explore how blockchain can be effectively applied in Chinese fintech companies due to a lack of empirical academic knowledge and studies. Despite the lack of understanding over the practical design and application of blockchain technologies in fintech companies, Renduchintala et al (2022, p37) summerised a range of common strengths, weaknesses, opportunities and threats from the application of blockchain technologies in fintech identified in empirical studies as shown in table 2 below.

Table 2: Strengths, weaknesses, opportunities and threats in the application of blockchain technologies in fintech (Renduchintala et al, 2022, p37)

	Positive	**Negative**
Internal (Attributes of fintech/ Defi)	***Strengths*** 1. Immutability and transparency of data and transactions. 2. No central parties dominate the services. 3. Benefits of CeFi can also be applied to DeFi, e.g., accessible and inclusive online services. 4. Custody of self-assets. 5. Smart contracts execute strict agreements automatically. 6. User-privacy preserving, e.g., applying decentralized identity to DeFi.	***Weakness*** 1. Slow-responding financial solutions: usually only updated after damage (e.g., huge scams or frauds), so DeFi may not be widely adopted if CeFi is well-operative. 2. DeFi solutions are pseudonymous (not anonymous). 3. High collateral requirements, e.g., lending in DeFi. 4. Key protection issue: user needs to secure their private key, but wallet providers are somewhat centralized.
External Attributes of the environment, blockchain & regulations	***Opportunities*** 1. Automatic standardization: standardization can be automatically done in a decentralized fashion (e.g., what the majority follows becomes the standard). 2. Globalization: borderless financial activities can be achieved without a centralized organization such as SWIFT. 3. Fast transactions in terms of fewer intermediary processes such as audition and verification. 4. Rich technical recourses, e.g., many open-source blockchain frameworks. 5. Pseudonymous to genuinely anonymous.	***Threats*** 1. Technical challenges in blockchains, for example, slow transactions and controversial consensus. 2. Expensive implementations and development of decentralized platforms. 3. Rigid and slow-responding financial regulations. 4. Immaturity, e.g., large-scale DeFi platforms, may suffer serious glitches. 5. Gas fee in blockchain transactions, even though there are fewer commission fees, blockchain processes usually require a gas fee per transaction.

The application of blockchain technologies on fintech companies has gathered increasing research attention in recent years, as numerous studies have attempted to examine the expected improvements in fintech service delivery in relation to blockchain's facilitated characteristics. A combination of a survey-based and systematic review study conducted by Renduchintala et al (2022) outlined key benefits of blockchain applications on fintech companies particularly in the payments, deposits, lending and investment management sectors due to its offered immutability and transparency in data processing and transactions. The unique characteristics of blockchains to facilitate transparency and clear visibility of all transaction records is also found to improve the performances of the financial sector supply chain, enabling different supply chain actors to verify transactions with strong confidence and trust as shown in Fosso Wamba et als' (2020) study. Giudici's (2018) study also found a positive impact of blockchain's high security through encrypting all transaction information and processes with cryptography, facilitating enhanced fintech risk management as unauthorized parties are unable to corrupt transactions with manipulative actions. This is further reinforced in Fernandes-Vazquez et als' (2019) mapping study of blockchain in fintech where its highly secured characteristics is found to substantially reduced cyber-security risks that have long been a key issue for fintech companies.

The lack of reliance on third parties or traditional intermediaries to deploy and maintain financial systems is found to substantially reduced administration and service costs for fintech companies, as Kalra's (2019) study founded a strong decline in cost per transaction, estimated to reduce the overall financial services infrastructure costs by over $15-20 billion according to Gregorio's (2022) study. This is also reinforced in Kumari & Devi's (2022) study as the cryptographic protocol used in blockchain enabled fintech systems is found to substantially reduce administration costs due to the elimination of transaction clearance and settlement needs. Another common theme identified in empirical studies is associated to the facilitated scalability characteristics of blockchain, enabling probabilistic verification and clustering functions to overcome the time lag and communication siloes in traditional financial services (Li et al, 2021). This is also evidential in Moro-Visconti et als' (2020) study as the automation of blockchain enabled fintech services can be performed with high frequency, topping 100,000 transactions per second that enables fintech services to be performed and delivered to a wide range of global users with minimal scalability costs per transaction.

