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Supply Chain Traceability and Resilience as Drivers of Blockchain Adoption in Pakistan's Agriculture Sector

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Abstract: Pakistan's agriculture sector is vital to its economy and public health, with food quality and safety becoming major concerns. Supply chain traceability and resilience are critical in ensuring these standards and maintaining customer trust. Blockchain technology offers transformative potential by enhancing transparency, security, and efficiency in agricultural supply chains. This study explores how traceability and resilience influence blockchain adoption to achieve sustainable competitive advantage in Pakistan's agri-food sector. Using a qualitative, inductive approach, data was collected through semi-structured interviews with six professionals familiar with blockchain applications. Findings highlight transparency as the main driver for adoption, alongside factors like data integrity and trust. While interest in blockchain is growing, technical knowledge gaps and security concerns remain key barriers. The study underscores blockchain's strategic role in strengthening agri-food supply chains for long-term competitiveness.

Key Words: *Blockchain, Agriculture, Supply Chain, Traceability, Resilience, Competitive advantage,*

INTRODUCTION

The last few decades have seen a dramatic shift in the field of technology, with the emergence and fall of several computer paradigms that have influenced the nature of today's digital world. Every generation has introduced ground-breaking inventions that have changed how we interact with information and how we perceive what technology is capable of, from the massive mainframes that dominated the early computing era to the decentralized networks driven by blockchain technology (Effanov & Roschin, 2017).

In recent times, supply chains have grown in complexity, rendering them more vulnerable to potential hazards, fluctuations, and disruptions (Razak et al., 2021). With the passage of time blockchain technology becoming more popular and successful in many cryptocurrency applications, other organizations and entities try to use its fault tolerance and transparency to solve issues when multiple untrusted actors are involved in the distribution of a resource (Manski & Jobs, 2023).

Blockchain technology combined with the internet of things allows supply chain management of perishable items to be tracked. Data regarding raw materials, quantities, and other details are included in the transactions in the agriculture supply chain.

The highly relevant area which needs blockchain transparency is agriculture. Agriculture is essential to the survival of most people on the planet.

The agricultural scene is changing as a result of the quick growth of digital technologies like blockchain, artificial intelligence, and precision farming. Pakistan's infrastructure and agriculture sectors are still being driven by technology adoption and the application of new operational standards. Agriculture is Pakistan's main source of income, it adds 18.5% to the annual GDP (Yaeen et al., 2022).

Blockchain Technology and Potential Applications

Blockchain technology is a distributed ledger technology that can record transactions and data securely and transparently. Utilizing technology to support traceability in the food production industry seeks to document every detail of the supply chain, from supplier interactions to product distribution, while also locating and linking critical information about production methods and environmental conditions (Folinas et al., 2023). Blockchain increases traceability and can provide customers with even greater confidence in the source of their food and its quality (Hameed et al., 2022). Dutta et al., (2020) suggest that blockchain technology can lead to improved farmer power by enabling farmers directly sourcing their produce to markets and engaging in equitable price setting.

The threats that threaten the supply chain risk realized that there are numerous internal and external dangers that have raised the level of vulnerability and hence require risk management approaches and tactics for enhancing the degree of organizational preparedness and resilience (Bayramova et al., 2021). An era of technological advancement characterized by computerization and convergence of the virtual world and the real world might

see blockchain as one of its elements. It has the power to alter social interactions, governmental structures, our relationship to the environment, and a nation's ability to achieve sustainable growth, therefore its impact goes beyond the economy (Sirimanne & Freire, 2021).

Many improvements can be gained by using Blockchain technology, several case studies illustrate blockchain technology's potential in the agricultural sector. In order to improve transparency and lower food recalls, IBM Food Trust and Walmart collaborated to deploy a blockchain-based mango monitoring system (IBM, 2023). Similar to this, the Indian government collaborated with a blockchain business to establish a direct line of communication between farmers and consumers, which raised farmer revenues and decreased consumer prices (The Hindu Business Line, 2023).

How Blockchain Works

Prior to being recorded in a public ledger, the transaction needs to be initiated and validated (Ranđić et al., 2018). Within a blockchain, transactions are arranged in the form of interconnected linear chain blocks. By using the Proof of Work principle, the hash of the previous block is included in each subsequent block. The node's job in this scenario is to find the random string. This random string needs to be hashed using the previous blocks' transactions and hashes, which results in a hash with a specific number of leading zeroes.

The entire functioning mechanism of the blockchain is displayed in Fig 1.

