

An Extended Technological-Organizational-Environmental (TOE) Model for E-Commerce Adoption for Nigerian Engineering Enterprises

Chioma Herrieth Obinna-Azubuike¹, Dr Nor Zairah Ab Rahim², Dr ABD Rahman Abdul Rahim³

¹Department of smart Engineering and Advanced technology, Engineering Business Management, Faculty of Razak Faculty of Technology and Informatics, Universiti Teknologi Malaysia, Malaysia. Email: chioma1986@graduate.utm.my

²Associate Professor, Department of Smart Engineering and Advanced Technology, Engineering Business Management, Faculty of Razak Faculty of Technology and Informatics, Universiti Teknologi Malaysia, Malaysia. Email: nzairah@utm.my

³Associate Professor, Department of Smart Engineering and Advanced Technology, Engineering Business Management, Faculty of Razak Faculty of Technology and Informatics, Universiti Teknologi Malaysia, Malaysia. Email: rahmanar@utm.my

ARTICLE INFO

ABSTRACT

Received: 22 Dec 2024

Revised: 06 Feb 2025

Accepted: 20 Feb 2025

Despite the significant benefits of e-commerce for Small and Medium-Sized Enterprises (SMEs), adoption rates remain relatively low among engineering SMEs in Nigeria. This study aims to examine the determinants of e-commerce adoption among engineering SMEs in Nigeria and its implications for digital transformation. Grounded in the Technology-Organization-Environment (TOE) framework, the study investigates technological, organizational, and environmental factors that facilitate or hinder adoption. A stratified random sampling technique was employed to select a representative sample of 600 respondents from diverse engineering sectors and regions in Nigeria. Data were collected using a structured online questionnaire and analyzed through Partial Least Squares Structural Equation Modeling (PLS-SEM). The results indicate that technological factors, such as ICT infrastructure, internet connectivity, logistics and supply chain efficiency, along with environmental factors like economic conditions and socio-cultural influences, significantly facilitate e-commerce adoption. Conversely, technological barriers, including cybersecurity challenges and inadequate electronic payment systems, and environmental barriers such as regulatory constraints, market dynamics, and technological advancements, hinder progress. Notably, all organizational factors such as organizational readiness, top management support, innovation culture, and employee training were found to have no significant influence. The study concludes that technological and environmental factors serve as key enablers of e-commerce adoption among engineering enterprises in Nigeria, whereas organizational factors act as barriers. This study offers theoretical contributions to the TOE framework by highlighting sector-specific and regional nuances in e-commerce adoption. Additionally, it provides managerial and policy implications to address technological, organizational, and environmental barriers, enabling engineering SMEs in Nigeria to thrive in the digital economy.

Keywords: E-commerce adoption; Engineering SMEs; TOE framework; Barriers to e-commerce adoption; Facilitators of e-commerce adoption; Nigeria

1. INTRODUCTION

E-commerce is one of the most important drivers of the competitiveness of SMEs in the contemporary economy. In Nigeria, SMEs have grown significantly, contributing more than 50% towards the total GDP and offering about 80% employment opportunities (PwC, 2020). More specifically, Nigeria has been considered suitable for e-commerce

development since internet usage in this country remains constantly high, as does the population of young people who are actively engaged in internet and e-shopper activity. According to Oloni (2024), the e-commerce market in the country was \$8.5 billion in 2024, to grow to \$14.9 billion in 2029 at an e-commerce CAGR of 11.8%. These figures reflect increased dynamic growth expected in the Nigerian e-commerce segment in the future years.

Studies show that e-commerce in Nigeria has tremendously expanded in covering various sectors such as retailing, tourism and travel, food services and accommodation, health, media, and entertainment industries (GlobeNewswire, 2024). The slow adoption of digital transformation and e-commerce within Nigeria's engineering industry is a cause for concern, especially as the number of internet users in the country is projected to reach approximately 118 million by 2027 (Adebayo, 2022; Sasu, 2024). Nevertheless, engineering SMEs in Nigeria have notable challenges when it comes to adopting these technologies, despite the potential positive change in business models and work processes in e-commerce.

Recent data from the Nigerian Communications Commission (NCC, 2023) shows that poor internet connectivity is still a major issue in Nigeria, with network downtime affecting both the rural and urban communities, although the country has seen improved internet penetration (IFG, 2024). Enterprises, especially those in rural areas, are mostly affected by poor internet connectivity because they depend on stable internet connections to conduct basic e-commerce activities such as transactions, procurement, and project coordination. When ICT infrastructure and internet connectivity are not in place, the pros of e-commerce adoption are hardly realized within any SME sector. Meanwhile, readiness at the organizational level, such as support from the top management, organizational culture, innovative culture, and employee IT skills, plays a pivotal role in e-commerce adoption among SMEs (Salah & Ayyash, 2024; Santhanam et al., 2023). However, research findings reveal that SMEs in Nigeria lack strategic leadership in relation to digital transformation (Ifeoluwa et al., 2022). Additionally, the lack of appropriate skills among employees regarding e-commerce technologies complicates the situation because companies often disregard training and capacity enhancement measures (Hendrawan et al., 2024). Meanwhile, Nigeria's legal landscape is mostly regarded as volatile, especially about online selling, taxation, and usage of data. Prior works note that regulatory ambiguity dissuades SMEs from participating in e-commerce, as the current laws in Nigeria for digital operations are still underdeveloped and ambiguous (Cumming et al., 2023; El-Ebiary et al., 2022). Also, market forces in Nigeria, including competition from larger firms and poor logistics, adversely hinder SMEs from competing effectively in the online space (Temowo, 2024; Tom Alexander & Jasper Andreas, 2022). The instability in the global economy, such as the fluctuating exchange rates, inflation rates, and high operating costs, could also hinder SME's investment in a digital environment. Another factor contributing to the limited acceptance of e-commerce among Nigerian SMEs in Nigeria is the social-cultural factor of consumers' attitudes towards online shopping. Despite the availability of e-commerce, consumers and business owners continue to have limited trust in doing business electronically, as face-to-face transactions are considered essential, and any form of electronically mediated communication is perceived as a risk (Ibrahim et al., 2024; Moses, 2023). Although a growing body of research has investigated and reported on the factors influencing the adoption of e-commerce by Nigerian SMEs (Aderemi et al., 2018; Agwu & Murray, 2015; Awa et al., 2015; Ezennia & Marimuthu, 2022), there is a noticeable gap in studies that have specifically reviewed the potential drivers and barriers of e-commerce adoption in engineering SMEs. Furthermore, limited studies have examined the impact of control variables such as company size, industry type, location, and owner/manager's education level on e-commerce adoption among Nigerian SMEs. This paper seeks to fill these gaps by examining the technological, organizational, and environmental drivers and barriers of e-commerce adoption by engineering enterprises in Nigeria, along with relevant control variables.

2. THEORETICAL BACKGROUND

This paper is underpinned by the Technological, Organizational, and Environmental (TOE) model developed by Tornatzky et al. (1990) which offers a systematic structure to examine factors facilitating or constraining technology

acquisition in organizations. The technological dimension is comprised of the technological status of the firm, perceived technology ease, and the firm's readiness to embrace technological solutions. Other factors like connectivity, quality of e-commerce platforms, and the extent of security are key determinants of e-commerce adoption by SMEs. The organizational dimension covers factors influencing technology adoption decisions such as employee IT skills, management support, and organizational culture. Other factors that might influence e-commerce adoption and SMEs' capability are financial resources, employee skills, and innovation culture. The environmental dimension examines all the external forces influencing the adoption of technology such as economic conditions, consumer behaviour, competition and regulatory environment within which these enterprises operate (Tornatzsky et al., 1990).

Several studies have applied the TOE framework in analyzing the adoption of technology across different sectors and geographical locations. For instance, Zhong & Moon (2023) examined the application of TOE in the context of technology 4.0 industry and concluded that compatibility, top management support, and competitive pressure are the major factors influencing technology adoption, while cost and employee capability are not significant factors. The study also revealed differences across sectors whereby employee capability was identified as a significant factor for technology adoption in the service sector compared to the manufacturing sector. Loo et al. (2024) conducted a systematic review of the TOE factors influencing e-commerce adoption among SMEs in the last decade. They discovered that technological advancement and digital preparedness were key enablers, while barriers included a lack of resources, and security issues among others due to the dynamic nature of technology. Also, significant organizational factors included change management and strategic positioning, while the environmental factors such as market forces and legislation in the context of determinants of SMEs' e-commerce adoption. At the same time, the environmental context, such as market trends and regulatory frameworks, plays a key role in shaping the e-commerce landscape in which SMEs operate. Hashimy et al. (2022) explored blockchain adoption by examining TOE perspectives: technological factors such as relative advantage and complexity, organizational factors like competency and top management support, and environmental influences including competitive pressure. El-Haddadeh et al. (2021) adapted a TOE-based model to explain the adoption of big data analytics and its role in achieving sustainable development goals. Their study found that technological factors (e.g., perceived benefits, technology complexity), organizational factors (e.g., readiness, IT infrastructure capability), and environmental influences (e.g., government policies, regulations, competitive pressure) significantly impact top management support, adoption decisions, and value creation UK firms.

The TOE framework is used in this research to analyze the determinants affecting the adoption of E-commerce by engineering SMEs in Nigeria. Therefore, through systematically examining the contextually valid technological, organizational, and environmental factors, it intends to discover factors that act as barriers or enablers to the adoption process. The findings of this application would improve the knowledge in the literature about e-commerce adoption in the Nigerian engineering sector and the study of technology adoption in developing economies. Therefore, it is proposed that technological (e.g., ICT infrastructure, Internet connectivity, electronic payment systems, cybersecurity Measures, and logistics and supply chain efficiency), organizational (e.g., top management, organizational readiness, innovation culture, employee training, and skills), and environmental factors (e.g., market dynamics, economic conditions, technological advancements, regulatory environment, and socio-cultural factors) be included to provide a more comprehensive understanding of e-commerce adoption among engineering enterprises in Nigeria. The first step involves identifying the most significant constructs from highly cited studies, as these factors have consistently demonstrated their importance in measuring technology or e-commerce adoption. By reviewing the existing literature on TOE-based technology adoption and considering the technological, organizational, and environmental factors in the context of e-commerce adoption in Nigeria, the relevant constructs for this research model have been selected.

3. CONCEPTUAL MODEL AND HYPOTHESIS DEVELOPMENT

3.1 Technological Factors and E-commerce Adoption in Engineering SMEs

The reliability and accessibility of ICT infrastructure are important for engineering SMEs that want to implement e-commerce. Yuwono et al. (2024) established that there is a rising trend in the uptake of ICT solutions in SMEs, although impacted by several challenges such as a lack of capital, knowledge, and resistance to change hence the need to formulate useful approaches to improve their usage. Oluyinka et al., (2014) found that the lack of appropriate ICT facilities remains an obstacle to the use of e-commerce in Nigeria greatly affecting its usage. Paun et al., (2024) opined that the level of ICT development influences e-commerce adoption, with firms that have better ICT systems recording higher uptake of e-commerce among the SMEs. Kang & Park's (2014) study indicates a strong positive relationship between the integration of IT and the growth of Tanzania's SME's e-commerce adoption. Studies undertaken by Awa et al. (2015) established that enhanced ICT impacted Nigerian firms on the adoption of e-commerce. The reliability of ICT infrastructure helps in minimizing the cost implications of e-commerce adoption by SMEs in Nigeria, as revealed by Ladokun et al. (2013). As indicated a study by Ezennia & Marimuthu (2022), the extent to which Nigerian online merchants engage in e-commerce and the ability to succeed is pegged on the availability of ICT infrastructure. Similarly, investigating SMEs in Bangladesh, Hossain et al. (2023) determined that there was a positive significant relationship between the percentage of firms that adopted ICT and the percentage of firms that adopted e-commerce. Therefore, the following hypothesis is made:

H1: *ICT infrastructure is positively associated with the adoption of e-commerce in engineering SMEs in Nigeria.*

Stable internet connectivity is crucial for e-commerce performance, especially for SMEs in Nigeria. The unequal distribution of internet connectivity affects these businesses, which in turn greatly impacts their efficiency of online transactions (Uneanya, 2019). Akanbi & Akintunde (2018) noted that e-commerce can greatly improve the performance of SMEs in Nigeria if factors like internet infrastructure are properly addressed. Research has also indicated that poor Internet connectivity not only reduces organizational productivity rates, but also leads to sales loss and poor customer experience (Deloitte, 2016; Nasereddin & Faqir, 2019). Their research underscores that firms with stable and reliable internet connectivity benefit from enhanced e-commerce operations, experiencing smoother transaction processes and improved customer satisfaction. However, SMEs experiencing poor internet connectivity are faced with several challenges including slow order placements, and ineffective communication with customers. Therefore, the availability of an internet connectivity is considered a key factor that influences the adoption and the smooth running of e-commerce among SMEs. This is supported by Uneanya (2019) who revealed that SMEs in Nigeria are willing to venture into e-commerce if they have access to high internet speed. Internet connectivity was validated to have a positive and significant effect on the adoption of e-commerce by SMEs in a study by (Hossain et al., 2023). These studies call for capital expenditure to support broadband networks because when readily available, it results in more online shopping and overall business performance. Thus, the following hypothesis;

