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Third-party application developers and the liminal space experience during digital entrepreneurship development

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Abstract

Purpose – The study aims to embrace the lingering call for more empirical studies that can theorize the role of digital platforms in digital entrepreneurship. Hence, this study seeks to reveal the liminal space entrepreneurial experience of third-party application developers, by investigating how the platform boundary resources promote third-party entrepreneurial actions, as they transition through the disoriented, uncertain and ambiguous processes of digital entrepreneurship development.

Design/methodology/approach – To conduct this investigation, an expert interview qualitative method was used. This approach is a well-established technique in the field of social sciences, which allowed a detailed exploration of the theory of liminality. Liminality refers to the transitional phase that individuals or groups experience when moving from one social or cultural context to another. The expert interview method is appropriate for this study because it involves engaging with knowledgeable individuals who have extensive experience and expertise in the subject area being investigated. Through in-depth and unstructured interviews, the experts were able to provide valuable insights and perspectives about the phenomenon investigated.

Findings – The research findings demonstrate that digital platform boundary resources play a significant role in the behaviour of third-party developers' who engage in the development of digital entrepreneurship in today's market. The study highlights three ways that show how these resources (software development kit (SDK), API, integrated development environment (IDE), libraries, frameworks) enable third-party developers to create new applications that are used to pursue entrepreneurship in a digital platform, leading to increased user engagement and revenue generation.

Originality/value – The research addresses the critical roles of digital platform boundary resources in digital entrepreneurship development processes. Also, using liminality theory, the research explicated the core experiences of third-party developers as they navigated the challenges and ambiguities experienced in the pursuit of entrepreneurship. Thus, contributing to the existing body of knowledge in literature and practice.

Keywords Digital platform, Platform boundary resources, Digital entrepreneurship,
Third-party application developers, Digital business, Digital start-up

Paper type Research paper

1. Introduction

The emergence of digital platform boundary resources has provided a significant opportunity for third-party application developers to achieve new business development by leveraging digital platforms. With these resources, third-party application developers can easily interact with the platform and unlock new avenues to pursue entrepreneurship (Bianco, Myllarniemi, Komssi, & Raatikainen, 2014; de Reuver, Sørensen, & Basole, 2017; Mohagheghzadeh & Lindman, 2022; Rubleske, 2020; Tiwana, 2013; Konsynski, &



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Bush, 2010). Thus, “Digital entrepreneurship is the development of a new economic activity that is either embodied in or enabled by digital technologies [whose outcome is a digital start-up]” (Foisal, Alam, & Abedin, 2023, p. 46). Digital start-ups are new businesses that utilize digital technology and innovation to create new products/services, streamlining traditional entrepreneurship processes to gain a competitive edge in any target market (Kraus, Palmer, Kailer, Kallinger, & Spitzer, 2018). The early stages of a digital start-up’s lifecycle (i.e. digital entrepreneurship development) are crucial, as they involve the development of a product/service that is unique and valuable to potential customers. This process requires a high level of interaction between entrepreneurs and target customers through digital technology (e.g. digital platforms), as they work to identify opportunities, refine ideas and create prototypes. Digital platform boundary resources are “the software tools and regulations that serve as the interface for the arm’s-length relationship between the platform owner and the application developer . . . such resources typically consist of a software development kit (SDK) and a multitude of related application programming interfaces (APIs)” (Ghazawneh & Henfridsson, 2012, p. 3).

Application developers interact with platform boundary resources to contribute to digital platform services by developing complementary applications that can offer economic value to both platform owners and third-party developers. This account suggests that “platform boundary resources constitute the virtual workplace where mediated collaboration among the actors in the platform ecosystem happens” (Farshchian & Thomassen, 2019, p. 559). Because platform boundary resources enable third-party developers to access and leverage the capabilities of the platform core architecture to create new applications that will offer advanced and useful functionalities (Bonina, Koskinen, Eaton, & Gawer, 2021; Ritala, 2024). The new features available not only broaden the range of options for users but also encourage innovation and collaboration among the development community. With the ability to integrate with existing systems and tools, this collaboration offers developers a flexible and scalable environment to build and deploy new applications on the platform architecture (Bianco *et al.*, 2014).