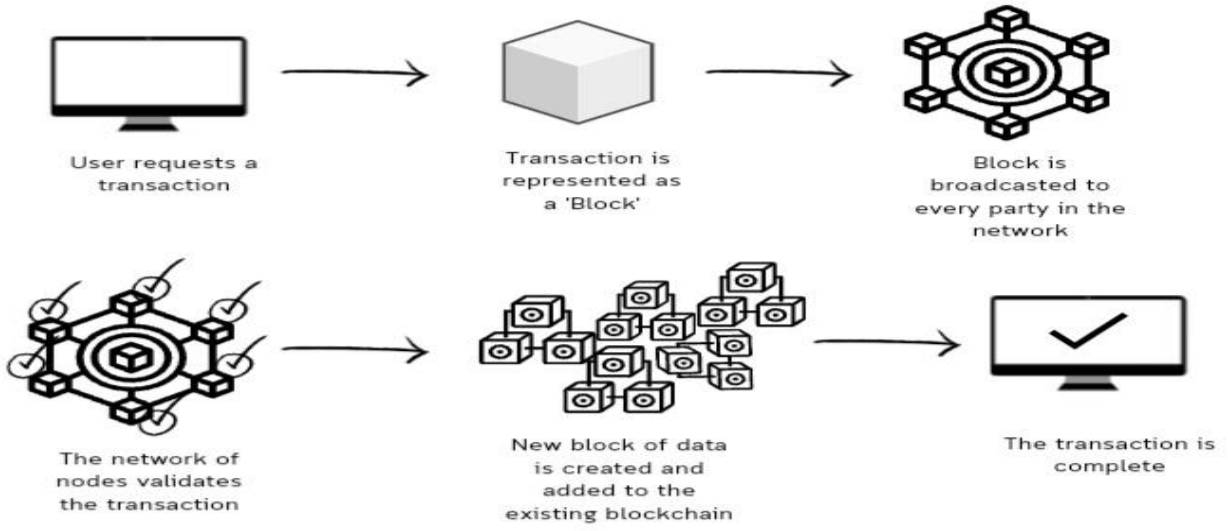

Fig 1: Entire functioning mechanism of the Blockchain

Some of the challenges are concerned with issues to do with supply chain management gaps, lack of traceability and susceptibility to numerous disruptions (Ghode et al., 2020) these are some of the issues that are proving hard to give sustainable competitive advantage in the global market. Pakistan's agriculture sector currently does not possess well-organized and integrated traceability systems that enable clients to track the origin of the agricultural products, the manufacturing processes undergone, and the distribution channels involved in getting the products to the markets (Khan et al., 2020). Because of this lack of traceability, food safety and quality suffer; moreover, the industry is in danger of contamination.

However, the Pakistan agricultural supply chain comprises another issue, which is the ability to establish consumer trust and transparency and last but not the least, the stability of the supply chain. Inconsistencies in weather, variability of sourcing materials, and interruptions in transportation and supply chains also heavily affect manufacture and delivery (Santoro et al., 2023).

Emerging problems of supply chain transparency and sustainability in Pakistan's agriculture industry can be effectively solved by implementing blockchain. Applying blocks of data that make up blockchain enables the recording of data mainly in the supply chain through an unalterable and decentralized system (Zeb et al., 2021).

However, there are certain challenges that may hinder the use of blockchain in agriculture; these include Technological difficulties that may arise since the use of blockchain solution is relatively new Technological know-how, and Security/privacy concerns regarding data that may be shared while using the blockchain solution (Khalid et al., 2021). Moreover, it is crucial for the stakeholders to be willing to come together and openly share the necessary information with each other regarding the implementation of blockchains, which may mean overcoming organizational and cultural resistance

(Qureshi & Jimenez, 2020).

Therefore, the question arises as to how supply chain traceability, resilience, and blockchain might help maintain the competitive advantage of Pakistan's agriculture industry. Solving these issues shall enhance the stability and transparency of the sector, enhance competitions, and encourage the adaptations of sustainable solutions.

RQ1: *How is the food supply chain traceability likely to result in the adoption of blockchain technology in the agriculture sector?*

RQ2: *How is the food supply chain resilience leading towards blockchain technology adoption?*

RQ3: *How does blockchain technology adoption improves the sustainable competitive advantage in the agriculture sector?*

BACKGROUND

Food safety emerges as a key issue that concerns both producers and consumers. End customers frequently worry about the quality and provenance of products and raw materials in supply chains. Ensuring transparency and traceability throughout the supply chain is a crucial challenge for the agricultural sector in the modern world, as customers are becoming more concerned about the origin and sustainability of their food. Because blockchain technology is decentralized and unchangeable, it has the potential to completely transform the agriculture industry by enhancing supply chain transparency, encouraging sustainable practices, and boosting customer confidence (Akella et al., 2023).

