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Frontier Technologies and Entrepreneurship: Exploring How Cutting-Edge Innovations Drive Business Agility and Growth in Nigeria

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Abstract

Frontier emerging technologies like AI, Blockchain, and IoT are transforming the entrepreneurial economy on a global scale. They are developed to change the way people communicate and address various business problems globally. Accordingly, this research also assesses the role of these technologies in promoting entrepreneurship in Nigeria, as well as their adoption, usage, and exploitation for supporting innovation-driven entrepreneurial development. The research design utilized for this research work was descriptive survey research. The population for this research study comprised 1,200 registered businessmen in Lagos State. Using normal sample size calculation, 300 respondents were obtained from this population. A structured questionnaire and interviews were utilized for data gathering. Descriptive data analysis and regression analysis using SPSS version 26 were done for the data gathered. On the other hand, data from interviews were analyzed for themes using thematic data analysis. Findings from this research study have shown that while the adoption of AI, Blockchain, and IoT has been positive and a major driving factor for entrepreneurial innovation, efficiency in business, and competitiveness in market performance, it also has support issues, which pertain to a lack of infrastructure support, a lack of regulatory support, and a lack of proper internet literacy. Therefore, summarizing all the findings from this research study, it would like to conclude that this remaining potential for limited entrepreneurship support from these technologies can now be aptly utilized with anticipatory policy revisions, improvement in infrastructure development support, and in technology-driven innovation entrepreneurial training courses, which would support a successful digital transformation in the prevailing business environment in Nigeria.

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Introduction

In the era of the Fourth Industrial Revolution, frontier technologies are revolutionary forces that transform economies, industries, and societies. Artificial Intelligence (AI), Blockchain, and the Internet of Things (IoT) are spearheading the revolution, promising innovative paths, productivity, and entrepreneurship competitive edge. Globally, the technologies enable firms to automate, increase transparency, improve customer satisfaction, and open up new markets (Schwab, 2023).

Every organisation in any part of this world can only operate effectively, interact with customers, suppliers and relate successfully with their competitors with good and strong information and communication

resources, as well as marketing strategies and e-commerce technologies. The advent and increase in frontier technologies, such as artificial intelligence, blockchain and internet of things are very significant in entrepreneurship development for creating new opportunities and reshaping challenges facing Small and Medium Scale Enterprises (SMEs). Frontier technologies drive new innovations across various sectors and redefine business strategies and models. These technologies interact and drive significant advancement, business agility and growth in different sectors such as finance, manufacturing, healthcare, food and beverages, and communication services (Wamba & Queiroz, 2020).

Frontier technologies are both opportunities and risks in the context of developing economies such as Nigeria. Opportunities are rooted in their ability to upend current business models, lower transaction costs, and enable data-driven decisions (UNCTAD, 2024). Some of the resulting challenges include constraints of infrastructure, cost of technology adoption, bad regulatory environments, and the absence of adequate personnel (Adepoju & Eze, 2024).

Many developing nations including Nigeria, are facing serious challenges of infrastructures and limited access to finance which hinder them from harnessing these frontier technologies for sustainable development whereas, the developed nations are moving and leading at a very high pace in the area of cutting-edge innovations, research and development, robust infrastructure, industrial development, and total adoption. Despite the growing argument on digital transformation in entrepreneurship and the gaining of more attention among researchers, policy makers, government and scholars, empirical studies that test the combined effect of AI, Blockchain, and IoT as proxies for frontier technologies on entrepreneurial performance in Nigeria are limited. Therefore, this area requires more scholarly attention and further study. Hence, this study bridges this gap by studying the extent to which these technologies influence entrepreneurial innovation, efficiency, and competitiveness in Lagos State, the business hub of Nigeria.

AI enables business executives to employ machine learning algorithms for predictive analysis, customer segmentation, and workflow automation (Bello et al., 2024). Blockchain, characterized by decentralization, immutability, and transparency, has revolutionized finance, supply chain management, and contract agreements through secure peer-to-peer transactions (World Bank, 2023). IoT, by the integration of sensors, devices, and networks, facilitates real-time monitoring, predictive maintenance, and enhanced product-service systems (Okonkwo & Musa, 2023).