H2: *Internet connectivity is positively associated with the likelihood of e-commerce adoption among engineering SMEs in Nigeria.*

The presence of secure and user-friendly electronic payment systems (EPS) is crucial for facilitating online sales, especially for engineering SMEs. These businesses need access to a variety of payment options, such as credit cards, mobile payments, and digital wallets, to accommodate diverse customer preferences and enhance transaction convenience. Electronic payment gateways in Nigeria such as Interswitch Webpay, Remita, Paystack, Amplify, GTPay, SeerBit, 2Checkout, VoguePay, PayStack, Monnify, Flutterwave, and PayPal provide businesses with secure and reliable solutions to accept online payments (Dada & Oluwadara, 2023; Webdesigns, 2023). Studies indicate that offering multiple payment options significantly increases customers' willingness to engage in online transactions, thereby positively influencing e-commerce services (Fatonah et al., 2018; Gupta et al., 2023; Kilay et al., 2022). A

study by Khsroo et al. (2024) revealed that EPS had a significant impact on the adoption of e-commerce among SMEs in Iraq. The availability of secure payment systems not only ensures smooth transaction processes but also fosters customer loyalty. Customers are more likely to repeat purchases and be loyal to businesses that provide safe and efficient payment methods, as highlighted in studies by Celestin & Sujatha (2024) and Igudia (2018). These studies emphasize that a reliable EPS can mitigate concerns over online fraud and enhance the overall customer experience, making it a key factor in the successful adoption of e-commerce by engineering SMEs. Historically, Nigeria's payment systems have relied heavily on cash, but the nation is transitioning towards a cashless society (Asaolu et al., 2011; Okifo & Igbunu, 2015). In addition, the security of EPS will encourage SMEs and consumers to embrace online shopping. Thus, the following hypothesis;

H3: *Electronic payment systems are positively associated with e-commerce adoption in engineering SMEs.*

Logistics and supply chain are major factors that can affect the successful implementation of e-commerce by engineering SMEs. In this regard, online businesses must maintain a timely and efficient delivery system that will satisfy the consumer. Consistent with Hande et al. (2015), prompt product delivery is a key factor shared by both the Indian B2B and B2C markets. Kawa & Swiatowiec-Szczepanska (2021) discovered that delivery time, delivery flexibility, delivery location, delivery tracking, and return ease had a positive influence on consumers' satisfaction with e-commerce. As highlighted in the study conducted by Gunasekaran et al. (2017), high levels of supply chain management improved the operating capacity of SMEs, increasing the ability to meet market needs and also increasing customer satisfaction. Similarly, Bowersox et al. (2014) argued effective and efficient management of supply chain networks is a crucial strategy for improving organizational practices and creating customer value. These efficiencies make it easier for firms to expand their reach through optimized logistics, enhancing their capabilities and competitiveness in the e-commerce market. According to Abtahi et al. (2023), the integration of e-commerce in supply chains can greatly improve supply chain performance and lead to greater competitiveness, reduction in the cost of operations, and accrued high returns on investment. According to Guo et al. (2024), large businesses can leverage their resources to incorporate e-commerce and enhance supply chain value, as well as introduce digitally-oriented innovations, while micro and small businesses are likely to face certain issues because of their financial and technological constraints. Therefore, logistics should play a crucial role in improving e-commerce strategies of engineering SMEs, giving customers better experiences. The following hypothesis are proposed;

H4: *Logistics and supply chain efficiency is positively associated with the adoption of e-commerce in engineering SMEs.*

Cybersecurity measures are crucial for fostering trust for the adoption of e-commerce among SMEs especially those in developing countries like Nigeria where security is a significant barrier to the adoption of the e-commerce. Various studies have shown that business organizations are inclined to adopt e-commerce solutions if they perceive that there is adequate protection against cyber risks, as cybersecurity measures serve to curb fear over data breaches and fraud (Morić et al., 2024; Oguta, 2024; Rajendran, 2024). In Nigeria, SMEs often cite cybersecurity as a key barrier to e-commerce adoption, with increased trust in digital platforms directly correlating with higher adoption rates when businesses feel their information is secure (Madueke & Eyupoglu, 2024; Odufuwa, 2024). Additionally, perceived security features, such as data encryption and secure payment systems, are essential in establishing initial trust, which sustains long-term usage and enhances the business's confidence in digital platforms (Hossain et al., 2024; Lisdayanti & Hapsari, 2024). Therefore, perceived cybersecurity affects organizational trust and remains the key driver of e-commerce in Nigeria according to Igwe et al. (2020). Hence;

H5: *Higher levels of perceived cybersecurity measures are associated with increased trust and adoption of e-commerce technologies among engineering enterprises in Nigeria.*

3.2 Organizational Factors and E-Commerce Adoption in Engineering SMEs

A firm's preparedness and capability to implement and use e-commerce systems is referred to as organizational readiness. This includes various dimensions, including technological readiness, financial readiness, human resource readiness, culture receptiveness, and strategic fit for e-commerce technology solutions in business processes. According to Purwantini et al. (2024), a higher level of organizational readiness increases the chances of success in the adoption of e-commerce. Mbamba (2023) also pointed out that the extent of e-commerce adoption within organizations depends on the commitment, technological resources and readiness. Su et al. (2023) further identified that organizational readiness played a dual role of driver and facilitator for the SMEs to adopt digital marketing strategies. Ong et al. (2020) confirmed a positive and significant association between organizational readiness and e-commerce use among SMEs from Malaysia. Hence, the following hypothesis;

H6: *Organizational readiness positively affects the likelihood of e-commerce adoption among engineering SMEs in Nigeria.*

Studies have shown that the adoption of e-commerce is largely contingent on the support of the top management within organizations. Mahroeian (2012) stressed that managerial support is a driving force behind how easily e-commerce can be adopted in Malaysia's SME sector. Likewise, Awiagah et al. (2015) noted managerial support as a significant driver of e-commerce adoption by SMEs in Ghana. Sutanonpaiboon & Pearson (2006) reported that managerial support as a significant factor that has a strong impact on an SMEs' adoption and implementation of e-commerce in Thailand. On the other hand, Faloye, (2014) concluded that a lack of interest from business owners or their representatives are the key issues causing the slow adoption of e-commerce amongst the retail businesses in Nigeria. Tang et al. (2024) found that top management support was statistically insignificant in e-commerce adoption among SMEs in Sarawak and Sabah. Hence;

H7: *Top management support is positively associated with e-commerce adoption in engineering SMEs.*

Innovative culture has been found to be central to the successful implementation of e-commerce technologies within the engineering SMEs. According to Ghobakhloo et al. (2011) and Rahayu & Day (2015), the innovativeness of a CEO significantly influences e-commerce adoption within SMEs. Bening et al. (2023) revealed that innovation culture is a critical factor in the implementation of e-commerce technology among the retail SMEs. Studies show that fostering innovation positively impacts SMEs' e-commerce adoption, emphasizing the need for an innovation-driven approach (Faccia et al., 2023; Gu, 2023; Salah & Ayyash, 2024; Skare et al., 2023). Integrating innovation and e-commerce models is essential for driving global sustainable development (Faccia et al., 2023). However, engineering SMEs in Nigeria may face significant challenges without a robust innovation culture. To overcome these barriers, fostering innovation across all facets of daily operations becomes critical, enabling businesses to effectively adopt e-commerce practices and enhance their competitiveness. Hence, the following hypothesis;

H8: *Innovation culture positively influences the adoption of e-commerce among engineering SMEs.*

Ensuring that employees receive adequate training and skill development is vital for effectively utilizing e-commerce tools and platforms within engineering SMEs. These organizations must prioritize investment in training programs that enhance digital literacy and equip staff with the necessary skills to navigate online business processes. Kiplangat et al. (2015) highlight that the level of training among business owners and employees significantly influences the adoption and effective use of e-commerce strategies. Enhanced training equips individuals with the necessary skills and knowledge, enabling better integration of e-commerce practices within organizations. Ochola (2015) found that employees' IT capacity positively influences the adoption of e-commerce among MSMEs in Kenya. A higher level of IT skills and knowledge within the workforce increases the ability to integrate and utilize e-commerce platforms effectively, contributing to improved business processes and market reach. Costa & Castro (2021). found that SMEs

that invest in comprehensive training programs experience smoother transitions to e-commerce and better operational outcomes. Similarly, To & Ngai (2006) highlighted that organizations with a strong focus on skill development see increased employee engagement and higher rates of technology integration. Thus, the following hypothesis;

H9: *Employee training and skills are positively correlated with the adoption of e-commerce in engineering SMEs.*

3.3 Environmental Factors and E-Commerce Adoption in Engineering SMEs

The competitive landscape and evolving market conditions are critical factors influencing e-commerce adoption among engineering SMEs. To stay competitive in the digital marketplace, these enterprises must analyze consumer behavior, preferences, and emerging trends. Balta et al. (2024) emphasize the critical role of digital pivoting for growth-oriented UK Southeast businesses facing challenges like the digital divide, inflation, and supply chain issues. Similarly, research by Raju et al. (2011) supports this notion, indicating that understanding market conditions allows SMEs to tailor their offerings to meet customer needs effectively. The findings of Githui & Njuru (2024) illustrate that SMEs leveraging insights from market trends can foster customer loyalty, thereby driving higher rates of e-commerce adoption. By proactively responding to changing market conditions, engineering SMEs position themselves to better serve their customers and capitalize on e-commerce opportunities. Hence, the following hypothesis;

H10: *Market dynamics are positively associated with the likelihood of e-commerce adoption in engineering SMEs.*

Economic factors play a pivotal role in influencing the capacity of engineering SMEs to invest in e-commerce initiatives. Elements such as overall economic stability, inflation rates, and access to funding directly affect their willingness and ability to embrace digital solutions. A favorable economic environment characterized by low inflation rates and readily available financing options encourages these enterprises to pursue e-commerce by providing the necessary resources and market opportunities. Foster & Rosenzweig (2010) argue that disparities in technology levels significantly contribute to global differences in wages and per-capita GDP. Countries with higher levels of technology tend to achieve greater economic output and income per person compared to those with lower technological development. Marra et al. (2003) highlight that risk and uncertainty influence various aspects of the technology adoption process. This implies that the decision to adopt new technologies is closely linked to how individuals or organizations view and control risk and uncertainty associated with technological innovation such as financial cost, reliability of performance, or any other unpredictable eventuality. These factors are still known to play a major role in influencing the extent and pace of adoption. SMEs in a stable economy are in a better position to adopt the technology because the uncertainties and opportunities for growth are well managed as opposed to SMEs in an unstable economy such as the Nigerian economy. Thus, the following hypothesis;

H11: *Economic conditions are positively associated with e-commerce adoption among engineering SMEs in Nigeria*

Technology plays a critical role in influencing the rate of e-commerce integration among engineering SMEs; this is largely due to the rapid pace of transformation in the technological sector. Such businesses must continue learning about new technologies and related trends in the digital environment, as it can help them improve their online activities and performance. Salah & Ayyash (2024) point out that integrating AI will be crucial to promoting e-commerce among SMEs. This means that technology, particularly AI plays a crucial role in the adoption of e-commerce by SMEs. The following specific conclusions are derived from the study: AI improves revenue-generating operational capabilities, consumer targeting and customized marketing, and bidding and selection procedures, thus benefitting SMEs through e-commerce (Abrokwhah-Larbi & Awuku-Larbi, 2023; Salah & Ayyash, 2024). Through increased awareness, organizations that can play an active role in the identification of new technological trends can take advantage of new technology tools and thus be able to compete better in the market. Furthermore, the adoption of technology organizes work and also enables businesses to provide more benefits to their customers resulting in better satisfaction and retention. Hence, the following hypothesis;

H12: *Technological advancements positively influence the adoption of e-commerce in engineering SMEs.*

Societal attitudes toward online shopping and digital engagement play a crucial role in the adoption of e-commerce among engineering SMEs in Nigeria. The growing acceptance of e-commerce among consumers is essential for these businesses seeking to enter the online marketplace. Sivakumar & Raj (2007) emphasized the crucial role of social influence in technology adoption within collectivist cultures. In developing economies with collectivist values, social influence shapes individual intentions and mirrors the underlying cultural dynamics. In a collectivist culture like Nigeria, these social influences could play a pivotal role in shaping SMEs' decisions to embrace e-commerce platforms. The cultural norms in Nigeria prioritize interpersonal communication and relationships, posing a significant obstacle for SMEs seeking to embark on online business. In their multi-country survey, Van Slyke et al. (2004) discovered a significant influence of national culture on consumers' intentions to make online purchases. According to Thatcher et al. (2006), cultural factors had a significant impact on the adoption decisions made by electronics and textile companies in Taiwan regarding B2B e-commerce. In his research, Gong (2009) used secondary data collected over time from 58 nations and found that internet shopping was more likely to be adopted and spread in high-context and polychronic societies. According to Rabayah et al. (2021), cultural factors like power distance and uncertainty avoidance had a significant impact on the use of e-commerce in Palestine. Positive socio-cultural attitudes toward digital engagement significantly influence e-commerce adoption. This implies that understanding cultural preferences and enhancing digital literacy are key strategies for fostering broader acceptance of online transactions. Hence, the following hypothesis;