The application of blockchain technologies in insurance service delivery is also found to substantially improve process performances, as the automated nature of blockchain technologies would reduce unnecessary paperwork and human errors (Raikwar et al, 2018). Varma et als' (2022) study also found blockchain technologies to improve banking service performance, offering enhanced stability and resilience to the system. However, Sanka & Cheung's (2021) study founded that not all fintech companies can benefit from the desired performance gains, particularly for IoT applied fintech companies where inappropriate integration could fail to store accurate data in a timely manner, resulting in potential performance bottlenecks and unnecessary increase in operational costs. Additionally, the challenging nature of blockchain characteristics is also found to negatively impact the efficiency of applied fintech systems, as Faccia & Petratos (2021) argues that a high level of programmability is required to design effective blockchain enabled fintech systems that are not available in fintech companies due to lack of technical expertise. The lack of technical knowledge and skillsets from employees in Nigerian companies is found to pose a major obstacle to the capability to effective programme blockchain applications and its integrated design on existing financial technology systems (Wumi-Ajayi et al, 2022).

The high levels of facilitated privacy by blockchain technologies is found to be another key characteristic to enhanced fintech systems, as Lee et al (2021) highlighted the inherited privacy qualities of blockchain to allow the authorization of specific users to access data stored on the blockchain, eliminating the likelihood of unauthorized access to ensure data privacy. The combination of consensus, cryptography and decentralization principles of blockchain technologies are found to secure the privacy of financial data, the rise of decentralized fintech business models designed with advanced cryptography

and through a distributed consensus would substantially reduce the theft or illicit access of financial information (Chen & Bellavittis, 2020). In consideration of the identified blockchain characteristics and their benefits on fintech service delivery/system improvements, these characteristics are used to measure the impacts of blockchain technology application on Chinese fintech companies as shown in table 3 below.

Table 3: Summary of blockchain characteristics variables used to measure fintech company performances

Blockchain characteristics variables	Authors	Description
Transparency	Fosso Wamba et al (2020), Giudici (2018)	The visibility of all transaction details and processes stored on the blockchain system of fintech companies
Reduced risks	Fernandes-Vazquez et al (2019), Giudici (2018)	The reduction of risks facilitated by the automated features of blockchain enabled fintech services
Reduced administration and service costs	Kalra (2019), Gregorio (2022), Kumari & Devi (2022)	The reduction of administration and service costs resulted of reduced intermediaries and human errors
Security	Fernandes-Vazquez et al (2019), Giudici (2018), Fosso Wamba et al (2020)	The provision of enhanced security in transactions due to the combination of cryptography, consensus and decentralization
Scalability	Li et al (2021), Moro-Visconti et al (2020)	The capability to scale with automation of financial service delivery at reduced unit costs per transaction
High performance	Raikwar et al (2018), Sanka & Cheung (2021)	The achieved performance measured in financial service delivery efficiency, transaction time and successful rates
Programmability	Faccia & Petratos (2021), Wimo-Ajayi et al (2022)	The capability to programme blockchain application designs and its integration onto existing fintech systems
Privacy	Lee et al (2021), Chen & Bellavittis (2020)	The provision of enhanced privacy in transactions due to the combination of cryptography, consensus and decentralization