Theoretical bases of this research was drawn on the Technology Organization Environment (TOE) theory that explains adoption of technological innovations in organizational environments (Tornatzky & Fleischer, 1990), and the Schumpeterian theory of innovation, which focuses on technology as a driver of creative destruction in entrepreneurship (Schumpeter, 1934). Previous studies (Eze & Umeh, 2024; UNCTAD, 2024) indicated that frontier technology adoption plays an important role in business scalability and coverage of markets but underscore the importance of enabling ecosystems for long-term uptake. The study is also anchored on the impact and transformation theory, digital divide theory as well as frontier technology readiness index.

Frontier Technologies Conceptualization

Frontier technologies represent new digitally based technologies that are rapidly reshaping entrepreneurship and market organisations. They include some of the most prominent of these, namely artificial intelligence (AI), blockchain, and the Internet of Things (IoT). According to the United Nations Conference on Trade and Development (UNCTAD, 2024), frontier technologies are the next generation of digital-led innovation and are the focus of national competitiveness in the contemporary economy.

Artificial intelligence (AI) encompasses machine-learning algorithms and smart systems with the ability

to replicate human decision-making capabilities. For business persons, applications of AI include customer segmentation, predictive analytics, detecting fraud, chatbots, and automating workflows. Evidence has empirically revealed that SMEs adopting AI have been able to achieve efficiency gains, customer responsiveness, and innovation potential, though data availability and digital skills problems are common OECD, 2023; Bello et al. 2024.

The technology of Blockchain, with its decentralized structure, immutability, and cryptography, Authentication offers a completely fresh perspective with regard to trusting transactions. This technology ensures trusted peer-to-peer transactions, facilitates the execution of smart contracts, and offers transparency in supply chains, hence decreasing Intermediaries and transaction costs. The increasing adoption of this technology, especially in SMEs, in areas of remittances, cross-border transactions, Development evidence from Chen & Martinez (2023) and the World Bank (2023) on supply chain tracing also highlight this.

Internet of Things-IoT refers to a structure that consists of interconnected things, sensors, as well as communication systems. This provides real-time monitoring, predictive functionality for maintaining systems, as well as optimal functioning. Industries benefit from IoT in streamlined supply chains, effective inventory management, and product-service innovation. Empirical Although evidence shows that infraction costs, cyber attacks, as well as expenditure for adoption of Questions still arise, particularly in developing economies.

Taken together, AI, blockchain, and IoT are not mere inflection points in technology but transformation agents in their own right that disrupt business models even as they drive innovation, efficiency, and competitiveness. Infrastructure, capabilities, and policies are needed for their adoption.

The TOE model of technology adoption study offers a structured approach, as epitomized by Tornatzky and Fleischer in 1990. This model enumerates various issues related to technology, organizational issues, as well as environmental issues. The above-mentioned entrepreneurial context in Nigeria has used this model to enumerate various issues related to environmental structure, organizational capabilities, as well as value of technology. For instance, in 1934, Schumpeter's original theory of innovation viewed technology as a lever of "creative destruction" through entrepreneurial entry to markets with disruptive products, processes, or business models. Typical examples of such disruptive innovations would be AI automation, blockchain contracts, and IoT services among modern entrepreneurial ecosystems.

The theory of the digital divide also applies, according to van Dijk 2020, since its focus is on disparities in access to digital technologies. While access may be provided, it is disparities in digital competence and effective utilization which determine the way in which entrepreneurs can make use of frontier technologies.

Finally, UNCTAD's Frontier Technology Readiness Index of 2024 makes a macro-level assessment from the standpoint of the readiness of a country in terms of ICT infrastructure, skills, industrial capacity, and finance metrics. The rank of Nigeria in this measure denotes improved mobile connectivity but with sustained financing and institutional gaps.

Recent literature indeed evidences the fact that this frontier technology set does impel fundamental changes in the face of entrepreneurship. For instance, Eze and Umeh (2024) established the fact that African SMEs which have adopted digital technologies enjoy better scalability, contingent upon supporting ecosystems such as access to finance and digital infrastructures. On their part, Afolayan and Okorie (2024) found that in Sub-Saharan Africa, the adoption of AI by SMEs is positively associated with competitiveness and market expansion.