As a relatively new player in the blockchain field, Pakistan is seeing an increase in interest in applying blockchain technology to strengthen financial inclusion and agricultural supply chains. Blockchain-based farming data management and financial services solutions are being developed by Pakistani firms such as AgriTech Pakistan and PakDeFi (Ali, 2024).

Leading The way in the adoption of blockchain technology is the United States, which is proactively incorporating blockchain into many facets of its economy and government functions. The US government has tripled its spending in research and innovation as part of its commitment to blockchain development. In 2022, the US made a significant commitment to blockchain technology by investing US$4.2 billion in this field (*Blockchain Solutions by Region 2022*, 2023). The joint IBM and Walmart case study, "Food to Fork," has set a precedent for the application of blockchain technology in the supply chain industry. Their accomplishments show how blockchain technology may improve customer confidence, efficiency, and transparency, opening the door to a more sustainable and safe food system (*Walmart Study*, 2017).

With more than 84% of all blockchain patents filed worldwide, China is the global leader in the deployment of blockchain technology. Forecasts indicate that the blockchain technology market is expected to grow significantly, with estimates putting it at over 27 billion yuan by 2025 and about 69 billion yuan by 2030 (Slotta, 2023). NEO provides a platform for creating smart contracts and decentralized apps (dApps), which helps to grow the Blockchain ecosystem. It successfully supports TRON, NEO, VeChain, and Qtum, among other smart contract initiatives (Lee, 2023).

There is a noticeable weakness in technological aspects of Agriculture projects in Pakistan which require governments and businesses attention to create smarter and sustainable processes in Pakistan's Agriculture supply chain. Policy makers of Pakistan need to enhance their digital capabilities so that they can position themselves strategically for this new wave of technology.

LITERATURE REVIEW

Recent years have seen a significant shift in technological advancement which is raising questions regarding environmental safety (Folinas et al., 2023). Due to those raising concerns many of the firms are opting for sustainable strategies to achieve sustainable goals (Parung, 2019).

The following are the four main ways that blockchain technology can help sustainable supply chains:

(1) significantly reduce product recalls and rework because of its tracking capabilities.

(2) simplify the process of tracing a product's actual carbon footprint and figuring out how much carbon tax each company should pay.

(3) encourage recycling behavior by offering incentives to participants in deposit-based recycling programs; and

(4) boost the effectiveness of emission reduction initiatives (Saberi et al., 2018).

The agriculture sector plays an important role in the lives of people and in the country's economy. In Pakistan it also plays an important part, accounting for more than 20% GDP and employing 40% of the labor force (Khan et al., 2022). Rapid growth of population demands an increase in agriculture production in a sustainable manner. Agricultural growth requires enhanced productivity and quality, sufficient marketing infrastructure and effective food management (Xu et al., 2020).

One of the most important parts of agriculture these days is food product monitoring, since both consumers and producers are increasingly concerned about food safety (Lewis & Boyle, 2017). Traceability through the capacity to trace the origin of agricultural products, confirm authenticity, and guarantee adherence to quality and safety requirements, this promotes accountability and

confidence among involved parties (Kamilaris et al., 2019).

The 21st century presents an immense number of problems for agriculture, the basic backbone of human civilization. Food security and food sustainability concerns are anchored on various factors such as the growing population, failure to establish adequate resources, and climatic influences (Mohapatra et al., 2021). If agriculture is going to be sustained, then it is going to require building for the future, which refers to the ability to adapt and thrive when confronted with changes (Santoro et al., 2023).

In the attempt to overcome the increasingly complex operational challenges within the agriculture sector, the businesses are always encouraged to adopt new technologies (Kamilaris et al., 2019). The new technological tool that has come to define the new industrial developments across the global platform is blockchain (Kim et al., 2022). Blockchain technology has forced the Companies in the agricultural industry to attain a sustainable competitive advantage and accelerate the market competition more ferociously (Tapscott & Tapscott, 2024). Specifically, in the recent past, the agriculture sector has been expressing interest in the increased use of blockchain technology as its applications are steadily rising. This technology offers farming bodies new horizons of opportunities and produces a digitization/innovation effect (Salah et al., 2019).

METHODOLOGY

Research Approach

This study employed an inductive approach because it was suitable for the research topic on the deployment of resilient and traceable supply chains based on the adoption of blockchain technology for sustainable competitive advantage in Pakistan's agriculture industry. Inductive method involves the collection of data then forming conclusions and hypotheses by the researcher generalizing over patterns and themes from the collected data. Therefore, inductive reasoning is ever applicable when engaged in qualitative research with the goals of explaining, describing and coming up with hypotheses about the research topic. Due to limited academic publications, real applications and testing of the theory, the present approach is more relevant and adaptable.