2.2. Impacts of Smart Contract (SC) Functions on Performances of Fintech Companies

The effects and implications of smart chain applications represent a major theme amongst empirical studies, disrupting and replacing the inefficiencies of traditional fintech services and system models with innovative, value-added efficiencies (Rahim et al, 2019; Thankor, 2020). According to Thankor (2020), blockchain assisted smart contracts have played a vital role in innovating existing payment systems, improving process efficiency with lower contracting and verification costs. The automated nature of fintech services executed via the fulfilment of pre-defined conditions on blockchain smart contracts is found to substantially improve fintech service delivery, leveraging automation in contractual agreements (Rahim et al, 2019), especially in Hong Kong's fintech sector where the competitiveness of fintech banking services have increased and substantially reduces human labour. The use of smart contracts is found to automate payment flows with precision, reducing previous siloes caused by the need for third parties to verify and perform due diligence on end parties (Schueffel, 2021). Biancone et als' (2019) study also reinforced the enhancement of managing payments in fintech services, benefited from the organized and pre-arranged payment flows between debtors and investors upon the satisfaction of mutually agreed conditions.

Brownsword's (2019) study highlighted the impacts of smart contracts on the fulfillment of contractual obligations, proposing that smart contracts allow financial companies to enforce obligations via autonomous codes in comparison to traditional legal agreements that require integrity and commitment to fulfil. Nonetheless, the imbedded contract obligations of smart contracts are challenged to lack a unified algorithmic financial contract standard, as Brammertz & Mendelowitz (2019) argues that most smart contracts in fintech services are currently designed in a one-off or customized basis,

despite recognizing its contributions to enhanced increase the transparency of contractual obligations. The built-in covenant compliance feature of smart contracts is found to positively impact the digital transformation of internal auditing processes, automatically verifying covenant compliance calculations with precision in legally binding promises (Pizzi et al, 2021). The facilitated digital signature feature in smart contracts is found to enhance the financial system processes to formalize processes between contracted parties, providing verifiable evidence that the signer has accepted or agreed to digital financial documents (Wang & Cheng, 2019). Additionally, Lo et al (2021) founded that digital signatures used in smart contracts would enhance the authentication process in fintech service delivery, saving time in the verification of consumer identities that was previously time-consuming and costly.

The adoption of smart contracts is found to substantially reduce both transaction costs and settlement risks at each step of fintech service delivery, as Marcel & Medel (2017) argues that smart contracts embedded on blockchain distributed ledger technologies would unify all settlement processes in a single transaction process stored in a single database. This is also reinforced in Al-Ajlouni et als' (2018) study where smart contracts are found to reduce counterparty and settlement risks in complex banking services. The self-execution feature of smart contracts is found to substantially enhance trust levels established between contracted parties (Panisi, 2017), removing the need for intermediaries, legal professionals and brokers in a seamless and clean transaction process (Moslein, 2019). The complicated nature of bond-like instruments used in Islamic finance is found to be eased via the adoption of smart contracts in Delle-Fogile et al's (2021) study, facilitating greater trust as the identity of contract parties are automatically checked. The self-verification feature of smart contracts is also used to explain the de-risking practices of fintech services in Hong Kong, stimulating higher financial inclusion, facilitating the detection of money laundering and financing of terrorism activities (Lee, 2022). In consideration of the identified smart contract benefits on fintech service delivery and improved system efficiencies, the identified features of smart contracts are used to measure the impacts of blockchain technology application on Chinese fintech companies as shown in table 4 below.

Table 4: Summary of smart contract features used to measure fintech company performances

Smart contract features	Authors	Description
Financial data automation	Rahim et al (2019), Thankor (2020)	The automation of processing, communicating and recording of financial data through smart contracts
Automated payment flows	Schueffel (2021); Biancone et al (2019)	The automation of payment flows between contracted parties upon the fulfilment of pre-defined conditions
Transparent contractual obligations	Brownsword (2019), Brammertz & Mendelowitz (2019)	The clear visibility of all contractual obligations written on smart contracts
Built-in covenant compliance	Pizzi et al (2021)	The built-in covenant compliance system that facilitates the verification of legally binding promises
Digital signature verification (KYC)	Wang & Cheng (2019), Lo et al (2021)	The authentication of identifies for contracted parties to validate/ confirm contractual agreements
Reduced counterparty/ settlement risks	Marcel & Medel (2017), Al-Ajlouni et al (2018)	The reduction of counterparty and settlement risks via a single step process facilitated by smart contracts
Self-execution	Panisi (2017), Moslein (2019)	The capability to self-execute processes upon the fulfilment of pre-defined conditions
Self-verification	Delle-Fogile et al (2021), Lee (2022)	The capability to self-verify identities via smart contracts