Thus, the adoption of blockchain in developing economies focused on leveraging its applications for trust and transparency in supply chains, especially

across borders. In return, Kenya specialized in the use of blockchain in added value chains in agriculture, while India used AI in scaling up SMEs.

Weak broadband diffusion, erratic power supplies, and fragmented regulatory regimes are some of the issues that have weakened the large-scale deployments recorded so far, although frontier technologies are finding decent adoption in Nigeria. It is observed that, despite the description of various single technology adoptions in isolation, relatively few empirical studies have focused on the cumulative impact of AI, blockchain, and IoT on entrepreneurial performance in Nigeria. This calls for the existing study whose purpose is to measure their joint effects toward innovation, efficiency, and competitiveness.

Materials and Methods

This study used a descriptive survey design. A descriptive survey design is appropriate in studying associations of variables in a natural setting. With this design, technology adoption could be measured quantitatively, while entrepreneur experiences could also be qualitatively described.

This therefore comprised a population of 1,200 business people in Lagos State, with experience in ICT, manufacturing, and services. This was a purposive sample because it was done for a reason; as such, it involved Lagos, which is the business focal point of Nigeria and has been relatively more exposed to technological advancement. Using a standard formula for sample size calculation at 95% confidence and 5% margin of error, 300 respondents were calculated. Stratified random sampling techniques were thereafter used for proportional representation of industries. Two data collection tools had been used in this research. The Structured Questionnaire had been used for quantitative data on the adoption of AI, Blockchain, and IoT by entrepreneurial outcomes in innovation, efficiency, and competitiveness. The Semi-structured Interviews instrument involved 20 interviews among entrepreneurs to understand better the challenges and opportunities in using F/T. Qualitative data are analyzed by descriptive statistics through means, frequencies, and percentages, with multiple regression analysis using SPSS software version 26 for the analysis of relations among F/T entrepreneurial outcomes. Thematic analyses of data from the interviews provided the next level of insight into patterns, meanings, and narratives that add to the depth of findings.

Results

Table 1 depicts the demographic representation of entrepreneurs involved in this study.

Table 1: Demographic Profile of Respondents (N = 276)

Variable	Category	Frequency	Percentage (%)
Gender	Male	168	60.9
	Female	108	39.1
Age Group	21–30 years	82	29.7
	31–40 years	117	42.4
	41–50 years	59	21.4
	51 years and above	18	6.5
Educational Level	Secondary	36	13.0
	Polytechnic/College	104	37.7
	University Degree	118	42.8
	Postgraduate	18	6.5

Business Sector	ICT/Tech-based	116	42.0
	Manufacturing	91	33.0
	Services	69	25.0

A large proportion of respondents (42.4%) fall in the 31-40 years group. This clearly indicates that adoption of technology occurs among the younger generation.

Table 2 describes the degree of adoption of AI, Blockchain, and IoT.

Table 2: Adoption of Frontier Technologies by Entrepreneurs (N=276)

Technology	High Adoption (%)	Moderate Adoption (%)	Low/No Adoption (%)
Artificial Intelligence (AI)	58%	27%	15%
Blockchain	44%	32%	24%
Internet of Things (IoT)	39%	29%	32%

The technology that has been most widely adopted is Artificial Intelligence, whereas technology adoption in IoT has been low. The regression analysis also focused on how the three frontier technologies are a predictor for entrepreneurial performance.

Table 3: Regression Analysis Results

Predictor Variable	β (Standardized Coefficient)	t-value	p-value	Significance
Artificial Intelligence (AI)	0.42	5.93	0.001	Significant
Blockchain	0.31	4.57	0.004	Significant
Internet of Things (IoT)	0.28	3.46	0.012	Significant
Model Summary	$R^2 = 0.62$	$F(3, 272) = 147.6$	$p < 0.01$	Model Significant

The model estimated that altogether, AI, Blockchain, and IoT explain 62% of the variance of entrepreneurial performance, while AI has the highest influence.

Adoption levels across industries broken down pinpoint sectoral differences.

Table 4: Adoption of Frontier Technologies by Industry

Sector	AI High Adoption (%)	Blockchain High Adoption (%)	IoT High Adoption (%)
ICT/Tech-based	71%	58%	54%
Manufacturing	46%	37%	29%
Services	39%	28%	22%

ICT companies are leaders, though the manufacturing andService companies are laggards in this regard; this might be particularly due to their capital-intensive nature and lack of technology know-how.