H13: *Socio-cultural attitudes toward e-commerce are positively related to the adoption of e-commerce among engineering SMEs in Nigeria.*

Studies show that supportive regulations, such as policies on data protection, cybersecurity, and financial transactions, are essential in building trust and encouraging businesses to embrace digital platforms (Jeong, 2023; Saeed et al., 2023). In Nigeria, regulatory clarity and enforcement are often seen as pivotal for reducing perceived risks, as clear legal frameworks help businesses feel secure in their online transactions and data management (Oguejiofor et al., 2023). Research indicates that when governments implement and enforce robust e-commerce policies, businesses are more likely to adopt digital solutions, as they view these measures as protective mechanisms against fraud and security threats (Luo & Choi, 2022). Awiagah et al. (2015) identified that regulatory conditions are crucial in facilitating the adoption of e-commerce by SMEs in Ghana. Similar findings from other studies suggest that supportive regulatory frameworks, including policies that ensure data security, consumer protection, and digital infrastructure, are essential for encouraging SMEs to embrace e-commerce. Aderemi et al. (2018) established a positive correlation between government policies and the adoption of e-commerce by enterprises operating in the informal sector of Nigeria. In contrast, Oluyinka et al. (2013) demonstrated that the absence of governmental support and regulations inhibited the acceptance of e-commerce within the Nigerian populace. By providing a stable and supportive environment, regulations help SMEs overcome barriers to adopting new technologies. Hence, the following hypothesis;

H14: *A favorable regulatory environment positively affects the adoption of e-commerce technologies among engineering enterprises in Nigeria.*

3.4 Control Variables and E-commerce Adoption

When studying e-commerce adoption among engineering SMEs, certain control variables can significantly influence the outcomes. These variables include company size, industry type, location, and the education level of the owner or manager. Understanding how these factors affect e-commerce adoption is essential for developing comprehensive strategies that consider the unique contexts of different SMEs. Amornkitvikai & Lee (2020) found that firm size does not significantly influence e-commerce utilization among Thai SMEs. This contrasts with the findings of Kraemer et al. (2005) and Kuan & Chau (2001), who argued that larger firms tend to adopt more ICTs due to their greater resources and IT expertise. Similarly, a study by Awa et al. (2015) found that SMEs with larger employee bases tend to adopt

e-commerce technologies more rapidly, driven by their ability to absorb the costs associated with technology implementation. Industries with a higher reliance on online sales, such as retail, demonstrate greater e-commerce adoption. In contrast, industries with less direct consumer interaction, like manufacturing, often lag in e-commerce integration. The findings of Amornkitvikai & Lee (2020) indicated that Thai SMEs in the retail sector demonstrated greater adoption of e-commerce practices in comparison to their counterparts in the food and beverage sector. Thus, the perceived benefits of e-commerce vary significantly based on industry type, influencing adoption rates accordingly. SMEs located in urban settings were more likely to adopt e-commerce due to better internet access and a more favorable business environment (Brima & Sesay, 2019). Thus, SMEs in urban locations exhibit higher levels of e-commerce engagement, attributing it to enhanced access to markets and resources. Meanwhile, SMEs led by owners or managers with higher educational qualifications are more likely to engage in e-commerce activities. This is supported by a study conducted by Lip-Sam & Hock-Eam (2011) which found that SME owners or CEOs with more experience and higher educational qualifications, especially tertiary education, are more inclined to adopt e-commerce. Meanwhile, Amornkitvikai et al. (2022) found that the educational level of SME owners does not have a significant impact on the level of e-commerce adoption. Hence, the following hypotheses are proposed:

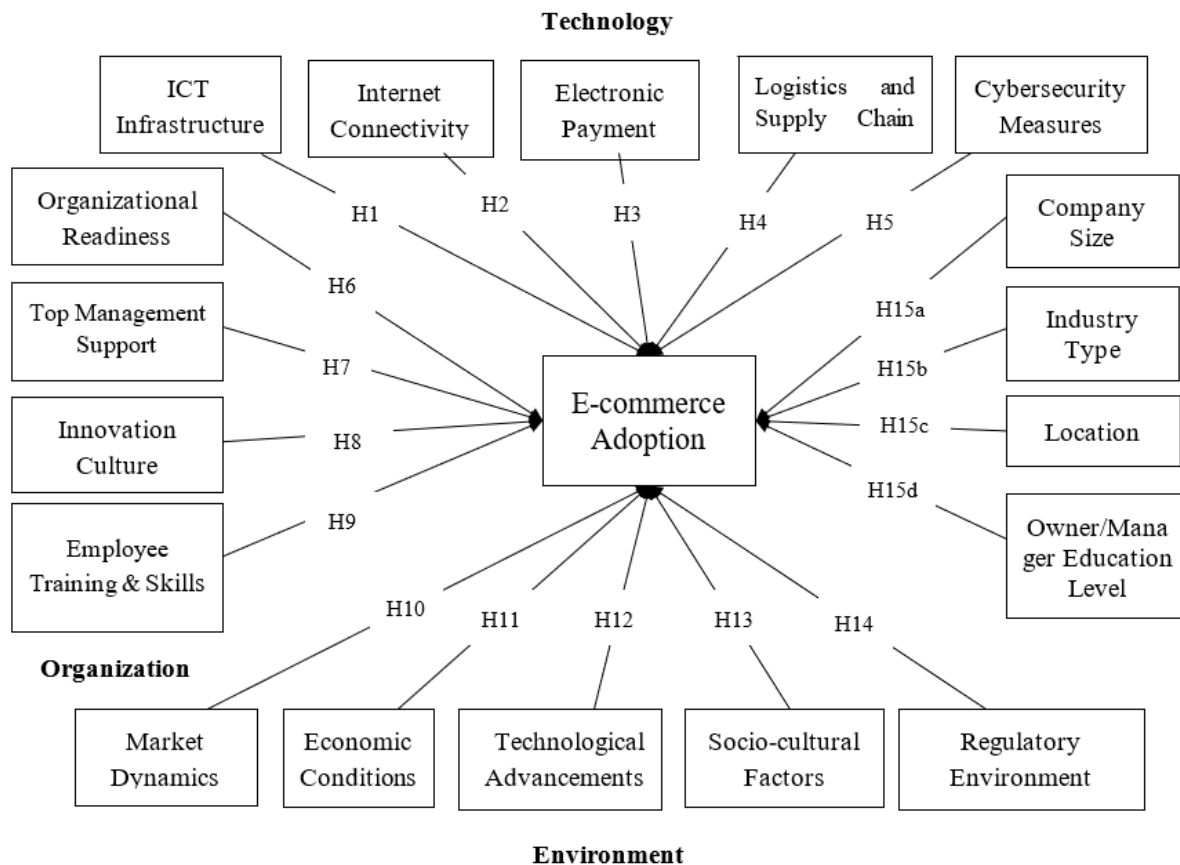
H15a: *Company size positively influences the likelihood of e-commerce adoption among engineering SMEs.*

H15b: *Industry type positively influences the adoption of e-commerce technologies, with industries more dependent on online sales exhibiting higher adoption rates.*

H15c: *Location positively influences e-commerce adoption, with engineering SMEs in urban areas more likely to adopt e-commerce technologies than those in rural areas.*

H15d: *The education level of the owner or manager positively influences the adoption of e-commerce technologies among engineering SMEs.*

Figure 1 Illustrates the research model along with the development of hypotheses



4. METHODOLOGY

4.1 Research Design, Sampling and Procedure

This study applied a quantitative research paradigm to examine the antecedents of e-commerce adoption by engineering SMEs in Nigeria. The quantitative design was used to gather and analyze numerical data; this was useful to understand the co-relationships of the variables within the Technological, Organizational, and Environmental (TOE) framework. The quantitative approach allowed for hypothesis development and making statistical inferences with regards to the factors influencing the adoption of e-commerce amongst engineering enterprises in Nigeria. To ensure the study achieved the set objectives, the study focused on engineering SMEs operating in Nigeria offering their service in sectors such as manufacturing, construction, energy, aerospace, and automotive amongst other sectors. The study targeted a sample size of 600 comprising SME owners, CEOs, COOs, CFOs, and general managers. A stratified sampling technique was used, which made it possible for various engineering sectors from diverse geopolitical zones to be represented in the study.

An online survey (Google Form) was used in the collection of data for this study. A structured questionnaire was formulated in reference to the TOE Framework, which consists of technological, organizational, and environmental statements concerning the adoption of e-commerce. To capture respondents' perception and experience on the factors under study, items were developed in a 5-point Likert scale. The questionnaire was pilot-tested among a small sample of engineering SMEs who are normally engaged in the manufacturing sector to ensure the validity and comprehensibility of the items before the actual data collection process. Data collected were then analyzed using various statistical tools. The study used Partial Least Squares Structural Equation Modeling (PLS-SEM) to assess the study's hypothesis and to reinstate the conceptual framework. In particular, PLS-SEM was used because of its capacity to analyze models with many indicators and constructs. It was used to assess the measurement model and confirm the reliability and validity of the constructs used in the study; the structural model was also tested for the interrelationship of factors such as technological factors, organizational factors, and environmental factors with e-commerce adoption. This approach yielded further understanding of the importance and robustness of the proposed relationships in the study; the validation of the research hypotheses was made possible by this method.

Table 1: Descriptive Statistics of Respondents

Category		Frequency	Percentage
Gender	Female	250	41.7%
	Male	350	58.3%
Position	Chief Executive Officer (CEO)	41	6.8%
	Chief Financial Officer (CFO)	97	16.2%
	Chief Operations Officer (COO)	45	7.5%
	General Manager	173	28.8%
	Others	46	7.7%
	Owner / Proprietor	198	33.0%
Location	North Central	72	12.0%
	North East	47	7.8%
	North West	103	17.2%
	South East	137	22.8%
	South South	111	18.5%
	South West	130	21.7%
Company Tenure (COMP_Tenure)	1-3 years	19	3.2%
	10 years and above	281	46.8%
	4-6 years	81	13.5%
	7-9 years	216	36.0%
	Less than 1 year	3	0.5%
Education	Bachelor's Degree	136	22.7%
	Diploma/OND/HND	43	7.2%
	Doctoral Degree	172	28.7%
	Master's Degree	248	41.3%
	Secondary School Certificate	1	0.2%
Employee Count (EMP_COUNT)	100-200 employees	231	38.5%
	2-49 employees	185	30.8%
	50-99 employees	184	30.7%
Engineering Sector	Aerospace	70	11.7%
	Automotive	68	11.3%

	Construction	73	12.2%
	Energy	98	16.3%
	Manufacturing	161	26.8%
	Other	130	21.7%
E-Commerce Adoption	Maybe	14	2.3%
	No	3	0.5%
	Yes	583	97.2%

Table 1 displays the descriptive statistics of respondents' demographic details, and confirms that most of the respondents were male (58.3%), with the majority holding the position of owner/proprietor (33.0%) or general manager (28.8%). The highest percentage (22.8%) of respondents were from the southeast region of Nigeria and the second largest (21.7%) were from the southwest region of Nigeria. In terms of the number of years in operation, 46.8% of the engineering enterprises had been in operation for 10 years and above, while the majority, 87.5%, had good educational qualifications, with 41.3% having a Master's Degree. Concerning the size of the company they worked for, 38.5% of the respondents said their company had between 100 and 200 employees. The largest engineering category was manufacturing at 26.8%. Lastly, and this shows the readiness of the participants to enhance the growth of their businesses through the use of e-business technologies, 97.2% had adopted e-commerce technologies, while 0.5% had not.