Research on digital platforms has been extensive, with a particular focus on their evolution, architecture and expansion of functionalities through boundary resources engagement (e.g. Bianco *et al.*, 2014; Mohagheghzadeh & Lindman, 2022; Mohagheghzadeh & Rudmark, 2017; Mohagheghzadeh & Svahn, 2016). Hence, most research focuses on how digital platform owners continue to leverage the transfer of design capabilities to third-party application developers to boost innovation and extend the functionalities of the digital platform. Thus, the activities of third-party developers who interact with digital platform boundary resources have facilitated lots of new applications required for digital platform business to be developed, which encourages transactions between different application users, application developers and other market participants (Heshmatisafa & Seppänen, 2023; Rubleske, 2020). However, starting a new business in a digital context requires a deeper conceptual understanding of the underlying processes, the interplay of different causal factors and the complexities arising from technological advancements and the prevailing environmental contextual conditions.

Unfortunately, most third-party application developers who seek to develop new applications representing products for new business development lack this knowledge. Consequently, the number of digital businesses that scale through the ambiguities, disorientations and uncertainties experienced during development and commercialization is few, as many are forced to shut down (Giardino, Bajwa, Wang, & Abrahamsson, 2015; Howarth, 2023; Page & Holmstrom, 2023; Ruby, 2023). This situation has remained a concern to both scholars and practitioners across the globe, most especially in the global south (e.g. Nigeria) where many environmental complexities and resource constraints are overwhelming. Hence the persistent call for in-depth study to help grasp a theoretical

understanding of the development processes of a viable digital entrepreneurship. Corroborating this view, a scholar noted that “[l]imited effort has been made on theorizing the role of specific aspects of digital technologies [e.g. digital platform] in shaping entrepreneurial opportunities, decisions, actions, and outcomes” (Nambisan, 2016, p. 2). This view has been re-echoed by other scholars in the literature on the importance of developing concepts that theorize the behaviour of third-party application developers in digital entrepreneurship development processes (Nambisan, 2016; Shen, Lindsay, & Xu, 2018; Taylor-Wesselink & Teulon, 2021; von Briel, Davidsson, & Recker, 2018; von Briel *et al.*, 2021).

Insufficient knowledge about how third-party developers should navigate through market resistance, competition and the complexities of digital entrepreneurship development is a problem for both scholars and practitioners (Anim-Yeboah, Boateng, Awuni Kolog, Owusu, & Bedi, 2020). This highlights the inadequacy of existing literature on digital entrepreneurship, as past studies pay little to no attention to how digital platform boundary resources affect the behaviour of third-party application developers who drive entrepreneurship development through their actions and practices (Anim-Yeboah *et al.*, 2020; Hein *et al.*, 2020; Rubleske, 2020). There exist a notable gap in the literature that requires investigation to comprehend how third-party application developers move from being complementors of digital platform functionality extensions to becoming digital entrepreneurs who embark on entrepreneurship endeavours. This is particularly important as digital platform boundary resources continue to evolve and encourage entrepreneurial activities that define the process of digital entrepreneurship development (Anim-Yeboah *et al.*, 2020; de Reuver *et al.*, 2017; von Briel, Recker, & Davidsson, 2018; von Briel *et al.*, 2021).

Digital entrepreneurship development is a multifaceted process, embroiled in ambiguity. It involves identifying opportunities that digital platforms offer, developing and evaluating innovative ideas and creating sustainable business models that can capture new economic value. It requires a combination of skills, resources and strategic planning to effectively navigate the challenges of the modern digital landscape to succeed in the marketplace. In digital entrepreneurship, individuals and organizations can leverage digital technology to create new products/services, reach new customers and improve operational efficiency, leading to increased profitability and growth. Thus, digital platform boundary resources provide the tools that influence the entrepreneurial behaviour of third-party application developers to promote digital entrepreneurship gestation. Digital entrepreneurship gestation is a process of new business development, involving a disoriented transitional activity from an act of ideation of a new digital business, development and experimentation of product/service prototype to the commercialization of newly developed products/services.