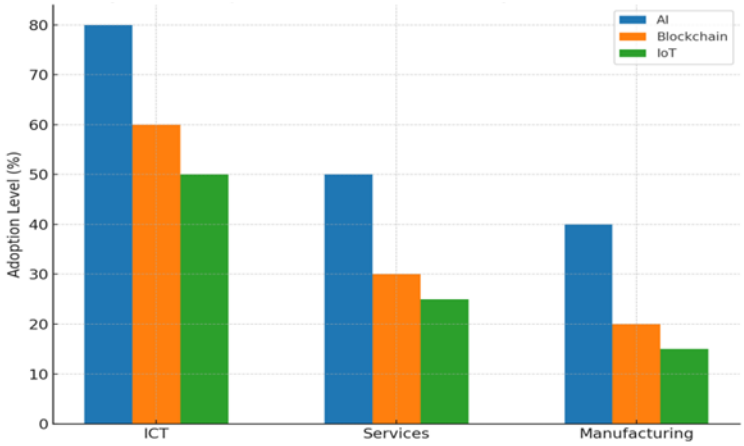

Figure 1: Adoption of Frontier Technologies Across Sector

The bar chart above shows a higher adoption of AI in ICT, lower adoption of Blockchain in services, and lowest IoT in manufacturing.

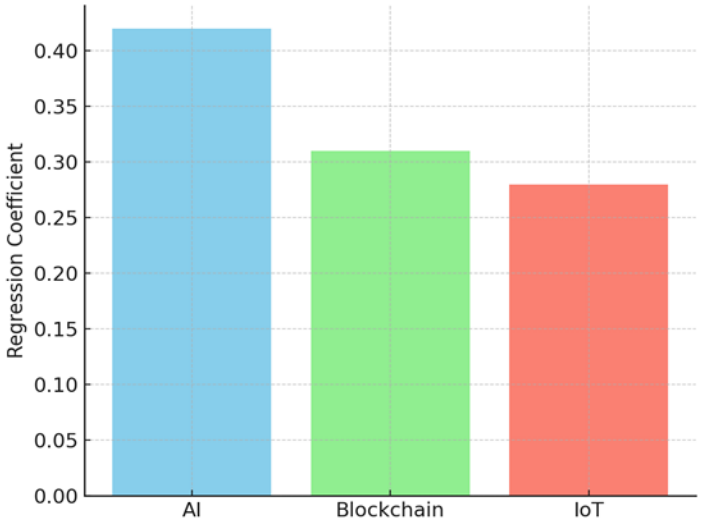

Figure 2: Regression coefficients of frontier technologies on entrepreneurial performance

Figure 2 is a bar graph representing AI = 0.42, Blockchain = 0.31, IoT = 0.28.

The interviewees pointed out three major themes that were most dominant:

1. Efficiency gains - "AI analytics enabled me to make predictions of demand and minimize wastage" (ICT entrepreneur, male, 35 years old).

2. Trust and Transparency: "Blockchain made my customers more trusting, especially since there were cross-border payments."-Fintech entrepreneur, Female, 29

3. Barriers to Adoption: In this context, the important barriers that were perceived were a lack of infrastructure, the prohibitively expensive nature of the IoT devices, and a lack of clarity on the regulatory issues.

Discussion

Overview and Synthesis

Empirical evidence indicates that the adoption of IoT, Blockchain, and AI positively and significantly relates to entrepreneurial performance in SMEs in Lagos. In quantitative terms, through regression analysis, the explained variation in performance stood at 62%, while the standardized regression coefficient turned out highest for AI at 0.42, followed by Blockchain at 0.31, and finally IoT at 0.28. The validation of this study has been made through interviews that provide insight into how different enabling processes of automation, speed of decision-making, customer analytics, transparency of transactions, and visibility of operations in real time contribute toward making technology input tangibly noteworthy.