5. DATA ANALYSIS

5.1 Construct Reliability and Validity

Table 2a: Reliability and Validity of Technological Factors

Construct	Item	Loadings	Cronbach- α	CR	AVE
ICT Infrastructure	ICTI_01	0.796	.891	0.762	0.634
	ICTI_02	0.895			
	ICTI_03	0.743			
	ICTI_04	0.619			
	ICTI_05	0.893			
Internet Connectivity	INTC_01	0.846	.893	0.757	0.625
	INTC_02	0.601			
	INTC_03	0.885			
	INTC_04	0.791			
	INTC_05	0.798			
Electronic Payment Systems	EPS_01	0.602	.890	0.748	0.585
	EPS_02	0.705			
	EPS_03	0.747			
	EPS_04	0.867			

Logistics and Supply Chain Efficiency	EPS_05	0.869			
	LSCE_01	0.858	.891	0.784	0.716
	LSCE_02	0.766			
	LSCE_03	0.991			
	LSCE_04	0.871			
Cybersecurity Measures	LSCE_05	0.717			
	CYBM_01	0.849	.893	0.765	0.522
	CYBM_02	0.848			
	CYBM_03	0.607			
	CYBM_04	0.657			
	CYBM_05	0.702			

Table 2b: Reliability and Validity of Organizational factors

Construct	Item	Loadings	Cronbach- α	CR	AVE
Organizational Readiness	OR_01	0.861	.889	0.774	0.679
	OR_02	0.840			
	OR_03	0.882			
	OR_04	0.608			
	OR_05	0.895			
Top Management Support	TMS_01	0.628	.890	0.761	0.631
	TMS_02	0.769			
	TMS_03	0.848			
	TMS_04	0.950			
	TMS_05	0.741			
Innovation Culture	INNC_01	0.787	.890	0.778	0.714
	INNC_02	0.891			
	INNC_03	0.845			
	INNC_04	0.816			
	INNC_05	0.881			
Employee Training and Skills	ETS_01	0.993	.890	0.784	0.704
	ETS_02	0.868			

ETS_03	0.797
ETS_04	0.606
ETS_05	0.883

Table 2c: Reliability and Validity of Environmental factors

Construct	Item	Loadings	Cronbach- α	CR	AVE
Market Dynamics	MD_01	0.718	.890	0.788	0.601
	MD_02	0.844			
	MD_03	0.832			
	MD_04	0.782			
	MD_05	0.688			
Economic Conditions	ECOND01	0.846	.891	0.798	0.652
	ECOND2	0.847			
	ECOND03	0.829			
	ECOND04	0.872			
	ECOND05	0.615			
Technological Advancements	TECHADV_01	0.874	.890	0.777	0.624
	TECHADV_02	0.884			
	TECHADV_03	0.857			
	TECHADV_04	0.688			
	TECHADV_05	0.604			
Socio-cultural Factors	SCF_01	0.730	.893	0.768	0.588
	SCF_02	0.638			
	SCF_03	0.564			
	SCF_04	0.890			
	SCF_05	0.944			
Regulatory Environment	RE_01	0.833	.890	0.765	0.665
	RE_02	0.633			
	RE_03	0.843			
	RE_04	0.872			
	RE_05	0.872			

Table 2d: Reliability and Validity of E-commerce Adoption

Construct	Item	Loadings	Cronbach- α	CR	AVE
E-commerce Adoption	EC_01	0.809	.896	0.732	0.667
	EC_02	0.878			
	EC_03	0.815			
	EC_04	0.898			
	EC_05	0.765			
	EC_06	0.821			
	EC_07	0.829			
	EC_08	0.824			
	EC_09	0.829			
	EC_10	0.754			

The reliability and validity analyses in the Tables 2a-d demonstrate strong internal consistency and convergent validity across Technological, Organizational, Environmental, and E-commerce Adoption factors. All constructs have Cronbach's Alpha values and Composite Reliability (CR) above 0.7, indicating high internal consistency, as per the standards suggested by Hair et al. (2019). Moreover, Average Variance Extracted (AVE) values exceed 0.5 for each construct, which supports convergent validity (Fornell & Larcker, 1981), suggesting that over 50% of the variance in each construct's items is explained by the construct itself. Although a few items exhibit lower loadings (e.g., ICTI_04, CYBM_04, EPS_01), they remain above the acceptable threshold of 0.6 (Gefen, Straub, & Boudreau, 2000), ensuring adequate representational strength. Overall, these reliability and validity indicators confirm that the constructs are well-measured and provide a robust basis for assessing e-commerce adoption factors in this model.

Table 3: R² and Adjusted R² values for the dependent variable (EC)

Dependent Variable	R ²	Adjusted R ²
EC	0.408	0.394

The R² value of 0.408 for e-commerce adoption (Table 3) indicates that 40.8% of the variance in in e-commerce adoption is explained by the independent variables in the model. This suggests a moderate level of explanatory power.

Table 4: Discriminant validity (Fornell-Larcker Criterion)

	CYBM	EC	ECON D	EPS	ETS	ICT	INNC	INTC	LSCE	MD	OR	RE	SCF	TECH ADV	TMS
CYBM	0.723														
EC	0.539	0.817													
ECOND	0.582	0.780	0.807												
EPS	0.419	0.591	0.766	0.765											
ETS	0.305	0.357	0.625	0.695	0.839										
ICT	0.394	0.513	0.577	0.692	0.546	0.796									
INNC	0.302	0.389	0.364	0.396	0.476	0.403	0.845								
INTC	0.428	0.407	0.285	0.381	0.327	0.441	0.347	0.791							
LSCE	0.377	0.380	0.290	0.420	0.386	0.347	0.413	0.343	0.846						
MD	0.304	0.363	0.479	0.355	0.441	0.421	0.422	0.313	0.366	0.775					
OR	0.383	0.407	0.337	0.467	0.416	0.397	0.420	0.413	0.500	0.315	0.824				
RE	0.378	0.353	0.437	0.410	0.429	0.393	0.416	0.270	0.379	0.448	0.422	0.815			
SCF	0.318	0.368	0.411	0.305	0.386	0.310	0.368	0.285	0.309	0.361	0.368	0.397	0.767		
TECHADV	0.329	0.376	0.442	0.411	0.434	0.384	0.442	0.298	0.366	0.466	0.421	0.436	0.474	0.790	
TMS	0.357	0.332	0.367	0.471	0.448	0.374	0.503	0.308	0.414	0.385	0.463	0.441	0.381	0.431	0.794

Table 4 shows strong discriminant validity, as each construct's AVE square root (the diagonal values) is higher than its correlations with other constructs. This result attests to the fact that each construct is different and captures its unique aspect, thereby satisfying Fornell-Larcker criterion, which is used to assess discriminant validity; and further establishes the reliability of the constructs in measuring different dimensions independently (Fornell & Larcker, 1981).

Table 5: Collinearity Statistics (VIF)

Item	VIF
ICTI_01	1.033
ICTI_02	1.045
ICTI_03	1.062
ICTI_04	1.068
ICTI_05	1.044
INTC_01	1.027
INTC_02	1.042
INTC_03	1.066
INTC_04	1.068
INTC_05	1.023
EPS_01	1.028
EPS_02	1.017
EPS_03	1.050
EPS_04	1.047

EPS_05	1.044
LSCE_01	1.052
LSCE_02	1.068
LSCE_03	1.073
LSCE_04	1.070
LSCE_05	1.030
CYBM_01	1.026
CYBM_02	1.032
CYBM_03	1.053
CYBM_04	1.065
CYBM_05	1.062
OR_01	1.042
OR_02	1.061
OR_03	1.078
OR_04	1.093
OR_05	1.053
TMS_01	1.054
TMS_02	1.061
TMS_03	1.075
TMS_04	1.071
TMS_05	1.026
INNC_01	1.027
INNC_02	1.061
INNC_03	1.087
INNC_04	1.097
INNC_05	1.051
ETS_01	1.035
ETS_02	1.072
ETS_03	1.066
ETS_04	1.071
ETS_05	1.047
MD_01	1.043
MD_02	1.059
MD_03	1.050
MD_04	1.060
MD_05	1.083
ECOND_01	1.043
ECOND_02	1.069
ECOND_03	1.066
ECOND_04	1.098
ECOND_05	1.089
TECHADV_01	1.028
TECHADV_02	1.049

TECHADV_03	1.063
TECHADV_04	1.102
TECHADV_05	1.071
SCF_01	1.049
SCF_02	1.061
SCF_03	1.067
SCF_04	1.070
SCF_05	1.058
RE_01	1.039
RE_02	1.047
RE_03	1.052
RE_04	1.057
RE_05	1.031
EC_01	1.056
EC_02	1.107
EC_03	1.129
EC_04	1.095
EC_05	1.091
EC_06	1.078
EC_07	1.088
EC_08	1.148
EC_09	1.142
EC_10	1.056

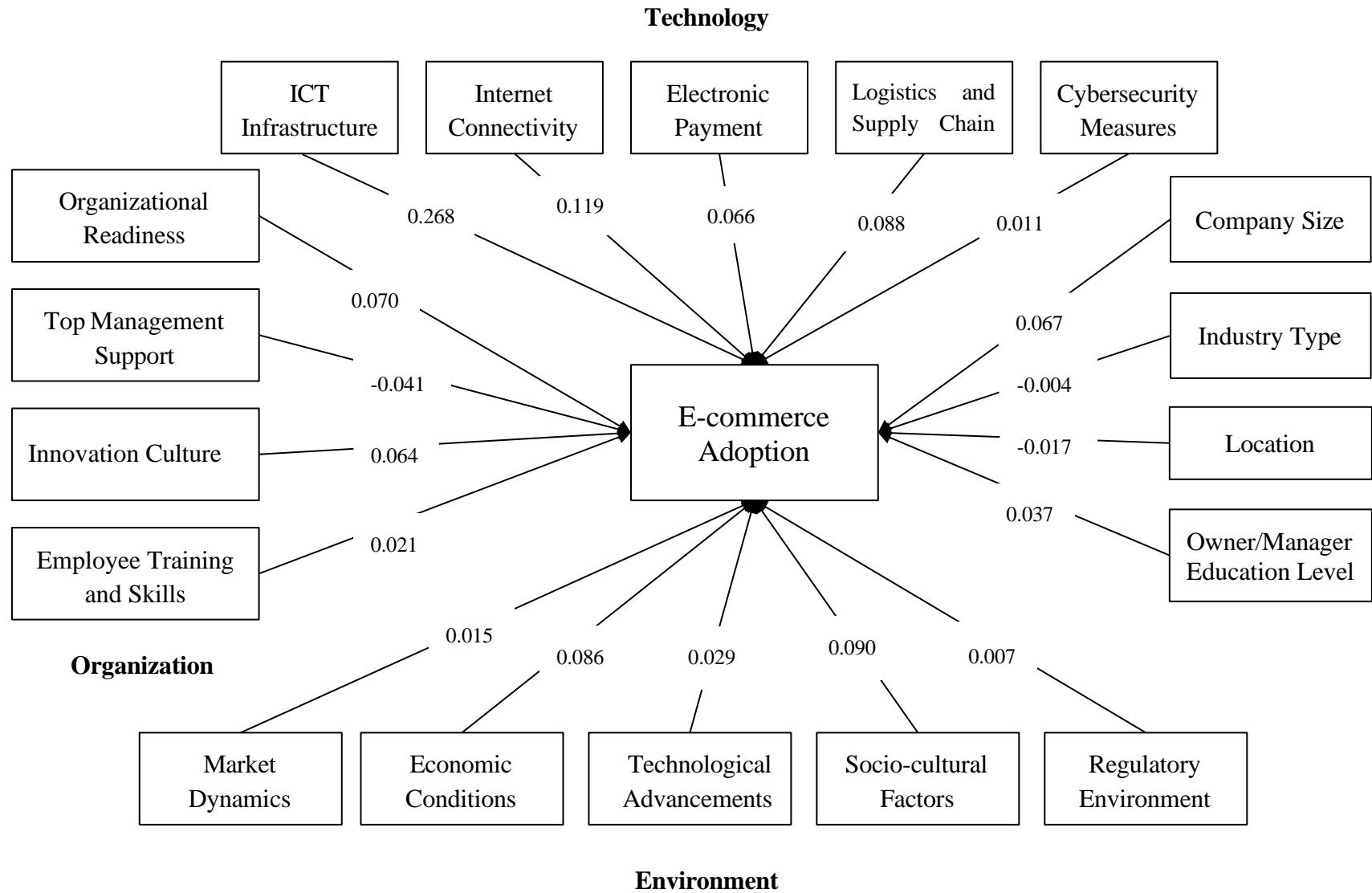
The Variance Inflation Factor (VIF) values presented in Table 5 are well below the acceptable VIF value of 5, with most of the values closely hovering around 1, implying that there is minimal multicollinearity among the variables. VIF values below 3 mean that the predictors are not strongly related to each other, and this means that each of the variables contains unique information for the model (Hair et al., 2019). Thus, this table shows that the problem of multicollinearity does not exist and, therefore, the stability and reliability of the regression coefficients is guaranteed.