3. Review of Methodologies, Results and Discussion

This section reviews the empirical methodologies and findings employed in literature relevant to the research design. The first section reviews the methodologies and findings employed in the context of blockchain application in China. The second section reviews and compares the methodologies, techniques and findings used on studying fintech markets in China and under a global perspective. The third section reviews the independent and dependent variables and findings related to study blockchain

application and fintech markets in empirical studies. We found that meta-analysis and conceptual papers are the most commonly employed methodological approaches, which means that the dynamics and complexity of blockchain technology application in fintech are difficult to measure using standardized paradigms.

3.1. Blockchain Application in China

Since the introduction of blockchain technologies in 2008 and its growth in popularity within the academic field in recent years, there has been increasing academic attention given on the application of blockchain technologies in China as summerised in table 5 below. It is apparent that blockchain technologies have been explored in relation to supply chains (Chen et al, 2020), personal genomic data (Jin et al, 2019), carbon trading (Pan et al, 2019), banking (Guo & Liang, 2016), development prospects (Zhao, 2019), medical resource sharing (Liu & Liu, 2021), overcoming trust gap in food safety (Qian et al, 2020), sustainability in food trade (Mao et al, 2018), energy power sectors (Song et al, 2019) and application in economics (Zheng & Huang, 2018). The reviewed list indicates that the application of blockchain technologies is multifaceted as it is adopted across different industries. However, a majority of empirical studies conducted on blockchain application in China is carried out as conceptual papers or meta-analysis due to the inaccessibility of relevant data, as only several studies have gathered primary data through interviews and questionnaires. This reflects the nascent nature of the research field on blockchain applications, illustrating strong research importance for more studies to explore the blockchain discipline.

Table 5: China blockchain application specific literature

Author	Research topic	IV/DV	Methods/ type of paper	Findings
Chen et al (2020)	Blockchain driven supply chain finance application for the auto retail industry in China	/	Conceptual paper	Identified main points in traditional SCF platforms and introduced BCT driven system design concepts to improve SCF
Jing et al (2019)	Application of a blockchain platform to manage and secure personal genomic data	Data ownership, data sharing, data security	Case study on LifeCODE.ai	Qualitative conceptual insights that opens up new avenues for dealing with data ownership, data sharing and data security issues in big data platforms
Pan et al (2019)	Application of blockchain in carbon trading	/	Conceptual paper	Discussing the steps of carbon emissions trading and the characteristics of blockchain
Guo & Liang (2016)	Blockchain application and outlook in the banking industry	/	Conceptual paper	Insights on how blockchain can revolutionise the underlying technology of payment clearing and credit information in banks
Zhao (2019)	Development and prospects of blockchain technology	/	Interviews	Discussion of key developments, regulations and prospects of blockchain in China
Chai et al (2020)	Blockchain technology application	/	Interviews	Discussion of mainstream blockchain technology applications from industry experts
Liu & Liu (2021)	Medical resource sharing mechanism developed via blockchain technology to overcome China's medical resource imbalance	Medical resource allocation indicators	China health statistics yearbook	Insights on how China's medical resource imbalance can be resolved by blockchain's characteristics