“In practice, gestation is not an easy process, but a difficult period in the life of a new business; it is full of uncertainties, and concerns, continuously faced with alarming resistance to stakes, and characterized by a phase where risky decisions are continuously made” (Ajah, 2023, p. 1). Hence, having a good knowledge of the required business strategies and competitive market penetration will offer third-party developers the opportunity to develop a viable digital business in the market. Therefore, a new study should be conducted to investigate third-party developers’ experiences as they interact with digital platform boundary resources to navigate through digital entrepreneurship development. The study will investigate the disorientations and ambiguities in the process as many third-party developers embarking on digital entrepreneurship are often unaware of what lies ahead and cannot accurately predict the outcome, leading to a constant state of unease, which could lead to failure. Hence, this study investigates the entrepreneurship behaviour of third-party developers, influenced by platform boundary resources, as they transition through the disoriented and ambiguous processes of digital entrepreneurship development (Garrigos-Simon, Alizadeh Moghadam, Abdi,

Pourmirali, & Abdi, 2021; Hanesch & Schallmo, 2022; Zaheer, Breyer, & Dumay, 2019). Proceeding, the researcher poses the following research question:

RQ1. How do digital platform boundary resources influence the behaviour of third-party application developers in the process of digital entrepreneurship development?

To address this research question, the researcher conducted a detailed empirical analysis of data collected from an empirical situation, to discover how digital platform boundary resources influence the entrepreneurial behaviour and experiences of third-party application developers. The researcher collected extensive data by adopting an expert interview qualitative method, where an expert interview was conducted among digital start-up founders across different sectors, who were selected through the snowballing technique, to gather relevant and appropriate data that will inform the study. To better elaborate on the findings, the study further adopted the theory of liminality to provide a detailed explanation of the phenomenon being investigated. Hence, the outcome of this study will extend the literature through the theorization of our findings. In practice, the study will enlighten third-party developers and practitioners on how to navigate the processes to deliver the right applications that will guarantee economic gain. The remainder of this paper is structured as follows. Section 2 is the literature review, Section 3 is the theoretical background for the study, Section 4 is the adopted methodology, Section 5 is the findings, Section 6 is the discussion of the findings, followed by Section 7 which contains the conclusion, implication, limitation and further study.

2. Literature review

With digital technology as the engine for new business development (Zhou, Dong, Feng, & Wu, 2024), digital platforms have greatly impacted entrepreneurship, especially in the realm of developing digital businesses and creating innovative products/services (Esteban, Ács, & Szerb 2024; Jiang, Jingxuan, & Gai, 2023; Lehmann & Recker, 2021; Täuscher & Laudien, 2018). This is evident in the market as “[d]igitalization has created new value and business opportunities for entrepreneur-driven firms” (Ojala, Fraccastoro, & Gabrielsson, 2023, p. 858). It has made the process of creating new products/services much simpler by breaking down industry boundaries and facilitating collaboration and partnership among individuals and organizations (Agustian, Mubarok, Zen, Wiwin, & Malik, 2023; Ajah, 2024; Suuronen, Ukko, Saunila, Rantala, & Rantanen, 2024). This new wave in business creates a new form of economy known as the digital economy and it has boosted the economies of different nations globally (Melinda, Anjani, & Ridwan, 2023). Thus, “[t]oday’s digital technologies have a significant impact on how new business ventures are imagined and created” (Fernandes, Ferreira, Veiga, Kraus, & Dabić, 2022, p. 5). Consequently, this has given rise to the emergence of socio-technical ecologies that go beyond boundaries, fostering new business innovation, development and growth in the digital landscape (Ajah, 2023; Lyytinen, Yoo, & Boland, 2016; Suuronen *et al.*, 2024). Also, digital platforms have contributed to the entrepreneurship process by providing a platform that drives the co-creation of products/services that are sustainable and can generate economic value for the parties involved (Böttcher, Empelmann, Weking, Hein, & Krcmar, 2023; Giang, Hai, Quyen, & Hoang, 2024; Hein *et al.*, 2020; Zeng, Yang, & Lee, 2023).