6. DISCUSSION

Table 6: Path Hypothesis Testing

Hypothesis	Path Coefficient	T Statistics	P Values	
H1. ICT -> EC	0.268	5.521	0.000	Supported
H2. INTC -> EC	0.119	2.784	0.005	Supported
H3. EPS -> EC	0.066	1.380	0.168	Not Supported
H4. LSCE -> EC	0.088	2.023	0.043	Supported
H5. CYBM -> EC	0.011	0.266	0.790	Not Supported

H6. OR -> EC	0.070	1.513	0.130	Not Supported
H7. TMS -> EC	-0.041	0.923	0.356	Not Supported
H8. INNC -> EC	0.064	1.395	0.163	Not Supported
H9. ETS -> EC	0.021	0.473	0.636	Not Supported
H10. MD -> EC	0.015	0.334	0.739	Not Supported
H11. ECOND -> EC	0.086	1.883	0.021	Supported
H12. TECHADV -> EC	0.029	0.668	0.504	Not Supported
H13. SCF -> EC	0.090	2.093	0.036	Supported
H14. RE -> EC	0.007	0.141	0.888	Not Supported
H15a. Company Size -> EC	0.067	1.971	0.049	Supported
H15b. Industry Type -> EC	-0.004	0.131	0.896	Not Supported
H15c. Location -> EC	-0.017	0.502	0.615	Not Supported
H15d. Owner/Manager Education Level -> EC	0.037	1.100	0.271	Not Supported



*Figure 2: Path coefficient for structural model***Table 7:** Summary of the Tested Hypotheses

Hypothesis	Result	Significance
H1. ICT -> EC	Supported	Significant
H2. INTC -> EC	Supported	Significant
H3. EPS -> EC	Not Supported	Not Significant
H4. LSCE -> EC	Supported	Significant
H5. CYBM -> EC	Not Supported	Not Significant
H6. OR -> EC	Not Supported	Not Significant
H7. TMS -> EC	Not Supported	Not Significant
H8. INNC -> EC	Not Supported	Not Significant
H9. ETS -> EC	Not Supported	Not Significant
H10. MD -> EC	Not Supported	Not Significant
H11. ECOND -> EC	Supported	Significant
H12. TECHADV -> EC	Not Supported	Not Significant
H13. SCF -> EC	Supported	Significant
H14. RE -> EC	Not Supported	Not Significant
H15a. Company Size -> EC	Supported	Significant
H15b. Industry Type -> EC	Not Supported	Not Significant
H15c. Location -> EC	Not Supported	Not Significant
H15d. Owner/Manager Education Level -> EC	Not Supported	Not Significant

Technological Factors

Hypothesis 1 (H1): ICT Infrastructure (ICT) → E-commerce Adoption (EC)

The finding establishes a positive and significant relationship between ICT infrastructure and e-commerce adoption in Nigerian engineering enterprises. It can be inferred that engineering enterprises in Nigeria that have convenient access to advanced ICT infrastructure would rather adopt e-commerce. This corresponds with other works (Ladokun et al., 2013; Awa et al., 2015; Ezennia & Marimuthu, 2022; Hossain et al., 2023; Paun et al., 2024), where ICT infrastructure was established as the fundamental driver for e-commerce adoption. With regard to Nigerian engineering firms, where infrastructure constraints in the past have limited the implementation of different forms of digital developments, modern ICT systems are now available to support the adoption of e-commerce. As enterprises in this sector push the digitalization agenda, it is paramount for them to acquire ICT resources if they are to compete effectively in the global market.

Hypothesis 2 (H2): Internet Connectivity (INTC) → E-commerce Adoption (EC)

The result obtained from the study indicates that internet connectivity has a moderate and significant positive correlation with e-commerce in Nigerian engineering enterprises. This finding aligns with other related literature works (Akanbi & Akintunde, 2018; Uneanya, 2019; Hossain et al., 2023) that acknowledged the importance of reliable internet connectivity which has a positive correlation in the use of e-commerce among SMEs. The positive relationship therefore highlights the fact that fixed and universal connectivity to the internet is crucial for the enhanced takeoff of e-commerce channels. This is particularly relevant for Nigerian engineering enterprises because a lack of quality and reliable internet connection may strongly determine the capability of engineering companies to adopt e-commerce, thereby limiting their ability to effectively compete in the modern global environment.

Hypothesis 3 (H3): Electronic Payment Systems (EPS) → E-commerce Adoption (EC)

However, there is no correlation between the use of Electronic Payment Systems (EPS) and e-commerce adoption

in Nigerian engineering enterprises. Though EPS is important for performing online transactions, this result implies that their direct impact on e-commerce adoption might be limited or not conspicuous compared to definite drivers like ICT infrastructure and internet connectivity. The finding, however, does not align with prior studies (Okifo & Igbunu, 2015; Fatonah et al., 2018; Kilay et al., 2022; Gupta et al., 2023; Khsroo et al., 2024), which found a positive and significant effect of EPS on e-commerce adoption. A possible explanation for the insignificant impact of EPS on e-commerce adoption could be the lack of trust or the limited diffusion of these systems in the study context, which recommends that future research should investigate factors like consumer confidence in EPS and EPS usability. Also, it could be that engineering enterprises in Nigeria give preference to other resources, such as ICT and internet connectivity, over EPS since these factors define the ability to effectively conduct and engage in e-commerce.

Hypothesis 4 (H4): Logistics and Supply Chain Efficiency (LSCE) → E-commerce Adoption (EC)

The study reveals a positive and significant relationship between logistics and supply chain efficiency (LSCE) and the adoption of e-commerce in Nigerian engineering enterprises. This implies that e-commerce adoption is influenced by enhanced and efficient handling of the supply chain, which enables fast delivery of e-commerce products. Logistics is a critical element in a positive shopping experience, especially in e-commerce, to facilitate the timely delivery of products. This aligns with previous findings (Hande et al., 2015; Gunasekaran et al., 2017; Kawa & Swiatowiec-Szczepanska, 2021; Abtahi et al., 2023), which underline the importance of efficient delivery systems in enhancing customer satisfaction and trust in e-commerce platforms. The result highlights the need for reliable logistics networks to sustain and expand e-commerce operations. Well-managed supply chains enable businesses to operate efficiently within the e-commerce environment. By ensuring the seamless flow of goods, businesses are better positioned to meet customer expectations, thereby enhancing their ability to compete in the online marketplace.

Hypothesis 5 (H5): Cybersecurity Measures (CYBM) → E-commerce Adoption (EC)

The result reveals that the correlation between cybersecurity measures (CYBM) and e-commerce adoption is not statistically significant. Although cybersecurity measures play an essential role in safeguarding the interests of both business owners and consumers in the e-commerce setting, the finding of this study reveals that within the engineering enterprises in Nigeria, cybersecurity measures are insignificant factors influencing e-commerce adoption. This is in contrast with prior studies (Igwe et al., 2020; Hossain et al., 2024; Lisdayanti & Hapsari, 2024; Morić et al., 2024; Oguta, 2024; Rajendran, 2024), which prove the relevance and significance of cybersecurity measures in the adoption of e-commerce. The relatively insignificant effect of cybersecurity measures could be attributed to possibly low awareness or investment in cybersecurity, indicating that engineering enterprises in Nigeria aiming to adopt e-commerce may not give paramount importance to online security on e-commerce platforms but focus on other operational aspects. This suggests that engineering enterprises in Nigeria are already participating in e-commerce regardless of the absence of solid internal cybersecurity measures and are perhaps outsourcing cybersecurity services or even deploying cybersecurity insurance solutions to absorb cybersecurity threats. Moreover, engineering enterprises might have other priorities in mind when choosing e-commerce, for example, ICT infrastructural or supply chain and logistics; hence, they might not rank cybersecurity as a high priority when implementing e-commerce, especially if they do not consider the cyber threats to be urgent or important enough to interrupt their e-commerce activities.

Organizational Factors

Hypothesis 6 (H6): Organizational Readiness (OR) → E-commerce Adoption (EC)

This study found a lack of significant relationship between organizational readiness (OR) and e-commerce adoption (EC) in the context of Nigerian engineering enterprises. This result differs from previous studies (Ong et al., 2020; Mbamba, 2023; Su et al., 2023; Purwantini et al., 2024), confirming organizational readiness as a significant factor. Given that the results of this research did not attain statistical significance, it can be postulated that engineering enterprises in Nigeria may still prioritize traditional B2B or offline sales channels, hence the lack of organizational readiness to adopt e-commerce. It could also be due to variations in organizational goals or resource capability. Organizational readiness may moderate or work more indirectly as an antecedent influencing

e-commerce implementation after basic technological facilitators are already in place. This finding conforms to the premise that, for Nigerian engineering enterprises to adapt to e-commerce practices, the foundational infrastructure has to be laid down before factors like organizational culture or staff training can play a role in increasing the readiness levels.

Hypothesis 7 (H7): Top Management Support (TMS) → E-commerce Adoption (EC)

The relationship between top management support (TMS) and e-commerce adoption (EC) is not positive or statistically significant, as indicated by the study findings ($\beta = -0.041$, $t = 0.923$, $p = 0.356$). This outcome aligns with Tang et al. (2024), which also identified top management support as an insignificant factor in driving e-commerce adoption. Similarly, Faloye (2014) pointed out that a lack of interest or commitment among business leaders often serves as a significant barrier to the adoption of digital technologies. These findings suggest that while top management support is traditionally considered crucial in decision-making and resource allocation, its impact on e-commerce adoption may be diminished in contexts where other factors, such as external market pressures, customer demand, or infrastructural challenges, play a more pivotal role. This could indicate a need for more collective organizational effort or a bottom-up approach to drive e-commerce initiatives effectively.

Hypothesis 8 (H8): Innovation Culture (INNC) → E-commerce Adoption (EC)

The study reveals that the relationship between innovation culture (INNC) and e-commerce adoption is positive but statistically insignificant. Although an innovation-oriented organizational culture is generally linked to the adoption of new technologies, this study suggests that an innovation culture alone may not be sufficient to drive e-commerce adoption in Nigerian engineering enterprises. This finding diverges from studies (Ghobakhloo et al., 2011; Rahayu & Day, 2015; Faccia et al., 2023; Gu, 2023; Skare et al., 2023; Salah & Ayyash, 2024) that emphasize innovation as a driver of adoption. The inconsistency may reflect contextual limitations, such as a lack of emphasis on innovation or resistance to change in the study environment. The absence of a significant relationship here indicates that external and technological enablers play a more pivotal role in e-commerce adoption. According to Hendricks & Mwapwele (2024), even if an organization is innovative enough, implementing e-commerce can be a challenge if the organizational technology is insufficient. Therefore, innovation culture may well act as a supportive factor, but it cannot be seen as a fundamentally driving factor where basic technological prerequisites have not been established.

Hypothesis 9 (H9): Employee Training and Skills (ETS) → E-commerce Adoption (EC)

The relationship between employee training and skills (ETS) and e-commerce adoption in this study is not significant. While employee training is widely regarded as crucial for equipping staff with the necessary skills to effectively use e-commerce platforms and tools, this finding contradicts previous research (To & Ngai, 2006; Kiplangat et al., 2015; Ochola, 2015; Costa & Castro, 2021), which emphasized the importance of employee IT competencies in facilitating e-commerce adoption. A possible reason behind the insignificance of employee training and skills in e-commerce adoption in Nigerian engineering enterprises is that other factors, including technological infrastructure, are more significant in influencing e-commerce adoption within the study setting. Moreover, if employees are already capable of performing some subsystems at a basic level, it means that employee IT training and skills might not yield a significant result, which explains its lack of significance in this finding. On the other hand, a lack of a well-planned training regimen or an ineffective one may not generate tangible benefits in promoting e-commerce initiatives.

Environmental Factors

Hypothesis 10 (H10): Market Dynamics (MD) → E-commerce Adoption (EC)

The relationship between market dynamics (MD) and e-commerce adoption appears to be insignificant. Although market dynamics—such as competition, consumer preferences, and market demand—are often regarded as key drivers of e-commerce adoption (Awa et al., 2017; Balta et al., 2024; Githui & Njuru, 2024; Raju et al., 2011), the findings of this study indicate that these external factors may not play a crucial role in determining e-commerce adoption among engineering enterprises in Nigeria. In the context of Nigerian engineering enterprises, where technological infrastructure may still be evolving, these technological factors seem to have a more significant and positive effect than the broader market conditions. The limited relationship between market dynamics and e-

commerce adoption in Nigerian engineering enterprises can be attributed to several factors. A possible explanation is that the Nigerian engineering sector is not marked by swift or competitive market changes that require prompt e-commerce adoption. Players in the industry rather rely on long-term contracts and business-to-business (B2B) transactions and may not be perturbed by fast-paced market dynamics for e-commerce activities.

Hypothesis 11 (H11): Economic Conditions (ECOND) → E-commerce Adoption (EC)

The study confirms that the correlation between economic conditions and the adoption of e-commerce in Nigerian engineering enterprises is positive and statistically significant. This shows that economic conditions such as inflation levels, consumers' buying capacity, and overall economic stability are central to determining the extent of e-commerce adoption. This is in concordance with Foster & Rosenzweig (2010) and Marra et al. (2003), who suggest that a stable economic environment increases technology adoption since it offsets risks and promotes investment. The finding underscores the key role of favorable economic conditions for e-commerce adoption. Thus, economic conditions often influence the ability of businesses to adopt e-commerce since they provide a sense of economic security and encourage commercial investments. When cash flow is available, organizations are more inclined to invest in hardware and other technological enhancements, enabling them to utilize e-commerce solutions effectively.

Hypothesis 12 (H12): Technological Advancements (TECHADV) → E-commerce Adoption (EC)

The findings indicate that the correlation between technological advancements (TECHADV) and e-commerce adoption is insignificant. While previous studies have identified technological advancements—such as new e-commerce tools, digital payment systems, artificial intelligence, customer experience enhancements, and innovation—as crucial drivers for e-commerce adoption (Abrokwah-Larbi & Awuku-Larbi, 2023; Salah & Ayyash, 2024), this study suggests that Nigerian engineering enterprises may be prioritizing factors beyond just the availability of modern technologies. The insignificance of this correlation may stem from these enterprises focusing more on economic conditions rather than levels of technological advancement. Furthermore, these results highlight the issue of perceived usefulness, implying that the relevance of technologies may depend on their alignment with the current challenges and financial capabilities of businesses, thereby rendering technological advancements a secondary consideration in the adoption process.