He et al (2020)	Distributed energy transaction model applied on the alliance blockchain in China	/	Conceptual paper	How the centralised control of distributed energy trading platforms can be improved by blockchain
Zou et al (2020)	Academic and application on blockchain	/	Meta-analysis (empirical)	Summarises the eight applications scenarios of blockchain from empirical studies
Qian et al (2020)	Overcoming trust gap in food safety (food trade) between EU and China	/	Meta-analysis (empirical)	Development of an interconnected conceptual traceability framework based on blockchain
Farooque et al (2020)	DEMATEL analysis of barriers to blockchain based life cycle assessment in China	Barriers to blockchain based LCA in China (Intra-organisational barriers, system and external barriers)	Quantitative Surveys	New insights on the barriers to blockchain based LCA in China
Mao et al (2018)	Sustainable and credible environment in food trade that uses innovative blockchain solutions	Profit rates	Case study of food company from Shandong China.	Proposed food trade mechanism based on an alliance chain that eliminates information asymmetry and guarantee market fairness
Song et al (2019)	Application of blockchain in the energy power industry of China	/	Conceptual paper	Identification of problems in blockchain application in the Chinese energy industry from empirical studies
Zeng & Zhang (2019)	Reviewing blockchain application development method studies	/	Meta-analysis (empirical)	Identification of key themes in blockchain application development
Shi (2019)	Application of blockchain as a service (BaaS) and its providers in China	/	Conceptual paper	SWOT of BaaS in China
Zheng & Huang (2018)	Challenges and countermeasures of blockchain finance and economics	/	Conceptual paper	Systematic analysis of blockchain technology and application in the financial and economic field from empirical study findings.

3.2. China and Global Fintech Markets

Numerous empirical studies have been conducted on China's fintech industry as summerised in table 6 below. It is apparent that the majority of empirical studies also follow a meta-analysis or conceptual paper approach, illustrating the potential difficulties in accessing relevant data and to measure the practically of fintech services. Buchanan & Cao's (2018) study compared the differences of fintech developments in China against the West, Marquez's (2019) and Zhang & Kim's (2020) study explored the impacts of fintech models/ services on the overall financial service sector. Pathrose & Priyanka (2022) explored the adaption of fintech policies in the Asian region, discussing how financial policies must be changed to accommodate the emergence of fintech services. Zhang et als' (2020) study performed a systematic review of cross sector fintech focusing on the market leaders of Alibaba and Tencent. Navaretti & Calzolari (2017) explored the relationship between fintech and banking in China, discovering the challenges and benefits of fintech to traditional banking processes. Yefremov (2021) explored China's recent introduction of the digital yuan system, identifying the impacts it has on restructuring the traditional monetary financial relations in China's financial system. Wang & Huang

(2017) explored the implications of fintech in relation to China's capital market, similar to Allen et als' (2022) study that studied empirical data on the impacts of fintech that disrupted China's traditional capital market and processes.

Table 6: China fintech specific literature

Author	Research topic	IV/DV	Methods/type of paper	Findings
Buchanan & Cao (2018)	Comparison of fintech revolution in China and the West	/	Meta-analysis	Comparison of key differences between fintech in China and the West
Marquez (2019)	Fintech impacts on the financial services sector	/	Meta-analysis	Systematic review of differences in fintech impacts on the financial services sector in the EU, Africa, China and the US
Pathrose (2022)	Adapting fintech and blockchain financial policies in emerging Asia	/	Conceptual paper	Discussion of fintech and blockchain adaptation in Asia
Zhang-Zhang et al (2020)	Eco-systematic view of cross sector fintech – case of Alibaba and Tencent	/	Conceptual paper	Comparing the fintech business model of Alibaba and Tencent
Zhu & Zhou (2016)	Applications of blockchain technology to equity crowdfunding in China	/	Conceptual paper	Analysis of blockchain technology to equity crowdfunding applications
Navaretti & Calzolari (2017)	Fintech and banking relationships	/	Meta-analysis	Discussion of their key challenges and benefits between fintech and banking from empirical studies
Yefremov (2021)	The digital yuan Chinese experiment	/	Conceptual paper	Discussion of the potential benefits from the digital yuan to restructure the system of monetary financial relations in China
Cheng & Qu (2020)	Fintech impacts to reduce credit risk in Chinese banks	A range of banking related variables including total loans, blockchain technology costs etc…	Data from Chinese commercial banks between 2008 and 2017	The exploration of relationship between fintech and credit risk for Chinese banks.
Wang & Huang (2017)	Fintech in China's capital market	/	Conceptual paper	Discussion of future implications of fintech in China according to current capital market trends
Allen et al (2022)	Financial structural transformation in China via fintech, cryptos and CBDC	/	Meta-analysis	Systematic review of empirical data on the impacts of fintech and DeFi to disrupting traditional financial processes
Wu & Duan (2019)	Application of blockchain in financial markets	/	Conceptual paper	Discussion of how blockchain can be used in the financial market
Hua & Huang (2020)	Development, impacts and risks of China's fintech sector	/	Meta-analysis	Discussion of current research trends in China's fintech sector and research gaps where a lack of primary solutions has been developed.