This research employs a descriptive research design because the aim of the study is to understand the current state and opportunities of the blockchain for establishing accountability and efficiency in the supply chain needed to gain a competitive edge for the agriculture sector of Pakistan.

The study's population consists of firms that were aware about blockchain technology. This indicates that the participants selected for the sample are thought to be informed about the subject and, as a result, may add to the findings that address the research questions. With the thought of purposive sampling, six companies (Table 1) with affiliations to the food industry or agriculture were approached to represent the sample for this research article. This sample size seems sufficient to ensure an adequate representative sample of the diverse food business involved in the agricultural supply chain.

Data Collection

To gather precise information about the current state of traceability, supply chain resilience, and awareness of blockchain technology within Pakistan's agricultural sector. This research aimed to understand how these factors, along with their potential adoption, influence the achievement of a sustainable competitive advantage for Pakistani agricultural businesses. The survey used semi-structured interviews for which few questions were prepared initially to start the conversation (Table 2) and the interviews were either conducted personally or through phone calls.

The survey was conducted among different food businesses of Pakistan. It collected specific data through the use of non-direct questions to get information about the participants' experiences and attitudes. Through the data collected, the research provided a clear understanding of the current state of the agricultural sector and its preparedness to adopt new technologies such as blockchain for improving traceability and resilience in the face of globalization.

Data Analysis

The content analysis was used as a research method that involves a systematic examination and interpretation of the content of different types of communication such as texts, documents, photos and audiovisual materials. The data collected must be analyzed and identified for patterns, themes, and meanings. Qualitative and quantitative researchers often employ content analysis to identify the latent meanings, ideas, and themes within the content being analyzed. Reducing textual or symbolic data into many segments is done through content analysis as stated by Krippendorff (2020). Researchers can sort different aspects of the content into different categories by employing different coding methods such as interpretative, numerical, and thematic coding.

Table 1.

Companies	Description
K&Ns	• Khalil Sattar formed K&Ns Pakistan in 1960. • Its area of expertise is the production of various poultry products. • They are well known for their hygienic processing techniques and quality assurance checks to guarantee food safety and quality.
Engro Foods	• In 2005, Engro foods was introduced as a subsidiary of Engro Corporation. • In Pakistan, it produces, processes and sells dairy products, juice, ice cream and frozen desserts. • It is the nation's second biggest producer of processed milk.
Shan Foods	• Shan's extraordinary success story began in 1981, when a single man's dream came true. • Mr. Sikander Sultan, Chairman of Shan Foods (Pvt.) Ltd., pioneered the spice industry with a one-room operation, paving the road for success. • Shan is a well-known worldwide brand that produces a wide range of spices to enhance the taste and flavor.
Rafhan Maize	• In 1953, Rafhan Maize Products Co. Limited was established as one of Pakistan's first companies involved in the refining of corn. • As an affiliate of Ingredion Incorporated, USA, Rafhan Maize can guarantee superior products, consistent supply and outstanding services.
Falak Rice	• In 1999, Matco introduced Falak Basmati Rice to the Pakistani market as a high-end product that offered a guarantee of quality and consistency with each purchase.
Fauji Foods	• Fauji Foods Limited was established in 2015. The House of Nurpur is gaining popularity among its consumer base for nutritious product offerings.

Table 2.

- What is the nature of your agriculture business?
- For how long your organization has been operating in Pakistan?
- How much knowledge do you and your organization have regarding blockchain technology?
- Are you currently implementing any traceability system?
- What kind of challenges do you have to face to ensure traceability?
- Is your organization working or exploring blockchain technology? Yes, or no? Reasons.
- What could be the driving force behind blockchain adoption?
- What kind of challenges do you think your organization will face if you adopt blockchain technology?
- What is your general perception regarding blockchain technology adoption?
- How important do you think blockchain technology is to achieve sustainable competitive advantage?

RESULTS

Data Analysis

To gather sufficient data for study, the goal was to conduct open-ended interviews from the various food businesses involved in the agricultural supply chain of Pakistan to gather required information. The data was collected via Phone calls and Face to Face meetings. As mentioned above for data analysis, thematic analysis was conducted. Three themes and 6 sub-themes were derived from interview codes (Figure 2).

Transparency

According to the interview results, transparency is the primary and main objective for blockchain adoption in Pakistan's agri-food sector. The openness and accessibility of information on the blockchain are referred to as transparency (Tian et al.,2020).

Additionally, this theme has been divided into the following two sub themes i.e. Trust & Contamination Risk.