Hypothesis 13 (H13): Socio-cultural Factors (SCF) → E-commerce Adoption (EC)

The relationship between socio-cultural factors (SCF) and e-commerce adoption (EC) shows a significant positive effect. This suggests that socio-cultural factors such as societal norms, cultural values, and peer behaviors are important determinants of e-commerce adoption, particularly within the context of Nigerian engineering enterprises. This supports previous studies (Gong, 2009; Rabayah et al., 2021; Sivakumar & Raj, 2007; Thatcher et al., 2006; Van Slyke et al., 2004) that highlight socio-cultural influences as significant drivers of technology adoption. The positive relationship indicates that engineering enterprises in Nigeria may be more inclined to adopt e-commerce solutions when there is a strong cultural alignment with digital platforms and a high level of trust in online transactions.

Hypothesis 14 (H14): Regulatory Environment (RE) → E-commerce Adoption (EC)

The study result does not support the hypothesis, as there is no significant correlation between regulatory environment and e-commerce adoption in Nigerian engineering enterprises. While the regulatory environment is broadly acknowledged as a fundamental component for ensuring the safety and effectiveness of e-commerce, this study's finding points to the fact that the regulatory environment is not significant to e-commerce adoption. A possible explanation is that, while adopting e-commerce solutions, special attention may not be paid to regulation compliance; more attention is paid to economic factors and sociocultural impacts. This is incongruous with the works by Awiagah et al. (2015), Aderemi et al. (2018), Luo & Choi (2022), Jeong (2023), and Saeed et al. (2023) that posit the significance of the regulatory environment. Another possible explanation for the insignificant correlation could be a result of weak e-commerce regulations in Nigeria, rendering the regulatory environment less effective in shaping e-commerce adoption decisions of engineering enterprises.

CONTROL VARIABLES

H15a: Company Size → E-commerce Adoption (EC)

The study confirms a positive and significant correlation between company size and e-commerce adoption, which is in accordance with some previous studies (Kuan & Chau, 2001; Kraemer et al., 2005; Awa et al., 2015). Large firms are likely to adopt e-commerce because they possess greater resources, the ability to access robust infrastructure, and the means to address the potential complexities and challenges linked to e-commerce. E-commerce is recognized as a strategic tool from the standpoint of these organizations, insofar as it can be instrumentally used to support and sustain growth in the competitive environment, especially in oversaturated markets that require further market outreach. In addition, as a rule, large companies have all the necessary resources to meet the technological requirements of e-commerce transactions and supply chain management. On the other hand, small businesses often suffer from a lack of resources to implement advanced technologies, even if the tools are cheap and easy to use for implementing e-commerce. The finding does not rule the potential of small businesses in adopting e-commerce strategies regardless of their resource constraints.

H15b: Industry Type → E-commerce Adoption (EC)

The finding reveals that there is an insignificant correlation between industry type and e-commerce adoption, which implies that the industry type or sector within which the engineering enterprises are operating does not compel or have a significant influence on the adoption of e-commerce. This is contrary to the study by Amornkitvikai & Lee (2020), who found industry type as one of the predictors of e-commerce adoption. Variability in e-commerce readiness across various engineering sub-specialties may have obscured this relationship. Consequently, it suggests that additional factors, beyond the commonly recognized elements of organizational capabilities, market characteristics, or socio-cultural influences, may play a role in the decision-making process regarding e-commerce adoption among engineering firms in Nigeria.

H15c: Location → E-commerce Adoption (EC)

The hypothesis aimed at investigating the impact of location on e-commerce adoption proved to be insignificant in this study. This is incongruent with the previous studies, including Brima & Sesay (2019), who established that geographical location plays a significant role in e-commerce buying. The insignificance that has been attained in this study may be due to the availability of ICT infrastructure and internet connectivity, which eliminates geographical factors that are associated with adoption of e-commerce.

H15d: Owner/Manager Education Level → E-commerce Adoption (EC)

The education level of the owner or manager does not have a statistically significant impact on e-commerce adoption. This conclusion is strongly supported by the research conducted by Amornkitvikai et al. (2022), which revealed similar findings. It indicates that the characteristics of the business and the resources at its disposal are far more influential than formal educational credentials in determining the implementation of e-commerce. On the other hand, it may signal that the lack of managerial education is not an issue, as training or outsourcing help can cover any knowledge deficiencies. This result may seem counterintuitive, given the assumption that individuals with a college or higher education are more inclined to understand the value of e-commerce and be willing to embrace change. Nonetheless, the findings imply that factors like the size of the business and technological and environmental factors could be stronger determinants of e-commerce adoption. Importantly, even business owners with limited educational backgrounds can achieve proficiency in e-commerce if their employees or external advisors are knowledgeable in the relevant technologies.

Table 8: Facilitators and Barriers of E-commerce Adoption Among Nigerian Engineering Enterprises

Facilitators	Barriers
Technological Facilitators	Technological Barriers
ICT Infrastructure	Electronic Payment Systems

Internet Connectivity	Cybersecurity Measures
Logistics and Supply Chain Efficiency	
Organizational Facilitators	Organizational Barriers
	Organizational Readiness
	Top Management Support
	Innovation Culture
	Employee Training and Skills
Environmental Facilitators	Environmental Barriers
Economic Conditions	Regulatory Environment
Socio-cultural Factors	Market Dynamics
	Technological Advancements

Table 8 summarizes the facilitators and barriers of e-commerce adoption among Nigerian engineering enterprises, based on the findings of this study.

7. IMPLICATIONS OF THE STUDY

7.1. Theoretical Implications

This paper employs the Technology–Organization–Environment (TOE) framework as the theoretical foundation to analyze the factors influencing e-commerce adoption by engineering enterprises in Nigeria. The application of the TOE framework in this study helped in identifying and classifying the facilitators and barriers of e-commerce adoption. In particular, ICT infrastructure, internet connectivity, and logistics and supply chain efficiency emerged as technological facilitators of e-commerce adoption in engineering enterprises in Nigeria. Environmental facilitators such as economic conditions and socio-cultural factors demonstrate how e-commerce adoption by engineering enterprises is influenced by external factors. In addition, the study offers a list of barriers that explains the challenges Nigerian engineering enterprises have experienced in the course of adopting e-commerce. Technological barriers include cybersecurity measures, and electronic payment systems; organizational barriers include organizational readiness, top management support, innovation culture, and employee training and skills, while the environmental barriers include market dynamics, technological advancements, and regulatory environment. This explains the multifaceted hurdle that engineering enterprises in Nigeria face in connection with e-commerce adoption. The results of this study contribute to the body of literature in the understanding of key challenges/barriers encountered during the adoption of e-commerce. The inclusion of the results from control variables adds further depth to the theoretical contributions. The result, which indicates that control variables such as company size enhances the probability of e-commerce adoption, is consistent with prior studies that firms with large size, resources, and infrastructure are capable of leveraging technology for competitive advantage compared to small firms. Conversely, industry type, location, and owner/manager education level were not statistically significant. These insights suggest that the nature of the usage of e-commerce in engineering enterprises depends more on technological and environmental factors than on the sector and business characteristics. Therefore, this paper extends the TOE framework by presenting the relationships between facilitators, barriers, demographic factors, and e-commerce adoption.

7.2 Managerial Implications

The managerial implications of this study provide effective recommendations for business leaders and managers in engineering enterprises, especially for those companies that are planning to adopt e-commerce in emerging markets. The results highlight the importance of focusing on both facilitators and barriers to an effective transition to digital operations. Organizations can leverage technological facilitators through procuring strong ICT frameworks, improving the availability and speed of the internet, and optimizing logistics and supply chains. They

all help create the basis for competitive activities in the digital economy. Additionally, the study reveals adoption barriers and recommends organizational readiness, IT employee training and skills development, an innovation-oriented culture, and management support. Strong leadership and top management support are also essential in creating a vision and strategy for e-commerce integration. From the environmental perspective, the managers need to take into account the socio-cultural factors and market forces that influence customers' decision making and rate of adoption. The adoption rate of e-commerce may be improved by adapting marketing activities and products to suit distinctive ends and means requirements. In addition, addressing technological issues such as cybersecurity and electronic payment systems is critical. Strong payment processing options and anti-fraud protection systems increase customer confidence and decrease risks, while consequent process automation optimizes organizational preparedness to operate in the digital environment.

7.3 Practical Implications

These findings provide valuable insights for engineering SMEs and policymakers by identifying key facilitators and barriers to e-commerce adoption. For SMEs, understanding the importance of robust ICT infrastructure, reliable internet connectivity, and efficient logistics can guide investments in essential technological enablers. Recognizing the influence of favorable economic conditions and socio-cultural factors can help SMEs tailor their strategies to align with market demands and cultural preferences. For policymakers, addressing barriers such as weak electronic payment systems, inadequate cybersecurity measures, and regulatory inconsistencies is crucial to fostering a supportive e-commerce ecosystem. Additionally, promoting organizational readiness through employee training, innovation culture, and top management support can empower SMEs to overcome internal challenges. Policymakers can also focus on improving market dynamics and leveraging technological advancements to create an environment conducive to e-commerce growth, driving economic development in the engineering sector. The analysis of control variables also reveals some valuable insights relevant to managers. The strong and positive influence that the company size has on e-commerce adoption means that large firms with the necessary resources have the potential to handle the challenges that come with e-commerce. Small businesses on the other hand can overcome this challenge through collaboration or seeking external assistance. Conversely, the lack of significant impact of industry type, location, and owner/manager education level suggests that managers should focus less on contextual factors and more on universal enablers such as competitive strategies, digital literacy training, and external expertise.

8. LIMITATIONS AND FUTURE RESEARCH

This study offers valuable insights into e-commerce adoption among engineering enterprises in Nigeria but has limitations that provide opportunities for future research. The cross-sectional design captures adoption at a single point, missing the dynamic nature of these processes over time. Self-reported survey data may also be subject to bias, suggesting the need for qualitative methods to complement findings. Additionally, the focus on Nigeria's engineering sector limits generalizability, and future studies could explore diverse industries or regions. The study focused on the TOE framework to explore technological, organizational, and environmental dimensions. While this framework is robust, it may not fully capture individual-level factors, such as entrepreneurial mindset or digital literacy, which could influence adoption decisions. Future research could integrate complementary models, such as the Unified Theory of Acceptance and Use of Technology (UTAUT), to examine the role of individual characteristics in technology adoption. The insignificance of all organizational factors indicates potential indirect effects or interactions that require further examination. Future research could explore these potential mediations or moderations. Furthermore, the study emphasizes facilitators and barriers to adoption but does not fully account for the post-adoption phase. Understanding how enterprises sustain and optimize e-commerce platforms after initial adoption is a crucial area for future exploration. Investigating post-adoption outcomes such as operational efficiency, customer retention, and market expansion could provide a more holistic understanding of e-commerce's impact on business performance. Future studies should employ a qualitative or a mixed approach, and explore longitudinal studies to track e-commerce trends in other sectors or cross-country.

9. CONCLUSION

This study examined the factors influencing e-commerce adoption among engineering enterprises in Nigeria, using the Technology-Organization-Environment (TOE) framework. The findings highlight the critical role of technological and environmental dimensions in driving adoption, with key facilitators such as ICT infrastructure, internet connectivity, logistics and supply chain efficiency, economic conditions, and favorable socio-cultural factors enabling engineering enterprises to embrace e-commerce. Conversely, barriers like cybersecurity concerns, inadequate electronic payment systems, technological advancements, regulatory challenges, and market dynamics underscore the complexities of adoption in emerging markets. Notably, the study found no significant influence of organizational factors, such as organizational readiness, top management support, innovation culture, and employee training and skills on e-commerce adoption. This outcome suggests that other dimensions or indirect effects may play a more pivotal role in determining adoption success. Furthermore, control variables like company size were shown to significantly influence e-commerce adoption, while industry type, location, and owner/manager education level did not yield significant effects. By advancing the TOE framework with context-specific insights, this study provides theoretical contributions and practical guidance for businesses and policymakers. Managers are encouraged to adopt a holistic approach, addressing both facilitators and barriers to maximize e-commerce potential. Policymakers should prioritize improving digital infrastructure and addressing regulatory challenges to foster broader adoption.