This suggests that digital platforms act as a “force of creative construction” (Acs, Song, Szerb, Audretsch, & Komlósi, 2021, p. 1629) and a context for digital entrepreneurship development. For instance, digital platforms like “Uber has transformed the taxi business without owning taxis, Airbnb has transformed hospitality without owning hotels, and Kickstarter has channelled funding to creative projects that would have otherwise struggled to get the attention of traditional investors” (Haki, Blaschke, Aier, Winter, & Tilson, 2024,

p. 181). However, not much has been investigated on how it impacts and disrupts traditional entrepreneurship processes. In the current digital landscape, digital platform offers boundary resources that leverage advanced digital technologies and interconnectedness to effectively harness and manage digitized resources that are not limited to their operations. The digital platform enables connections between various actors especially third-party developers to generate value through cross-side network effects, which in turn lead to mutually beneficial outcomes for all stakeholders involved (Capello, Lenzi, & Panzera, 2022; Cuvero1 *et al.*, 2023; Gawer, 2021; Suuronen *et al.*, 2024). Digital platforms drive the digital business ecosystem of multiple actors, constituted by platform owners, third-party application developers and application users (Bianco *et al.*, 2014; Eaton, Elaluf-Calderwood, Sørensen, & Yoo, 2015; Ghazawneh & Henfridsson, 2012). These three groups of actors are critical for the evolution and advancement of digital platforms, more so, promoting entrepreneurship development processes. In particular, they enable varied viable functionalities to continuously extend the existing functions of the digital platform to meet the pressing needs of users (Ghazawneh & Henfridsson, 2012; Hein *et al.*, 2020; Lukita, Chakim, Supriati, Santoso, & Kamil, 2023).

In practice, digital platforms offer an “extensible codebase of a software-based system that provides core functionality shared by the modules that interoperate with it and the interfaces through which they interoperate” (Tiwana *et al.*, 2010, p. 676). Such extension in a platform functionality is driven by platform boundary resources, which enable, facilitate and control an arms-length relationship between platform owners and third-party developers (Bianco *et al.*, 2014; Karhu, Gustafsson, Eaton, Henfridsson, & Sørensen, 2020; Karhu, Gustafsson, & Lyytinen, 2020; Rubleske, 2020). The utilization of digital platform boundary resources enables external application developers to cascade related actions from different developers, thereby fostering a generative process within the digital ecosystem for digital business development and benefits (Kovacevic-Opacic & Marjanovic, 2024). This results in a flourishing digital ecosystem while also empowering platform owners to govern the actions of third-party developers on the platform (Eaton *et al.*, 2015; Ens, Hukal, & Jensen, 2023; Ghazawneh & Henfridsson, 2012). A good example of digital platform boundary resources that have attracted many third-party application developers, who seek to pursue digital entrepreneurship include application programming interfaces (APIs), SDKs, integrated development environment (IDE), libraries, App. stores and platform governance. These boundary resources are offered by digital platforms like “Apple’s iOS and Google’s Android [that] have each managed to attract over two million apps that are built on top of the platforms” (Karhu, Gustafsson, Eaton *et al.*, 2020; Karhu, Gustafsson *et al.*, 2020, p. 105).

In literature, some groups of scholars studied digital platforms that leverage the expertise of third-party developers through platform boundary resources to drive innovation and development of new applications that extend the functionalities of the digital platform (Bianco *et al.*, 2014; Eaton *et al.*, 2015; Kovacevic-Opacic & Marjanovic, 2024; Mohagheghzadeh & Rudmark, 2017). This study shows that well-designed platform boundary resources influence platform owners to shift platform design responsibility to third-party developers, to enable the platform to access the right capabilities that are not available among the platform’s original designers (Mohagheghzadeh & Lindman, 2022; Mohagheghzadeh & Svahn, 2016; Tiwana *et al.*, 2010). This shift in responsibility has created numerous entrepreneurship opportunities for third-party application developers and nascent entrepreneurs who are interested in pursuing digital business to create and capture economic value. Consequently, digital platforms’ intention to evolve in their functionalities has unknowingly promoted digital businesses among third-party application developers within the ecosystem.