Trust

The research findings indicate that most Pakistan's agri-food companies are exploring blockchain technology because, as consumers' curiosity about the origin of products grows, companies must become more transparent to win their trust. Engro Foods emphasized the pressures from customers about product details:

"*Consumers are becoming more and more interested in knowing where items come from and what circumstances were used throughout production.*"

Customers are increasingly more interested in knowing whether a product is produced locally, according to Pakistani agri-food organizations. This can be highlighted in the following quote by Shan Foods:

"*In light of the current enthusiasm for local production, it is extremely important to share the story.*"

Furthermore, the results demonstrate that firms' readiness to make sure that their customers trust their communications and get a knowledge of their business practices is correlated with their capacity to communicate added value through enhanced transparency and traceability.

"Compiling thorough traceability data and presenting it gives consumers peace of mind that the product is made ethically." (Engro Foods)

The Pakistani agri-food industry is keen to ensure clients of its sustainable practices by communicating added value through transparency and traceability, which they think may be accomplished through the implementation of BCT. Following quote from expert Rafhan Maize shows how their organization connects sustainability with blockchain technology adoption.

"*Blockchain technology is a great tool to assess the environmental impact.*"

To sum up, businesses are under growing pressure from consumers who want more information, which makes them more interested in using BCT to produce and share added value and boost stakeholders' trust in a variety of ways.

Contamination Risk

The results show that, because of contamination risk and food safety regulations, most of Pakistan's agri-food businesses are exploring blockchain technology. Because of their unreliability, lack of structure, and openness, the current systems are very vulnerable to changes in data. The following quote highlights the importance of accessing timely and unchanged data:

"*Blockchain technology will help to improve control, facilitate accurate information, and eliminate the possibility of contaminated food, which could otherwise harm a company's reputation.*" (Fauji Foods)

Food fraud, ineffective procedures, food safety, and the impact of food production on the environment are the difficulties that food management systems must overcome (Katsikouli et al., 2020). The importance of delivering fresh products can be highlighted with the following quote:

"*Real-time data, such as temperature, storage condition, and expiration date, can be accessed with the use of blockchain. This unchangeable data will assist the company in avoiding contamination and providing safe and fresh products.*" (K&Ns)

In conclusion, businesses are exploring blockchain technology as a transparent ledger system to get a hold on real time data which can help them to reduce the risk of contamination and build trust with consumers.

Organization's Operational Efficiency

Increased transparency promotes the adoption of BCT, but research also reveals organizational circumstances that influence adoption decisions and act as stimulants for the use of blockchain technology. Thus, in Pakistan's agri-food business the second theme for blockchain implementation is Organization's operational efficiency. The theme is further divided into 2 sub themes i.e. Technical Knowledge & Security Concerns for Blockchain Adoption.

Technical Knowledge

Businesses can gain from a digitized supply chain by improving overall performance (Haddud & Khare, 2020). For instance, via improved traceability and visibility, more efficient procedures, increased capacity to adapt to changes, and more involved suppliers and consumers (Haddud & Khare, 2020).

"*Changes at the organizational and managerial levels may be necessary as a result of the difficult and complex transformation that digital technologies demand of operational structure and management techniques.*" (Engro Foods)

Organizational resistance is a common coexisting

factor with change that can be viewed as a dominant barrier to the adoption of new technologies (Horvath & Szabo, 2019). The following quotes from different organizations highlight the importance of being aware of technological knowledge:

"*Businesses must establish procedures that can support employees' adaptability and tolerance to changing surroundings in order to meet the difficulties."* (Falak Rice)

"*Adoption of blockchain technology is difficult since there aren't enough comprehensive and strategic guidelines for deployment and evaluation."* (Shan Foods)

"*The organization's capabilities, managerial judgment, and external incentives all play a role in the choice to adopt new technologies." (*Fauji Foods)

"*Decision makers' ignorance of new technology may prevent them from taking full advantage of company capabilities and create obstacles to adopting them."* (Rafhan Maize)

"*Lack of technological expertise makes it challenging for management and potential users to identify the technologies that are best suited for a certain supply chain and to understand the benefits and implications of putting them into practice."* (K&Ns)

Thus, the operational effectiveness of a company might be severely affected by a lack of technological expertise. It prevents innovative technology that could simplify operations from being adopted, stifling innovation. The internal requirements that are identified to be critical determinants influencing Pakistan's agri-food organizations' conditions and possibility of adopting BCT include knowledge and skills, comprehending the win, and the ability or willingness to change.