The Outsize Role of AI: Mechanisms of Influence and Alignments

The contribution size of AI is reflected strongly on its efficient and innovative benefits. The respondents were unanimous in their experience of faster decision-making cycles, fewer error occurrences, and improved customer engagement with predictive analytics and recommendation systems. These micron-level benefits are additive to macro-level flexibility in companies, where product development cycles, pricing flexibility, and customized services are a reality. There are regional findings that are proven to exist, that AI technology has increased African SME competitiveness, and also that technology readiness, with data availability and analysis capabilities, along

with organizational support, including company support from leaders, has increased their benefits from their AI-related investments.

Blockchain for Trust, Traceability, and Market Access

The performance-related correlation with blockchain reflects that this technology has functional value as a trust infrastructure in information asymmetry and payment frictions. Entrepreneurs were satisfied with increased customer trust, fewer charge-backs, and secure cross-border transactions. In supply chain management, immutable ledger functionality has been used for dispute resolution and product authentication. These are in line with transparency and trade ease benefits in emerging markets, as testified in a recent study on emerging markets in 2023 by Chen & Martinez. It must be noted that in Nigeria, fintech application reflects a priority, whereas value-chain applications in other areas, like the protection of intellectual property, traceability in agriculture, among others, are in their infancy.

Operational Benefits and Frictions of IoT Adoption

Although adoption has been relatively low, IoT has been clearly aligned with performance. Benefits offered range from inventory management, preventive maintenance, to logistics optimization, generating increased volume and reduced down-times, especially in manufacturing and multi-site servicing. Barriers were costs of devices, complexities of integration, as well as uncertainties in connectivity, which are consistent with African literature on supply chain studies, pointing to a reliance upon infrastructure for IoT value addition (Okonkwo & Musa, 2023).

Complement

The interview narratives manifest complementarities rather than substitution. IoT provides high-frequency data for operations; AI converts data into insights and forecasts; blockchain secures transactions. The companies that employed a minimum of two technologies reported a disproportionately higher degree of dependability of processes and customer trust, which means a sense of complementarities. There is a realistic architecture that manifests: sense (IoT) → think (AI) → trust (Blockchain).

Heterogeneity across Sectors and Firms

Adoption is sector-driven, where digital natives such as firms in the ICT/e-commerce sector take the lead, followed by manufacturing, and finally, traditional services. There is a variation in these conditions, such as capital intensity, legacy, and government regulation. This aligns with proof of higher adoption speed when there are fewer tangible lock-ins and a high level of digital literacy in a population and society, as evidenced in Ibrahim and Fatoki, 2023. There are alignments in themes, where technology-related training and experience with other technology adaptations in an organization enhance this adaptation, with small and younger companies proving their capacities to test AI tools due to a lack of organizational lock-in.

Theoretical Implications

The evidence forces a gear shift for TOE to move to an emerging economy, which reiterates that environmental enablers are important antecedents for payoffs at an organizational level. On a Schumpeterian view, payoffs from innovation with market potential position a conjecture on destroying traditional ways of working, which are responsible for increasing a divide between leaders and followers in a digitized prepared setting.

Implications for Resilience and Agility

Part of the key contribution is to resilience. AI bolsters forecasting and scenario planning, enabling companies to cope better with demand shocks. Blockchain reduces settlement risk and disputes in volatile markets. IoT provides visibility that allows data-driven responses to interruptions in supplies. Together, these provide recovery times faster, as well as service levels during turbulence maintained at the firm level and ecosystem resilience squarely aligning with the conference theme.

Robustness, Validity, and Potential Biases

While the cross-sectional design limits strong causal inferences, triangulation with the interviews increases one's faith in the mechanisms whereby adoption relates to outcomes. Common-method bias was precluded through the use of objective items (e.g., if certain tools/processes existed) and by parsing adoption and outcomes into separate items in the instrument. However, self-reporting overstates associations and survivorship bias occurs if technology-savvy companies were more apt to respond. Subsequent studies should use longitudinal datasets and, where feasible, administrative measures (sensor readings, transaction histories) to improve causal inference.

Practical Take

• Adoption order for control of influence and risk – from enabling AI for decision/customer support, to blockchain for trust-building processes like contracting and payments, to developing operation instrumentation with IoT where value potential of physical flows are present.