For instance, Petrik, Model, Drebinger, and Herzwurm (2021) explored how third-party developers access platform boundary resources to develop complement applications that can satisfy the needs of application users. The study shows that complementary orientation in

digital platforms influences the satisfaction of third-party developers who are seeking to develop complements to meet the needs of application users. In another study, Skog, Wimelius, and Sandberg (2018) investigated how digital platforms promoted entrepreneurship by investigating how Spotify leveraged the potential of platform boundary resources to emerge as a global business in music streaming. The result of the study shows that Spotify focuses on the scaling of platform functionalities, which enables the development of complements that satisfy the yearning needs of the customers that are in the ecosystem. Thus, the interesting perspective in literature toward the impact of digital platform boundary resources in digital entrepreneurship is the promotion of innovation and creativity through the co-creation of viable market offerings (Karhu, Gustafsson, & Lyttinen, 2018). However, another set of studies focus on platform governance (e.g. Farshchian & Thomassen, 2019; Ghazawneh & Henfridsson, 2012; Huber, Kude, & Dibbern, 2017; Karhu, Gustafsson, Eaton *et al.*, 2020; Karhu, Gustafsson *et al.*, 2020; Karhu *et al.*, 2018). These studies aim to examine how platform owners exercise control over third-party application developers who utilize the platform boundary resources. The platform owners regulate the platform resources by establishing rules and policies that promote and enforce specific behaviours among third-party developers involved in developing complementary products (Farshchian & Thomassen, 2019).

For instance, Ghazawneh and Henfridsson (2010) investigated how platform boundary resources govern the activities of third-party application developers in the Apple iPhone developers program. The study developed a framework that describes how platform boundary resources (APIs, SDKs, IDE, libraries and open-source licenses) can be used to govern the activities of third-party developers. This is especially important as they promote distributed coordination and control of the platform resources (Ens *et al.*, 2023; Ghazawneh & Henfridsson, 2010; Vargo, Fehrer, Wieland, & Nariswari, 2024). Karhu *et al.* (2018) emphasize that some digital platform owners utilize open-source licenses to encourage collaboration and innovation, hence, allowing third-party developers to access and modify the platform's core (Heshmatisafa & Seppänen, 2023; Karhu *et al.*, 2018). However, some scholars cautioned against being too open to prevent third-party developers from strategically exploiting core resources of the digital platform through platform forking (Karhu *et al.*, 2018). Karhu *et al.* (2018) describe platform forking as a process where "a forker, bypasses the host's controlling boundary resources and exploits the platform's shared resources, core and complements, to create a competing platform business" (Karhu *et al.*, 2018, p. 479). A good example of platform forking is the "case of Google, which established the Android Open Source Project (AOSP) to attract more device manufacturers to the Android platform. However, Amazon exploited the openness of Android to build its competing Android-like platform, Amazon Fire . . . Amazon monetizes Amazon Fire content and apps in a way that provides no revenue or benefit to Google" (Karhu, Gustafsson, Eaton *et al.*, 2020; Karhu, Gustafsson *et al.*, 2020, p. 106).

Therefore, Karhu *et al.* (2018) suggest that platform owners must be cautious of the level of open policy they offer to third-party developers, by enforcing some piece of regulations, policies and APIs, to ensure forking and multi-homing activities are minimized and possibly mitigated. This suggestion was further emphasized by Karhu, Gustafsson, Eaton *et al.* (2020) and Karhu, Gustafsson *et al.* (2020) in their recent study where they aver that platform owners must engage a strategy that "deploy four tactics – leverage, control, exploit, and defence to make the necessary trade-offs between variety and unity, and open and closed [as the platform evolves]" (Karhu, Gustafsson, Eaton *et al.*, 2020; Karhu, Gustafsson *et al.*, 2020, p. 105). Hence, owners of digital platforms need to retain certain command over the third-party developers they allow into their systems to maintain coherence and consistency. This includes monitoring the level of freedom granted to these developers to ensure they function within pre-established limits. Therefore, the existing literature discusses the architecture and evolution of digital platforms, as well as ways to secure them from third-party interference.

However, there is a paucity of research on how platform boundary resources influence the behaviour of third-party developers who pursue digital entrepreneurship. It is crucial to examine this aspect to understand the dynamics of developing digital entrepreneurship and the impact of platform boundary resources on entrepreneurs and third-party developers. By doing so, we can gain a better understanding of how digital platform boundary resources drive individuals' interest in creating complementary applications that are pivotal to engaging in entrepreneurial processes for economic value capturing.