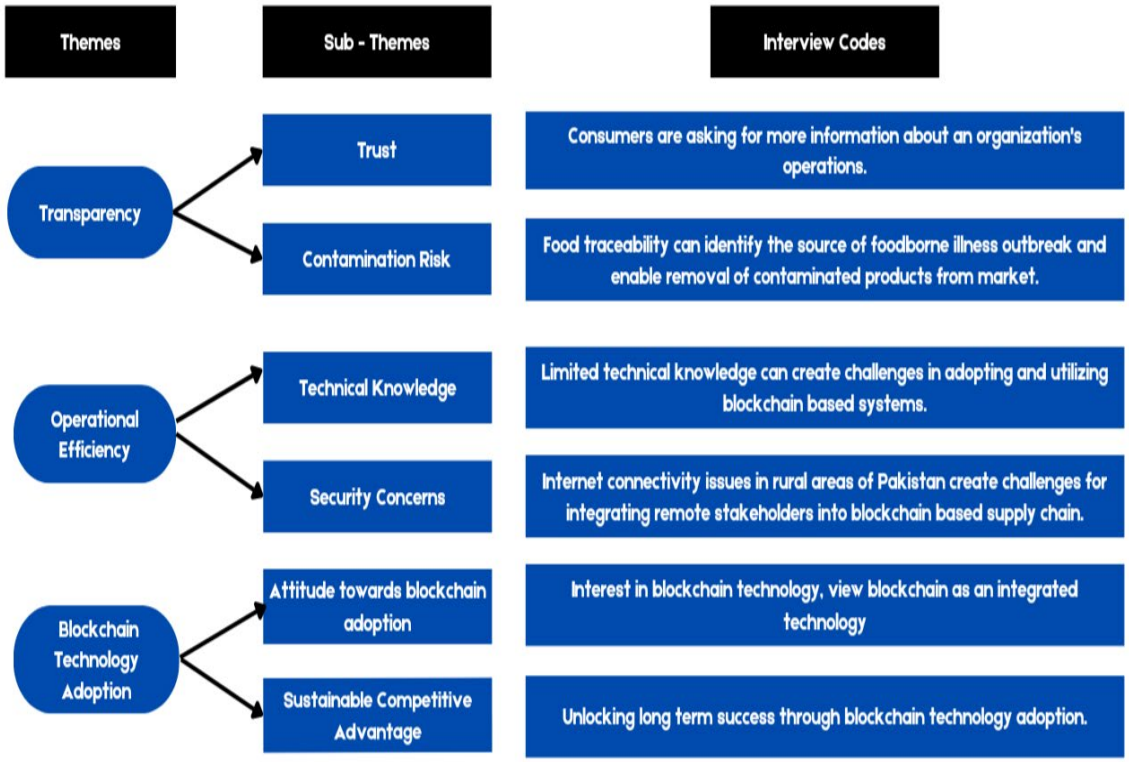

Fig 2: Derived Themes and sub themes

Security Concerns

Concerns about security have a significant impact on how efficiently blockchain adoption operates. Vulnerabilities, possible attacks, and the difficulty of guaranteeing safe transactions are just a few of the problems that might restrict adoption and reduce overall effectiveness (Horvath & Szabo, 2019). An organization's concern regarding their security and safety are found to have an impact on blockchain adoption which ultimately affects the organization's operational efficiency. The ability to track the whole product movement can create difficulties for an organization:

"*Blockchain technology may be more necessary for recording the entire supply chain process, but it also has the potential to leak confidential information to unauthorized parties, affecting a company's standing in the market."* (Falak Rice)

"*Increased awareness often sparks a desire to know deeper details."* (Rafhan Maize)

Blockchain networks, like any digital system, are vulnerable to cyberattacks. Hackers could potentially target the network to manipulate data, disrupt operations, or steal sensitive information.

"*It is a challenge to adopt blockchain in the sector if we don't have a secure system to protect sensitive information."* (Shan Foods)

In conclusion, security concerns remain a major obstacle to the widespread use of blockchain technology, even though it has enormous potential to improve the efficiency and transparency of Pakistan's agri-food sector. Businesses are concerned about data privacy and cybersecurity risks because they are reluctant to give sensitive data to relatively new technology which affects the operational efficiency of the organization.

Blockchain Technology Adoption

The findings of this research indicates that the agri - food sector of Pakistan is exploring blockchain technology adoption. This serves as the final theme which is further subdivided into 2; Attitude towards blockchain adoption and Sustainable Competitive advantage.

Attitude Towards Blockchain Adoption

The results of this thesis investigate the opinions of Pakistani agri-food organizations toward the implementation of blockchain technology. Despite the fact that blockchain technology is still relatively new to the businesses, the results indicate that they are generally curious about the technology. The following quote, for instance, demonstrates interest.