In comparison to the research scopes undertaken when studying blockchain and fintech amongst

global literature, it is apparent that the majority of empirical studies conducted on fintech are also performed under meta-analysis and conceptual paper approaches as shown in table 7 below. This further reinforced the limitation identified in Chinese fintech studies where the nature of understanding fintech impacts possess major challenges in data availability and research design. Nonetheless, Nelaturu et als' (2022) study explored the taxonomy, challenges and future directions of blockchain applications of fintech, performing a meta-analysis to systematically review the findings of empirical studies from around the globe. Vazquez et al (2019) produced a mapping study of blockchain application in global fintech projects, reviewing 49 papers in areas of security, scalability, legal, regulatory, privacy and latency challenges overcome by blockchain application in fintech. Aggarwal et al's (2021) study explored the role of blockchain in the 4th industrial revolution, Pant (2021) explored the emerging trends in fintech, digital money, fintech innovation and blockchain based fintech solutions. Hendershott et al (2022) and Martincevic et al (2020) explored the impacts of fintech innovations and the digitalisation of financial activities, Kukreja et al (2021) focused on exploring fintech impacts on the financial services in India.

Table 7: Global blockchain/ fintech literature

Author	Research topic	IV/DV	Methods/ type of paper	Findings
Nelaturu et al (2022)	Blockchain in fintech, taxonomy, challenges and future directions	/	Meta-analysis	Systematic review of empirical studies on the taxonomy, challenges and future directions of blockchain application in fintech
Fernandz-Vazquez et al (2019)	Mapping study of blockchain in fintech	/	Meta-analysis	Systematic review of 49 papers from SCI journals, emphasising on challenges in security, scalability, legal, regulatory, privacy and latency challenges
Aggarwal et al (2021)	Blockchain as the drive of the 4th Industrial revolution	/	Conceptual paper	Discussion of how blockchain can accommodate the transition of the 4th industrial revolution
Pant (2021)	Emerging trends in fintech	/	Meta-analysis	Systematic review of literature on fintech, digital money, fintech innovation and blockchain
Hendershott et al (2021)	Research frontiers across fintech	/	Meta-analysis	Systematic review of articles related to finance innovation and fintech
Martincevic et al (2020)	Fintech revolution in the financial industry	/	Metanalysis	Discussion of empirical studies conducted on the digitalisation of financial activities in the fintech sector
Kukreja et al (2021)	Impact of fintech on financial services in India	/	Meta-analysis	Critical review of empirical studies conducted on the fintech sector of India
Li & Xu (2021)	Insights into financial technology via a bibliometric and visual study	/	Meta-analysis	Review of 848 empirical studies to establish the key trends of fintech research studies
Puschmann & Leifel (2020)	Sustainable digital finance	/	Conceptual paper	Proposed a new sustainable digital finance innovation platform based on the current sustainable needs of digital finance from empirical research knowledge
McKinsey (2018)	Synergy and disruption: 10 trends shaping fintech	/	Industry data	The identification of key trends based on global fintech industry data
Cortina & Schmukler (2018)	Fintech revolution and its threat to global banking	/	Conceptual paper	The identification of key threats caused by fintech to the global

				banking system from empirical research findings.