REFERENCES

- [1] Abrokwah-Larbi, K., & Awuku-Larbi, Y. (2024). The impact of artificial intelligence in marketing on the performance of business organizations: evidence from SMEs in an emerging economy. *Journal of Entrepreneurship in Emerging Economies*, 16(4), 1090-1117.
- [2] Abtahi, A. T., Farhana, N., & Hasan, M. M. (2023). A study on the impact of e-commerce adoption for enhancing supply chain efficiency in Bangladesh SMEs. *Business and Economics in Developing Countries*, 1(1), 29-33. <https://doi.org/10.26480/bedc.01.2023.29.33>
- [3] Adebayo, A. (2022). Nigerian Internet users to reach 118m by 2027. *New Telegraph*. Retrieved from: <https://newtelegraphng.com/nigerian-internet-users-to-reach-118m-by-2027/>
- [4] Aderemi, H.O., Ajao, B.F., and Oyeibisi, T.O. (2018). Factors influencing the implementation of e-commerce innovations: The case of the Nigerian informal sector. *African Journal of Science, Technology, Innovation and Development*, 10 (4), 473-481
- [5] Agwu, E. M., & Murray, P. J. (2015). Empirical study of barriers to electronic commerce adoption by Small and Medium scale businesses in Nigeria. *International Journal of Innovation in the Digital Economy*, 6(2).
- [6] Amornkitvikai, Y., & Lee, C. (2020). Determinants of e-commerce adoption and utilization by SMEs in Thailand (Economics Working Paper 1-41). College of Population Studies, Chulalongkorn University. ISEAS – Yusof Ishak Institute, Singapore.
- [7] Amornkitvikai, Y., Tham, S.Y., Harvie, C., & Buachoom, W.W. (2022) Barriers and Factors Affecting the E-Commerce Sustainability of Thai Micro-, Small- and Medium-Sized Enterprises (MSMEs). *Sustainability* 2022, 14, 8476.
- [8] Asaolu, T. O., Ayoola, T. J., & Akinkoye, E. Y. (2011). Electronic Payment System in Nigeria: Implementation, Constraints and Solutions. *Journal of Management and Society*, 1(2), 16–21.
- [9] Awa, H. O., Awara, N. F., & Lebari, E. D. (2015). Critical factors inhibiting Electronic Commerce (EC) adoption in Nigeria: A study of operators of SMEs. *Journal of Science & Technology Policy Management*, 6(2), 143-164.
- [10] Awa, H.O., Ojiabo, O.U., & Emecheta, B.C. (2015) Integrating TAM, TPB and TOE frameworks and expanding their characteristic constructs for e-commerce adoption by SMEs. *Journal of Science and Technology Policy Management*, 6(1), 76- 94.
- [11] Awa, H. O., Ojiabo, O. U., & Orokor, L. E. (2017). Integrated technology-organization-environment (T-O-E) taxonomies for technology adoption. *Journal of Enterprise Information Management*, 30(6), 893-921.
- [12] Awiagah, R., Kang, J., & Lim, J. I. (2016). Factors affecting e-commerce adoption among SMEs in Ghana. *Information Development*, 32(4), 815-836.

- [13] Balta, M.E., Papadopoulos, T. and Spanaki, K. (2024), "Business model pivoting and digital technologies in turbulent environments", *International Journal of Entrepreneurial Behavior & Research*, Vol. 30 No. 2/3, pp. 773-799. <https://doi.org/10.1108/IJEBr-02-2023-0210>
- [14] Bening, S. A., Dachyar, M., Pratama, N. R., Park, J., & Chang, Y. (2023). E-Commerce Technologies Adoption Strategy Selection in Indonesian SMEs Using the Decision-Makers, Technological, Organizational and Environmental (DTOE) Framework. *Sustainability*, 15(12), 9361. <https://doi.org/10.3390/su15129361>
- [15] Bowersox, D. J., Closs, D. J., Cooper, M. B., & Bowersox, J. C. (2014). *Supply Chain Management Logistics Management* (4th ed.). New York: McGraw-Hill Education.
- [16] Brima, A. S., & Sesay, B. (2019). Barriers to e-commerce adoption among SMEs in Sierra Leone: The moderating role of geographical location. *International Journal of Science and Management Studies (IJSMS)*, 2(1). <https://doi.org/10.51386/25815946/ijms-v2i1p101>
- [17] Celestin, M., & Sujatha, S. (2024). Understanding the shift to digital payments and its impact on consumer preferences: The role of fintech in shaping the future of payments. *International Journal of Advanced Trends in Engineering Science and Technology*, 9(2), 66-73. <https://doi.org/10.5281/zenodo.13955406>
- [18] Costa, J., & Castro, R. (2021). SMEs must go online—E-commerce as an escape hatch for resilience and survivability. *Journal of Theoretical and Applied Electronic Commerce Research*, 16(7), 3043-3062.
- [19] Cumming, D., Johan, S., Khan, Z., & Meyer, M. (2023). E-commerce policy and international business. *Management International Review*, 63(1), 3-25.
- [20] Akanbi, B. E., & Akintunde, T. S. (2018). E-commerce adoption and small medium scale enterprises performance in Nigeria. *European Journal of Management and Marketing Studies*, 3(1), 14–16.
- [21] Dada, B., & Oluwadara, S. (2023) An objective analysis of seven payment gateways in Nigeria. Available at: <https://www.benjamindada.com/best-payment-gateway-nigeria/#:~:text=The%20seven%20payment%20gateways%20are,%2C%20Seerbit%2C%20Fincra%20and%20Monnify.&text=Electronic%20payments%20have%20risen%20in,Bank's%20cashless%20policy%20of%202012.>
- [22] Deloitte. (2016, October). The economic impact of disruptions to Internet connectivity: A report for Facebook. Retrieved from <https://globalnetworkinitiative.org/wp-content/uploads/GNI-The-Economic-Impact-of-Disruptions-to-Internet-Connectivity.pdf>
- [23] El-Ebiary, Y. A. B., Al Moaiad, Y., Hassan, A. H., Al-Kofahi, M., Alqudah, O. (M. A.), Liban, A., Al-Hodiany, Z. M., & Hilles, S. M. S. (2022). E-commerce adoption: Problems facing SMEs in Nigeria. *International Journal of Special Education*, 37(3), 6580.
- [24] El-Haddadeh, R., Osmani, M., Hindi, N., & Fadlalla, A. (2021). Value creation for realising the sustainable development goals: Fostering organisational adoption of big data analytics. *Journal of Business Research*, 131, 402-410. <https://doi.org/10.1016/j.jbusres.2020.10.066>
- [25] Ezennia, C. S., & Marimuthu, M. (2022). Factors that positively influence e-commerce adoption among professionals in Surulere, Lagos, Nigeria. *African journal of science, technology, innovation and development*, 14(2), 405-417.
- [26] Faccia, A., Le Roux, C. L., & Pandey, V. (2023). Innovation and E-Commerce Models, the Technology Catalysts for Sustainable Development: The Emirate of Dubai Case Study. *Sustainability*, 15(4), 3419. <https://doi.org/10.3390/su15043419>
- Faloye, D. O. (2014). The adoption of e-commerce in small businesses: An empirical evidence from the retail sector in Nigeria. *Journal of Business and Retail Management Research (JBRMR)*, 8(2), 54–65. Retrieved from www.jbrmr.com
- [27] Fatonah, S., Yulandari, A., & Wibowo, F. W. (2018). A Review of E-Payment System in E-Commerce. *Journal of Physics: Conference Series*, 1140(1). <https://doi.org/10.1088/1742-6596/1140/1/012033>.
- [28] Fornell, C., & Larcker, D. F. (1981). Evaluating Structural Equation Models with Unobservable Variables and Measurement Error. *Journal of Marketing Research*, 18(1), 39-50.
- [29] Foster, A. D., & Rosenzweig, M. R. (2010). Microeconomics of technology adoption. *Annual Review of Economics*, 2(1), 395–424. <https://doi.org/10.1146/annurev.economics.102308.124433>
- [30] Gefen, D., Straub, D. W., & Boudreau, M. C. (2000). Structural Equation Modeling and Regression: Guidelines for Research Practice. *Communications of the Association for Information Systems*, 4(1), 7.

-
- [31] Ghobakhloo, M., Arias-Aranda, D. and Benitez-Amado, J. (2011), Adoption of e-commerce applications in SMEs, *Industrial Management & Data Systems*, 111 (8), 1238-1269. <https://doi.org/10.1108/02635571111170785>
- [32] Githui, F. K., & Njuru, J. W. (2024). Impact of E-Commerce as a Business Tactic on Sales Growth of SMEs in Nairobi. *International Journal of Science and Business*, 34(1), 108-116.
- [33] GlobeNewswire (2024). Nigeria Ecommerce Market Databook 2024, Featuring Key Players Jiji, Jumia, Konga, PayPorte, Slot, Chopnownow, Dominos Pizza, GoFood, Jumia Food, SoFresh, Bolt, GiDiCab, Rida, Travelstart and Wakanow.
- [34] Gong, W. (2009). National culture and global diffusion of business-to-consumer e-commerce, *Cross Cultural Management: An International Journal*, 16 (1), 83-101.
- [35] Gu, J. (2023). What drives SMEs to adopt e-commerce? The joint role of testosterone and absorptive capacity. *Asia Pacific Journal of Marketing and Logistics*, 35(1), 90-107. <https://doi.org/10.1108/APJML-09-2021-0709>
- [36] Gunasekaran, A., Subramanian, N., & Rahman, S. (2017). Improving Supply Chain Performance through Management Capabilities. *Production Planning & Control*, 28, 473-477.
- [37] Guo, J., Jia, F., Yan, F., & Chen, L. (2024). E-commerce supply chain finance for SMEs: the role of green innovation. *International Journal of Logistics Research and Applications*, 27(9), 1596-1615.
- [38] <https://doi.org/10.1080/09537287.2017.1309680>
- [39] Gupta, S., Kushwaha, P. S., Badhera, U., Chatterjee, P., & Santibanez Gonzalez, E. D. R. (2023). Identification of benefits, challenges, and pathways in e-commerce industries: An integrated two-phase decision-making model. *Sustainable Operations and Computers*, 4, 200-218. <https://doi.org/10.1016/j.susoc.2023.05.002>
- [40] Hair, J. F., Hult, G. T. M., Ringle, C. M., & Sarstedt, M. (2019). *A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM)* (2nd ed.). SAGE Publications.
- [41] Hande, P.V., Ghosh, D., Atingovil, A. (2015). A comparative study on factors shaping buying behaviour on B2B and B2C E-commerce platforms in India. *EXCEL International Journal of Multidisciplinary Management Studies*, 5(3), 1-10.
- [42] Hashimy, L., Jain, G., & Grifell-Tatjé, E. (2023). Determinants of blockchain adoption as decentralized business model by Spanish firms – an innovation theory perspective", *Industrial Management & Data Systems*, 123 (1), 204-228. <https://doi.org/10.1108/IMDS-01-2022-0030>
- [43] Hendrawan, S. A., Chatra, A., Iman, N., & Hidayatullah, S. (2024). Digital transformation in MSMEs: Challenges and opportunities in technology management. *Jurnal Informasi dan Teknologi*, 6(2). <https://doi.org/10.60083/jidt.v6i2.551>
- [44] Hendricks, S., & Mwapwele, S. D. (2024). A systematic literature review on the factors influencing e-commerce adoption in developing countries. *Data and Information Management*, 8(1), 100045.
- [45] Hossain, M. B., Dewan, N., Senin, A. A., & Illes, C. B. (2023). Evaluating the utilization of technological factors to promote e-commerce adoption in small and medium enterprises. *Electronic Commerce Research*, 1-20.
- [46] Hossain, M. A., Islam, S., Rahman, M. M., & Arif, N. U. M. (2024). Impact of online payment systems on customer trust and loyalty in E-commerce analyzing security and convenience. *Academic Journal on Science, Technology, Engineering & Mathematics Education*, 4(03), 1-15.
- [47] Ibrahim, K. M., Hassan, A., Carim, A. A., & Oni, M. T. (2024). Online Technology and Business Performance of SMEs In Osun State. *UNIZIK Journal of Marketing*, 1(1), 131-146.
- [48] Ifeoluwa, A. O., Privat, U. A., & Rusu, L. (2022). Barriers in digital transformation in small and medium enterprises in Nigeria. *International Journal of Innovation in the Digital Economy*, 13(1), 1–17. <https://doi.org/10.4018/IJIDE.311510>
- [49] Igudia, P. (2018). Electronic payment systems adoption by SMEs in Nigeria: A literature review. *Nigerian Journal of Management Sciences*, 6(2), 151-165.
- [50] Igwe, E. N., Alaba, O. B., & Abass, O. A. (2020). A review of e-commerce adoption in Nigeria based on security and trust. *University of Ibadan Journal of Science and Logistics in ICT Research*, 5(1), 120–134. <https://doi.org/10.15580/GJAS.2018.3.031218042>
- [51] Islam, M. A., Akter, S., Akhter, S., and Kabir, A. H. (2021). A study on the impact of capital structure on financial performance: A case study of small and medium enterprises (SMEs) in Bangladesh. *Accounting and Finance Research*, 10(3), 26-35.