"*There's a strong sense of exploration and potential, but the details are still being worked out."* (Falak Rice)

However, some organizations remain skeptical, potentially due to difficulties in pinpointing the specific benefits of adoption.

"With so much information available, a key challenge is selecting the critical data that needs to be stored on the blockchain." (Rafhan Maize)

Organizations see blockchain technology as complementary to existing systems, requiring integration for full functionality. This perception leads them to believe that a standalone BCT implementation might be impractical. Highlighted by Shan Foods:

"*Integrating the technology with business and control systems will unlock its greatest benefits."* (Shan Foods)

The idea that blockchain integration technology offers a comprehensive perspective appears to be universal rather than exclusive to the agri-food industry (Kamble et al., 2020).

Sustainable Competitive Advantage

Blockchain technology goes beyond simply enhancing communication, information reliability, and fostering closer producer-consumer relationships. It presents a powerful opportunity to tackle critical issues within the food supply chain. This includes reducing food waste, improving working conditions for all participants, and promoting sustainable competitive edge (Wünsche & Fernqvist, 2022).

"*Blockchain presents a revolutionary opportunity to transform the food production landscape, fostering greater sustainability and efficiency throughout the entire supply chain."* (Fauji Foods)

"*Effective technologies like blockchain are crucial for securing and sustaining a competitive advantage."* (Fauji Foods)
"Blockchain is empowering businesses to develop groundbreaking solutions that boost their competitive edge." (K&Ns)

Blockchain is more than just a potential invention, it is a transformative force that elevates business processes and competitiveness. In the agricultural sector, its innovative applications are revolutionizing the industry. From improved traceability and streamlined operations to enhanced trust with consumers, blockchain empowers firms to gain sustainable competitive advantage. This widespread adoption is driving massive technological advancements in agriculture, showcasing the power of blockchain to increase a firm's effectiveness and functionality.

DISCUSSION

There is evident concern in extending an interest in adopting blockchain technology in the agri-food sector in Pakistan. It is believed to improve traceability, increase resilience, and, in the process, improve competitiveness to overcome the related downside. However, there are some issues which pose a great challenge for its utilization. Some of them are security risk factors which may hinder completion and protection of the projects, the absence of technical expertise in the field and prospects of opposition from various other players in the market.

Q1. Is the food supply chain traceability likely to result in adoption of blockchain technology in the agriculture sector?

Externally, blockchain, a distributed and immutable ledger for recording transactions, also enhances visibility throughout the supply chain process from upstream – the mining of raw materials, to downstream – the delivery of the product to the consumers (Wong et al. 2020).

Among the three discussed factors, the first one which is potential benefits from blockchain regarding increased transparency and decreased fraud are regarded as the most crucial argument for Pakistani agri-food businesses to adopt blockchain technology. Therefore, through facilitating customers to believe in the genuineness and ethical sourcing of products, blockchain can play a key role in addressing the need for value creation.

Q2. Is the food supply chain resilience leading towards Blockchain technology adoption?

Blockchain's transparency enables tracking and monitoring which helps in minimizing the information gap and enhances the supply chain resilience. However, there are some issues regarding the spread of widespread adoption. A major challenge is the lack of industry knowledge on the technology, which hampers the full appreciation and application of the technology. Security issues also play a role in exacerbating the situation. Companies face the challenge of data openness (what data to share) versus cyber threats (cyber attacks). These factors hinder the adoption of blockchain and thus the enhancement of a resilient agri-food supply chain.

Q3. Does attitude towards blockchain technology adoption impact the realization of sustainable competitive advantage in the agricultural sector?

Concerning the case of Pakistani agri-food organizations, it has been revealed that there is a growing interest in the use of blockchain technology, which is viewed as one of the directions toward attaining sustainable competitive advantage. However, the stand that individuals, and organizations, that engage in the agricultural value chain takes has a strong influence on the final decision on the use of such technology. Today's contextual challenges call for innovative solutions, and one of the recent breakthroughs proving to foster firm competitiveness is blockchain technology (Olatunji et al., 2019)