3.3. IV/DV Based Blockchain Application and Fintech Market

A limited number of empirical studies have explored the application of blockchain in the fintech sector via the testing of variable relationships as summerised in table 8 below. Lee & Lim's (2019) study explored the behavioural intention to adopt blockchain technologies via measurement constructs derived from Venkatesh et als' (2003) unified theory of acceptance and user of technology model, evaluating how likely users would accept the integration of blockchain technologies in fintech services. Li & Wan's (2021) study explored relationship between blockchain application and corporate performance, identifying a negative relationship where corporate performance variables such as firm age, income growth and market share to negatively correlate with blockchain application. Nazim et als' (2021) study explore the behavioural intention to adopt blockchain technology amongst banks in the Islamic financial system, gathering primary data through quantitative surveys distributed to 150 Islamic bankers and measured their behavioural intention under Venkatesh et als' (2003) UTAUT model.

Table 8: IV/DV related blockchain/ fintech literature

Author	Research topic	IV/DV	Methods/ type of paper	Findings
Lee & Lim (2019)	Behavioural intention to using blockchain technology (unified theory of acceptance and use of technology model proposed by Venkatesh et al (2003)	Eight constructs including ease of use, security, trust, cost, facilitating, usefulness, privacy, intention and experience perceptions toward blockchain	Quantitative surveys	Determination of how users are likely to accept the merging blockchain technology
Li & Wan (2021)	Analysis of the negative relationship between blockchain application and corporate performance	Corporate performance variables such as proportion of largest shareholder, firm age, income growth, market share	Industry statistics	Identification of statistical relationship between blockchain application and corporate performance
Nazim et al (2021)	Behavioural intention to adopt blockchain technology amongst banks in Islamic financial system	DV = behavioural intention to adopt blockchain IV = performance expectancy, effort expectancy, social influence, facilitating condition, environmental factors	Quantitative surveys	The study of behavioural intentions of 150 Islamic bankers to adopt blockchain
Vedapradha & Ravi (2020)	An EOM approach to reconciliation in banking via blockchain	DV = ROI IV = customer strategy, employee development, change management, financial analysis, capital management	Quantitative surveys	A statistically high association between technology and business process, accounting and data reporting via blockchain
Li (2020)	Fundamental drivers to blockchain technology adoption (TRA – Technology acceptance model)	DV = behavioural intention to adopt IV = perceived usefulness, ease of use, trend, attitudes towards adoption, subjective norm of adoption	Quantitative questionnaires	263 questionnaires identified the key drivers to blockchain technology adoption
Mselmi (2019)	Blockchain technology and systematic risk	DV = Long run marginal expected shortfall, systemic risk index, capital shortfall, volatility IV = Blockchain related variables	Forbes report data on 142 financial companies	Analysis of the relationship between the banking sector implementation of blockchain technology and the systemic risk of financial institutions across different continents

Vedapradha & Ravi's (2020) study adopted an EOM approach to explore the reconciliation benefits

in banking services via blockchain adoption, finding a statistically high association between technology and business process, accounting and data reporting via blockchain enabled system features. Li (2020) explored the drivers to blockchain technology adoption with measurement constructs derived from the technology acceptance model (TAM), differing from the behavioural intention constructs measured in Nazim et al (2021) and Lee & Lim's (2009) study. Li (2020) collected primary data from 263 questionnaire participants, identifying a positive correlation between perceived usefulness, ease of use, trend, attitudes towards adoption and the subjective norms of adoption (perceived social pressure) to the willingness to adopt blockchain technologies. Mselmi's (2019) study performed a critical analysis on the relationship between the blockchain technology applied banking services and the systemic risk of financial institutions across different continents, utilising secondary data collected from Forbes on 142 banking service providers, finding that blockchain technologies positively correlated to the long run marginal expected shortfall and systemic risk index.