3. Theoretical background

3.1 Theory of liminality

The concept of liminality is an ambivalent experience in a transitional process across boundaries or borders of margins and threshold (Darveau & Cheikh-Ammar, 2021; Rose, Leisyte, Haertel, & Terkowsky, 2018). It is experienced by an individual or a group of people who set out a separation to lose their identity of who they are, to engage in an adventure that will enable them to emerge with a new identity in a new reality that is guided by new norm and orientations (Gibbons, Ross, & Bevans, 2014; Leeming, 2014). The experience of the individual or group of people involved is referred to as the liminal (Darveau & Cheikh-Ammar, 2021). "The concept of liminality refers to the transitional phases in a human's life; phases that involve ambiguity and the dissolution of order that open a fluid or malleable space in which new ideas, practices and identities may emerge and develop" (Liedgren, Desmet, & Gaggioli, 2023, p. 1).

This suggests that liminality is characterized by disorientation, complexity and uncertainties, where an individual/group has separated themselves from their initial status but has not yet attained a prospective status, as they are still conducting activities in transition to fulfilling all necessary rites of passage (Gibbons *et al.*, 2014; Liedgren *et al.*, 2023; Pentikäinen, 1979). The liminality concept originated from the field of anthropology (Darveau & Cheikh-Ammar, 2021), developed by Arnold van Gennep in his study of rites of passage (Malksoo, 2012; Mueller-Greene, 2022; Söderlund & Borg, 2017). He identified three phases of activities that individuals/groups undergo when participating in the rite of passage, and he described the phases as "the preliminal (rites of separation from the previous world), the liminal (rites of the threshold stage), and finally the postliminal (rites of incorporation into the new world)" (Mueller-Greene, 2022, p. 268).

The preliminal phase is the separation or isolation phase of the individual or group of people from their known identity or form, it is a process of detachment from who they used to be, as they now pursue a new reality without any known identity (Ratiani, 2012; Söderlund & Borg, 2017). The liminal phase is the transition phase where the individual/group cannot be identified with any concrete identity or form, a space where structure and norm are suspended as activities become complex and disoriented (Stenner & De Luca Picone, 2023; Stephenson, 2020). This phase is the actual focus of the theory of liminality (Willson, 2019). The third phase is the incorporation phase, which corresponds to the phase where reaggregation of form is carried out to give a new stable identity or form to the individual/group of people involved, with new obligations and norms that are different from the liminal phase experiences (Söderlund & Borg, 2017). However, the concept was further improved in the work of anthropologist Victor Turner in the 1960s to expand the views for better understanding (Alkhalef & Sasaki, 2021; Beech, 2010; Söderlund & Borg, 2017; Wels, van der Waal, Spiegel, & Kamsteeg, 2015). During the transitional phase, the experiences may seem ambiguous and disorienting. Because it can be difficult to adjust to this unfamiliar space, where norms are absent and expectations are difficult to meet. Yet, it is important to remember that this is a real and tangible process individuals/groups are going through, and they have the ability to navigate through it (Rose *et al.*, 2018).

Therefore, the theory of liminality helps to explain the reconstruction process of the identity of an individual or a group of people pursuing a new identity or status. Alkhaled and Sasaki (2021, p. 1585) "argue that the concept of liminality is useful for understanding the uncertainties experienced by the forcibly displaced who are forced into the liminal space at the boundary of two dominant spaces, which is not fully part of either". A good example is a third-party developer who abandoned their original task of extending the functionality through the extension of a digital platform extendable core, to now seeking to become a digital entrepreneur who pursues entrepreneurship by developing user-centred applications as products/services that can meet the needs of a target market. Third-party developers undergo complex, ambiguous and uncertain gestation processes to develop new and innovative digital businesses for revenue generation (Rose *et al.*, 2018; Rubleske, 2020). In the current investigation, digital platform boundary resources (API, SDK, IDE, flexible control governance) and other environmental structures triggered the liminal space activities that permeate the gestation process of a new digital business. They influence the behaviour and desire of third-party developers to pursue the development of a new application that provides functionalities that satisfy the specific needs of an application user.