• "Capabilities grow with tools." Adopt vendor-independent architectures, data governance, and security. Ecosystem Priorities Power and Broadband Reliability Digital Skills – experiential training a regulatory ecosystem that de-risks investment

Future Research Direction

Future direction of research will probe: (i) the complementarity effects of AI, blockchain, and IoT; (ii) adoption and performance correlation studies, for instance, AI and customer retention, IoT and manufacturing output rate; (iii) finance models, for example, leasing and revenue sharing that lead to low capital expenditure; and (iv) inclusion effects, analyzing how F&Cs either bridge or widen the opportunity divide, by region and entrepreneur characteristics in the Nigerian context.

Policy and Practice Implications

The policy implications of IFLS are:

1. Development of Digital Infrastructure: Facilities of cheap internet access and availability of electricity are a prerequisite for cutting down costs of adaptation.
2. Regulation Reform: There would also be a need for a regulatory reform that would involve a crystal-clear "innovation-friendly" policy that would minimize risks without stifling
3. Capacity Building: Digital literacy has to be offered by the government and institutions, which would attempt to cover SMEs in other areas other than Lagos.
4. Incentivized Funding: Tax incentives, grant, and concessional loans should encourage entrepreneurs to invest in frontier technology.

Managerial and Entrepreneurial Implications

1. Implement AI, blockchain, and IoT in a planned way in key business sectors to make them competitive.
2. SMEs should make use of technology as a driver, in addition to technology being a driver.
3. Collaboration with fintech firms, technology parks, and universities can offer low-cost tech knowledge.

Social Implications

A successful outcome for the implementation would mean that there would be improvement in the labor market, transparency, and value chain comparative advantage in Nigeria. Disregard of the structure would cause a widening of the digital divide, putting small businesses even further behind.

Conclusion and Recommendations

This research has found that the role of frontier technologies such as Artificial Intelligence, Blockchain, and Internet of Things has become a determining factor for entrepreneurial creativity, efficiency, and competitiveness for Nigerian businesses. The econometric test has also validated

that these businesses experience costs savings in customer engagement and business reliability, as well as market expansion. These technologies, in a volatile and uncertain business environment, form the platform for an entrepreneurial company to react quickly in anticipation of tomorrow in order to grow.

At the same time, the study also ensures that despite all advancements, the distribution of dividends from frontier technology is still uneven. Entrepreneurs are still grappling with pertinent issues concerning structural inhibitions, low digital acumen, and a nonsensical regulatory structure that has yet to keep up with the demands of even frontier technology. This slows down adaptation and even seems to widen the divide between those firms that are digitally progressive and those that are not able to move beyond the structural inhibitions. Thus, while that there would be no doubts concerning the transformative capabilities of these technologies, how to make this potential a reality has to be pro-actively fostered.

To get Nigeria benefitting from these opportunities to their fullest potential, certain tasks need to be accomplished on different planes. To lay the foundation for expanding access to good and stable internet and power, certain basic needs must be met. These are that entrepreneurs cannot derive benefit from their digital resources if their internet and electricity needs are not met on a constant basis. Another area of indubitable significance in this area is developing skills training that would cater to their needs as small and medium-sized businesses. Since it becomes a critical necessity that entrepreneurs develop knowledge of new technology, it also becomes imperative that they develop knowledge on how this technology has to be utilized effectively in a value-added manner. New finance models are also set to transform in a manner that would not stand in the way of aspiring entrepreneurs. Schemes like cheap technology access, innovation, and pay-as-you-go access would help.

On the other side, the regulatory framework would be required to transform from a reactive model to a proactive model. The policies of consumer protection and innovation will make a stable platform for encouraging experiments without any risk. Furthermore, as the value of frontier technologies has a very high sector-specific nature, their adoption strategies would also need to be reality-based. IoT technology would find direct application in manufacturing as well as in logistics, whereas Blockchain technology would find application in agriculture as well as in trade, and AI would find revolutionary potential in services.

With these systemic approaches actively being pursued, it would not be long before Nigeria, in addition to being a continental giant, becomes an internationally vibrant technology-driven entrepreneurial haven. Alongside economic development, this would additionally set in motion various other developments, such as job opportunities, inclusion, and indigenization of businesses in face of worldwide disruption. The prospects of entrepreneurial success in this Nigerian setting would, consequently, not rest solely upon the development of superior technologies but also upon how available, utilized, and enabling such technologies are.

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