3.4. Research Trends and Challenges for Future Studies

The majority of empirical investigations conducted on the adoption of blockchain technology in the fintech market have predominantly employed conceptual or meta-analysis methodology designs. This approach has raised significant concerns regarding the effectiveness of exploring the dynamics of blockchain applications in fintech systems and services. As a result, it is necessary to develop blockchain-specific measurement scales in future research to fully capture the extensive features of this technology. Moreover, the absence of research studies utilizing specific independent and dependent variables to investigate blockchain applications in fintech underscores the lack of research consensus in studying blockchain within recognized parameters, which is evident in the research context of China and across global perspectives. There is a dearth of research focusing on the distinctive cultural factors that drive the adoption of blockchain technology in the fintech sectors of different countries. A review conducted in this regard has revealed that there are significant variations in the way blockchain technologies are implemented in China, as compared to the global context. Consequently, there is an urgent requirement for future studies in this area, despite the apparent difficulties arising from the lack of established parameters in the literature for assessing the impact of cultural drivers on blockchain application.

There is a well-established consensus in research that blockchain technologies possess unique characteristics that can enhance fintech systems and processes. These characteristics, such as increased transparency, reduced risks, administration and service costs, improved security, scalability, performance, programmability, and privacy, are widely believed to improve the performance of fintech firms. This provides a foundation for future studies to explore how specific blockchain characteristics enhance fintech systems and processes, and highlights the key success factors that fintech firms should consider to optimize their services through blockchain adoption. However, there are challenges in creating a standardized methodological approach to measure blockchain characteristics' enhanced performance, mainly due to the variation in fintech firm systems and the way blockchain technology is designed and applied. The emergence of blockchain-enabled smart contracts is widely recognized as a means to optimize fintech company performance. These contracts facilitate financial data automation, automated payment flows, transparent contractual obligations, built-in covenant compliance, digital signature verification (KYC), reduced counterparty/settlement risks, self-execution, and self-verification functions. Therefore, in-depth, individual function-specific understanding is necessary for future studies. The identified research trends on blockchain application in fintech is summerised in figure 2 below.

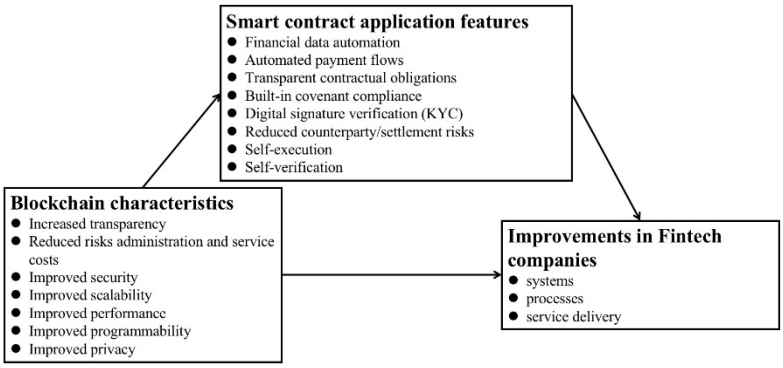

Fig. 2: Key research trends on blockchain application in fintech

4. Conclusion

This study presents a comprehensive qualitative literature review of the application of blockchain technologies in fintech companies. We found that blockchain offers unique features that can optimize the performance of fintech companies by improving traditionally inefficient processes and providing cutting-edge optimization gains in areas such as transparency, risks and costs management, security, scalability, performance, programmability, and privacy. Moreover, the emergence of blockchain-enabled smart contract features are widely recognized as a means to optimize the performance of fintech companies. Furthermore, the analysis revealed that meta-analysis and conceptual papers are the most commonly employed methodological approaches in the literature. This indicates that the dynamics and complexity of blockchain technology application in fintech are difficult to measure using standardized paradigms. The major research trends in relevant blockchain and fintech applied literature were discussed, highlighting potential methodological and practical challenges in future studies. In the academic field, this study will contribute to the development of more robust methodological systems to accurately measure and understand the dynamics of blockchain application in fintech. In the practitioner field, it is helpful for fintech companies to have a deeply understanding in the applications, benefits, and challenges of blockchain technology.

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