Most importantly, third-party developers operating in the liminal space, do this by suspending what they know, suspending disbelief and embracing ambiguity and uncertainty, to enable them to orchestrate appropriate ways of acting to change the narrative through innovative engagement (Liedgren *et al.*, 2023). This suggests that digital entrepreneurship gestation presents a situational process that is characterized by a region of ambiguity, moments of creativity, experiences of disruption, uncertainties and hierarchy reversal as actions and practices are conducted to earn the necessary rites of passage for the emergence of a new and viable digital business (Malksoo, 2012; Willson, 2019). In the phenomenon investigated, third-party developers usually experience profound vulnerability, disorientation and confusion as gestation proceeds, which keeps them in a constant change of views and iteration of actions that are driven by the confusing decisions that arise from the experiences of unanticipated contingencies and feedbacks from target application users and market forces, as prototype experimentation is conducted. However, the moment is also a time for creativity and innovation for third-party developers who strive for a viable and acceptable new application. Therefore, the liminal space in a digital entrepreneurship development process is the region between new business idea creation/identification and the emergence of a new product/service in a target market for its first sale.

In literature, the theory of liminality is a theory used to explicate meaningful transformational events and experiences of people about an investigated phenomenon of interest (Darveau & Cheikh-Ammar, 2021). It "has become a 'master concept' through which all that the term connotes—a position of marginality, critical subversion of rules and norms, transgression, generative creativity, parody and satire, fusion experiences—are unquestionably taken as inherently positive social-cultural goods" (Stephenson, 2020, p. 4). This is a theory that has been adopted in different studies to explain any phenomenon being investigated (Darveau & Cheikh-Ammar, 2021). Scholars adopt the theory to provide a transformational or transitional explanation of an entity transiting from one state to another. Examples include the career of academics (Willson, 2019), the development of a conceptual framework for the technology that delivers transcendence and deeper experiences (Liedgren *et al.*, 2023), the study of memory in Salman Rushdie's *Midnight Children* (Mueller-Greene, 2022), in identity reconstruction of people (Beech, 2010), and the understanding of family caregiving rite of passage (Gibbons *et al.*, 2014). Other studies include the experience of cancer survival (Blows, Bird, Seymour, & Cox, 2012), as a cultural change (Howard-Grenville, Golden-Biddle, Irwin, & Mao, 2011), in entrepreneurship education (Rose *et al.*, 2018), and in management and organizational studies (Söderlund & Borg, 2017). Therefore, liminality is a powerful lens that has been adopted to study entities and structural transformation to

understand rising resistances, dominations and unwavering disorientation of processual events characterizing a phenomenon of interest (Malksoo, 2012; Willson, 2019).

4. Methodology

The objective of this study is to examine how third-party developers engage with digital platform boundary resources to facilitate the pursuit of digital entrepreneurship development. Especially, to understand how third-party developers navigate through the rising resistance from the market forces, dominations of the competitors and unwavering disorientation of the processes involved in digital entrepreneurship development. Although the process of entrepreneurship development has been widely researched, this investigation aims to comprehend and theorize the influence of digital platform boundary resources. Especially, to understand the behaviour of third-party developers who are striving to create and capture value through developing new digital applications as a new business product/service for a target market. To conduct this investigation, the researcher adopted an expert interview qualitative research method, as the research design methodology for the study.