- [52] Jeong, Y. (2023). Enhancing policy and regulatory approaches to strengthen digital, platform, and data economies (ADB Sustainable Development Working Paper Series No. 91). Asian Development Bank.
- [53] Kang, J., & Park, S. (2014). Factors influencing electronic commerce adoption in developing countries: the case of Tanzania. *South African Journal of Business Management*, 45 (2)
- [54] Kawa, A. & Światowiec-Szczepańska, J. (2021). Logistics as a value in e-commerce and its influence on satisfaction in industries: a multilevel analysis, *Journal of Business & Industrial Marketing*, 36 (13), 220-235.
- [55] Khsroo, I. T. N., Burhanuddin, M., Ali, M. A., & Shihab Ahmed, M. (2024). The Influence of Technological Factors on Adoption E-Commerce in SME: The Role of Trust. *Journal of Global Information Technology Management*, 27(2), 148–167. <https://doi.org/10.1080/1097198X.2024.2327945>
- [56] Kilay, A. L., Simamora, B. H., & Putra, D. P. (2022). The influence of e-payment and e-commerce services on supply chain performance: Implications of open innovation and solutions for the digitalization of micro, small, and medium enterprises (MSMEs) in Indonesia. *Journal of Open Innovation: Technology, Market, and Complexity*, 8(3), 119. <https://doi.org/10.3390/joitmc8030119>
- [57] Kiplangat, B. J., Shisia, A., & Asienga, I. C. (2015). Effects of human competencies in the adoption of e-commerce strategies among SMEs in Kenya. *International Journal of Economics, Commerce and Management*, 3(10), 846–863. <http://ijecm.co.uk/>
- [58] Kraemer, K. L., Gibbs, J., & Dedrick, J. (2005). Impacts of Globalization on E-Commerce Use and Firm Performance: A Cross-Country Investigation. *The Information Society*, 21(5), 323-340. doi:10.1080/01972240500253350
- [59] Kuan, K. K. Y., & Chau, P. Y. K. (2001). A perception-based model for EDI adoption in small business using a technology-organization-environment framework. *Information and Management*, 38, 507-521. doi:10.1016/S0378-7206(01)00073-8
- [60] Ladokun, I. O., Osunwole, O. O., & Olaoye, B. O. (2013). Information and Communication Technology in Small and Medium Enterprises: Factors affecting the Adoption and use of ICT in Nigeria. *International Journal of Academic Research in Economics and Management Sciences*, 2 (6), 74.
- [61] Lip-Sam, T., & Hock-Eam, L. (2011). Estimating the determinants of B2B e-commerce adoption among small and medium enterprises. *International Journal of Business and Society*, 12(1), 15-30.
- [62] Lisdayanti, A., & Hapsari, A. Y. (2024). The influence of security perception and consumer trust on repurchase intention on e-commerce platforms. *Technium Business and Management*, 8, 107-121.
- [63] Loo, M.K., Ramachandran, S. & Raja Yusof, R.N. (2024). Systematic Review of Factors and Barriers Influencing E-Commerce Adoption among SMEs over the Last Decade: A TOE Framework Perspective. *J Knowl Econ*. <https://doi.org/10.1007/s13132-024-02257-5>
- [64] Luo, S., & Choi, T. M. (2022). E-commerce supply chains with considerations of cyber-security: Should governments play a role?. *Production and Operations Management*, 31(5), 2107-2126.
- [65] Madueke, C. J., & Eyupoglu, S. (2024). Sustaining Economic Growth: E-Service Quality's Role in Fostering Customer Loyalty in Nigeria SMEs. *Sustainability*, 16(21), 9175.
- [66] Mahroeian, H. (2012). A study on the effect of different factors on e-Commerce adoption among SMEs of Malaysia. *Management Science Letters*, 2(7), 2679-2688. <https://doi.org/10.5267/j.msl.2012.08.021>
- [67] Marra, M., Pannell, D. J., & Ghadim, A. A. (2003). The economics of risk, uncertainty and learning in the adoption of new agricultural technologies: Where are we on the learning curve? *Agricultural Systems*, 75(2–3), 215–234. [https://doi.org/10.1016/S0308-521X\(02\)00066-5](https://doi.org/10.1016/S0308-521X(02)00066-5)
- [68] Mbamba, U. O. (2023). Relationship between Organisational E-readiness and E-Commerce Implementation in Developing Countries: Perspectives from Tanzania. *University of Dar es Salaam Library Journal*, 18(1), 152-166.
- [69] Mordoe Intelligence (2024). E-commerce in Nigeria Market Size & Share Analysis - Growth Trends & Forecasts (2024 - 2029). Retrieved from: <https://www.mordorintelligence.com/industry-reports/nigeria-ecommerce-market>
- [70] Morić, Z., Dakic, V., Djekic, D., & Regvart, D. (2024). Protection of Personal Data in the Context of E-Commerce. *Journal of cybersecurity and privacy*, 4(3), 731-761.
- [71] Moses, V. (2023). DIGITAL TRANSFORMATION AND E-COMMERCE ADOPTION AMONG SMALL BUSINESSES IN DEVELOPING AFRICAN ECONOMIES: EVIDENCE FROM ETHIOPIA AND UGANDA. *Branding: Jurnal Manajemen dan Bisnis*, 2(1).

- [72] Nasereddin, H. H. O., & Faqir, M. J. M. (2019). The impact of Internet of Things on customer service: A preliminary study. *Periodicals of Engineering and Natural Sciences*, 7(1), 148–155. Available at <http://pen.ius.edu.ba>
- [73] Ochola, P. (2015). An Empirical Study of Determinants of E-Commerce Adoption Amongst Micro, Small, and Medium Enterprises (MSMEs) in Kenya. *International Journal of Economics, Commerce, and Management*, 3(12), 223-234.
- [74] Odufuwa, F., Mariti, R., Deen-Swarray, M., Ahmed, A. A., & Partridge, A. (2024). Digital Technology Adoption by Microenterprises: Nigeria Report.
- [75] Oguejiofor, B. B., Omotosho, A., Abioye, K. M., Alabi, A. M., Oguntinyinbo, F. N., Daraojimba, A. I., & Daraojimba, C. (2023). A review on data-driven regulatory compliance in Nigeria. *International Journal of Applied Research in Social Sciences*, 5(8), 231–243. <https://doi.org/10.51594/ijarss.v5i8.571>
- [76] Oguta, G. C. (2024). Securing the virtual marketplace: Navigating the landscape of security and privacy challenges in E-Commerce. *GSC Advanced Research and Reviews*, 18(1), 084-117.
- [77] Okifo, J., & Igbunu, R. (2015). Electronic Payment System in Nigeria: Its Economic Benefits and Challenges. *Journal of Education and Practice*, 6(16), 56–63.
- [78] Oloni, V. (2024, September 6). From brick to click: E-commerce and the future of retail. Veriv Africa.
- [79] Oluyinka, S., Shamsuddin, A., Ajabe, M. A., & Enegbuma, W. I. (2014). A study of electronic commerce adoption factors in Nigeria. *International Journal of Information Systems and Change Management*, 6(4), 293–315. <https://doi.org/10.1504/IJISCM.2013.060974>
- [80] Oluyinka, S., Shamsuddin, A., Wahab, E., Ajagbe, M. A., and Enegbuma, W. I. (2013), A study of electronic commerce adoption factors in Nigeria. *International Journal of Information Systems and Change Management*, 6 (4), 293-315.
- [81] Ong, T. S., Teh, B. H., Kasbun, N. F., Mahroeian, H., & Hossain, M. I. (2020). Electronic Commerce Adoption among Malaysian SMEs. *Journal of Critical Reviews*, 7(19), 555-565.
- [82] Paun, C., Ivascu, C., Olteteanu, A., & Dantis, D. (2024). The Main Drivers of E-Commerce Adoption: A Global Panel Data Analysis. *Journal of Theoretical and Applied Electronic Commerce Research*, 19(3), 2198-2217. <https://doi.org/10.3390/jtaer19030107>
- [83] Purwantini, A. H., Hidayati, L. L. A., & Aligarh, F. (2024). The Influence of Organizational Readiness on e-Commerce Adoption and Its Impact on Micro-enterprises Performance. In *E3S Web of Conferences* (Vol. 500, p. 05001). EDP Sciences.
- [84] PwC. (2020). PwC's MSME Survey 2020: Building to last. PwC Nigeria. <https://www.pwc.com/ng/en/assets/pdf/pwc-msme-survey-2020-final.pdf>
- [85] Rabayah, K. S., Maree, M., & Alhashmi, S. M. (2021). Cultural factors that influence the adoption of e-commerce: A Palestinian case study. *Information Development*, 38(4), 623–640.
- [86] Rahayu, R., & Day, J. (2015). Determinant Factors of E-commerce Adoption by SMEs in Developing Country: Evidence from Indonesia. *Procedia - Social and Behavioral Sciences*, 195, 142–150. <https://doi.org/10.1016/j.sbspro.2015.06.42>
- [87] Rajendran, R. (2024). Data Breach Fraudulence and Preventive Measures in E-Commerce Platforms. In *Advancements in Cybercrime Investigation and Digital Forensics* (pp. 161-184). Apple Academic Press.
- [88] Raju, P. S., Lonial, S. C., & Crum, M. D. (2011). Market orientation in the context of SMEs: A conceptual framework. *Journal of Business Research*, 64(12), 1320-1326.
- [89] Raju, P. S., Lonial, S. C., & Crum, M. D. (2011). Market orientation in the context of SMEs: A conceptual framework. *Journal of Business Research*, 64(12), 1320-1326.
- [90] Saeed, S., Altamimi, S. A., Alkayyal, N. A., Alshehri, E., & Alabbad, D. A. (2023). Digital transformation and cybersecurity challenges for business resilience: Issues and recommendations. *Sensors* (Basel), 23(15), 6666. <https://doi.org/10.3390/s23156666>
- [91] Salah, O. H., & Ayyash, M. M. (2024). E-commerce adoption by SMEs and its effect on marketing performance: An extended TOE framework with AI integration, innovation culture, and customer tech-savviness. *Journal of Open Innovation: Technology, Market, and Complexity*, 10(1), 100183.
- [92] Santhanam, R., Venugopal, P., Dasgupta, S., Kumar, R. S., Saravanan, M. P., & Kayande, R. A. (2023). Analysis of organizational culture and e-commerce adoption in the context of top management perspectives. *The Scientific Temper*, 14(04), 1474-1481.

-
- [93] Sasu, D. D. (2024, March 19). Number of internet users in Nigeria from 2018 to 2022, with forecasts from 2023 to 2027 (in millions). Statista. <https://www.statista.com/statistics/183849/internet-users-nigeria/>
 - [94] Sivakumar, K., & Raj, S. P. (2007). Turning Advertising Strategy into Effective Sales Force Action. *Journal of Marketing*, 71, 70-80.
 - [95] Skare, M., Gavurova, B., & Rigelsky, M. (2023). Innovation activity and the outcomes of B2C, B2B, and B2G e-commerce in EU countries. *Journal of Business Research*, 163, Article 113874. <https://doi.org/10.1016/j.jbusres.2023.113874>
 - [96] Su, J., Zhang, Y., & Wu, X. (2023). How market pressures and organizational readiness drive digital marketing adoption strategies' evolution in small and medium enterprises. *Technological Forecasting and Social Change*, 193, 122655.
 - [97] Sutanonpaiboon, J., & Pearson, A. M. (2006). E-Commerce Adoption: Perceptions of Managers/Owners of Small- and Medium-Sized Enterprises (SMEs) in Thailand. *Journal of Internet Commerce*, 5(3), 53–82. https://doi.org/10.1300/J179v05n03_03
 - [98] Tang, A., Lily, J., & Cheng, C. T. (2024). SME's E-Commerce Adoption in Sabah and Sarawak: The Moderating Role of Government Support. *Journal of Entrepreneurship and Business*, 12(2), 32-56.
 - [99] Temowo, O. (2024). The Impact of Technology-Driven Supply Chain Systems on Market Penetration of SMES In Developing Economies: A Study of Nigerian SMES.
 - [100] To, M. L., & Ngai, E. W. (2006). Predicting the organisational adoption of B2C e-commerce: an empirical study. *Industrial Management & Data Systems*, 106(8), 1133-1147.
 - [101] Tom Alexander, B., & Jasper Andreas, V. D. D. (2022). E-Commerce in Nigeria: A qualitative study on challenges in the Nigerian E-Commerce landscape and solution approaches.
 - [102] Thatcher, S. M., Foster, W., & Zhu, L. (2006). B2B e-commerce adoption decisions in Taiwan: The interaction of cultural and other institutional factors. *Electronic Commerce Research and Applications*, 5(2), 92-104.
 - [103] Tornatzky, L.G.M., Tshell, F., & Alok, K.C. (1990). *The Process of Technological Innovation*; Lexington Books; The Free Press: Cochran, PA, USA, 1990
 - [104] Uneanya, M.N. (2019). Factors that Affect e-Commerce Adoption in Nigeria (Doctoral dissertation, Capella University).
 - [105] Van Slyke, C., Lou, H., Belanger, F., & Sridhar, V. (2004) The Influence of Culture on Consumer-Oriented Electronic Commerce Adoption, SAIS 2004 Proceedings. 51, 1-7.
 - [106] Webdesigns (2023) 15 Best Online Payment Gateways In Nigeria. Available at: <https://webdesigns.com.ng/best-online-payment-gateways-nigeria/>
 - [107] Yuwono, T., Suroso, A. & Novandari, W. (2024). Information and communication technology in SMEs: a systematic literature review. *J Innov Entrep* 13, 31. <https://doi.org/10.1186/s13731-024-00392-6>
 - [108] Zhong, Y., & Moon, H. C. (2023). Investigating the Impact of Industry 4.0 Technology through a TOE-Based Innovation Model. *Systems*, 11(6), 277. <https://doi.org/10.3390/systems11060277>