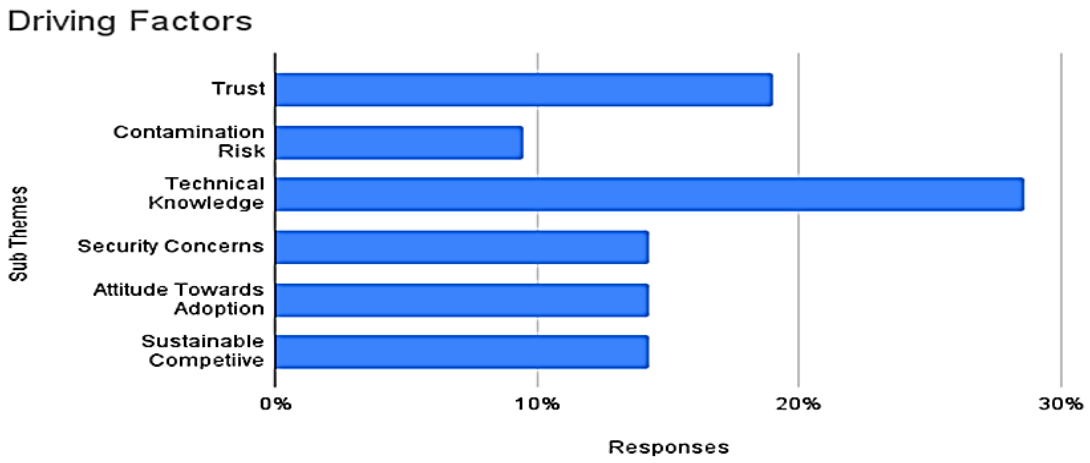

Fig 3; Graph illustrating thematic analysis results

Theoretical Implications

This study investigates the factors that led to Pakistan's agri-food business adopting blockchain technology. By giving researchers insight into the reasoning behind this acceptance, the study significantly advances the fields of knowledge already known about blockchain technology in this industry. This study extends the existing understanding of blockchain's benefits for traceability and transparency while addressing a crucial but little-studied topic: the adoption of blockchain technology in Pakistan's agri-food industry, a poor country. This focused strategy fills the knowledge vacuum currently present in the literature for certain nations and sectors, hence addressing the need for more research on the adoption of blockchain technology in developing economies.

The article builds on prior works by offering a complete comprehension of the blockchain adoption process within agriculture and food industry in Pakistan. This is made possible through novel ideas which help outline all-important considerations that drive firms to either accept or reject this technology. The global talk about the adoption of blockchain is enhanced further by highlighting country-specific goals among them being Pakistan as an example of a developing country.

Managerial Implications

This article offers valuable insights into blockchain technology adoption specifically within Pakistan's agri-food sector. This study thus provides useful information for organizations to evaluate their level of preparedness for blockchain technology. These organizations can use it to build a successful path towards adoption by determining what they already have and areas they need to improve. This research does not just give an overview of the factors affecting adoption but also provides a model for examining them with emphasis on ones that facilitate or impede the process. Furthermore, these findings show how blockchain technology goes beyond present understanding to help agro-food enterprises raise trust levels among stakeholders and enhance supply chain resilience. Eventually, such insights could aid firms in becoming more competitive and sustainable in future through operationalizing strategic blockchain technology.

CONCLUSION

Blockchain technology has the potential to significantly alter Pakistan's agri-food industry. This indicates that blockchain has the potential to significantly impact this company's competitiveness, supply chain vulnerability, and honesty, among other issues. Second, the technology minimizes disruptions by helping firms track and monitor things along the distribution route by filling in information gaps. It will take some time to clear the obstacles in the way of mainstream acceptance. The issue is that many businesses in the sector do not yet have sufficient familiarity with technology. Concerns about security are particularly significant since businesses must figure out how to safeguard themselves against cyberattacks while sharing information freely, which fosters trust.

However, these limitations are evident and the

research reveals growing tendencies of acquiring competitive sustainability by the Pakistani agri-food companies to center on blockchains. Concerning the adoption of such technologies, attitudes of stakeholders are what prevail; therefore, the right attitudes towards blockchain technology need to be adopted so that the firms concerned can regain control overflows of information on the supply chain section.

The present study has several limitations, including the difficulty in finding Pakistani agri-food companies with sufficient knowledge of blockchain technology. Because of this, the companies involved in this study had varying levels of knowledge about technology.

Secondly, because many businesses weren't familiar with blockchain yet, it was hard to pick a specific product to track within the supply chain. So, this research focused on a whole industry (agri-food) in one country (Pakistan) to get a clearer picture.

Thirdly, as there wasn't a lot of existing research on how businesses are adopting or looking forward to adopting blockchain in Pakistan's agri-food industry, this research includes a comprehensive literature review to fill the gaps in our knowledge before diving deeper.

Therefore, considering the results, limitations of the study as well as the absence of the related research proposal, for further study suggestion is to explore the blockchain adoption of a certain product supply chain in the context of Pakistan's agri-food sector. This suggestion stems from the previous findings that show that factors such as product characteristics and other supply chain conditions are decision influences that affect an organization's manner of adoption. Therefore, studies of such a nature would offer ideas more specific to the process of adoption.

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