This study seeks to address the research question presented in the introduction section of this article by delving into investigating the behavioural patterns of third-party developers during the process of digital entrepreneurship gestation. Because the phenomenon the researcher investigated involves human behaviour, it is complex and contextually driven, and it is impacted by the sociocultural environment where such entrepreneurial activities are conducted (Fredriksen & Hadjerrouit, 2019). The expert interview qualitative research approach (Bogner & Menz, 2009; Döringer, 2021; Libakova & Sertakova, 2015) is a type of qualitative research methodology that guarantees “[an] empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context” (Yin, 2009, p. 18). This method of qualitative research “aims at exploring or collecting data about a specific field of interest” (Döringer, 2021, p. 265), by focusing on the experts who are deeply immersed in the development and operation of the phenomenon being investigated. To gain valuable insights into the process of digital entrepreneurship development, the researcher will be seeking the knowledge and experiences of third-party application developers who are considered experts in this field (Bogner & Menz, 2009). To understand the entrepreneurial behaviour of third-party developers, the researcher was enlightened by the interpretive paradigm, which is commonly adopted in qualitative research (e.g. Bogner & Menz, 2009; Boudreau & Robey, 2005; Döringer, 2021; Kim, Kim, & Lee, 2009; Levina & Vaast, 2008; Moe, Dingsøyr, & Dybå, 2010). This philosophical paradigm offers valuable insights into the behaviour of third-party developers as they engage in activities that promote ideation and product/service development in the digital entrepreneurship processes.

4.1 Context of the investigation

This study focuses on Nigeria’s digital start-up ecosystem because it is a context in the global south that has been understudied in literature, perhaps, there is a need to understand how third-party developers navigate the digital divide/gaps experienced in Nigeria due to inadequate digital infrastructure. Nigeria possesses a digital start-up ecosystem, in its early stage, which constitutes a community of interactive actors involving third-party developers, digital entrepreneurs, mentors, investors, support organizations and government institutions (Motoyama & Knowlton, 2017). It is on record that it has “produced three exits, which are over USD 100 million: namely Andela, Konga, and Jumia. For instance, the online marketplace Jumia, which was launched in Lagos in 2012, has 3 million customers, 3,000 employees, and operates in 23 countries. Jumia group became the continent’s first ‘unicorn’ with a 1 billion USD [plus] valuation in 2016” (OC&C, 2018, p. 10). However, the limited number of digital

technology skilled individuals, limited financing, unhealthy government policies and low levels of digital technology infrastructure awareness across the country continue to affect the performance of digital start-ups during commercialization. Corroborating this view, Abubakre, Faik, and Mkansi (2021, p. 4) "linked the success of [individual] digital enterprises to individuals' positive IT attitude, high personal innovativeness, and experience with IT" in a place like Yabacon Valley, Nigeria's own Silicon Valley (Lixi *et al.*, 2019). However, Nigeria's large population continue to breed an attractive market that is ranked among the top three countries in sub-Saharan Africa (Taura, Bolat, & Madichie, 2019). The other two countries include Kenya and South Africa, which all have recorded the highest investment in digital start-ups and possess a large start-up ecosystem in sub-Saharan Africa (David-West, Umukoro, & Onuoha, 2018; Taura *et al.*, 2019). A study presents a record showing that "Nigeria is the most popular investment destination on the continent. Between 2015 and 2022, 383 tech start-ups raised a combined US\$2,068,709,445 – a higher total than any other country" (Disrupt Africa, 2022, p. 14). This suggests that Nigeria's digital start-up ecosystem remains a strong market for digital venture investors, irrespective of the digital infrastructural deficiencies persistently experienced.

Nigeria's digital start-up ecosystem is an evolving ecosystem, with over 100 technology hubs (i.e. tech hubs) known as support organizations across Nigeria (David-West *et al.*, 2018; Lixi *et al.*, 2019; Taura *et al.*, 2019). However, a recent study in Nigeria emphasizes that the number of tech hubs and co-working spaces has risen to about 300 across the country, with Lagos having the largest number, followed by Abuja, while few numbers are scattered across other parts of the country (Disrupt Africa, 2022). For instance "Co-Creation Hub (CcHub), Vatebra Tech Hub, Wennovation Hub, 360 Creative Hub and Leadspace (all in Lagos); Aiivon Innovation Hub, Ventures Park, and Work AND Connect (all in Abuja); and LPI Innovation Hub (Ibadan)" (Disrupt Africa, 2022, p. 44). These statistics present an overview of the number of technology hubs in Nigeria. The technology hubs provide networking resources and third-party developers' collaboration, accommodate and incubate third-party developers who seek to pursue entrepreneurship, to nurture their ideas towards metamorphosising into digital start-ups (Lixi *et al.*, 2019; OC&C, 2018). "World Bank defines tech hubs as spaces mainly focused on developing a digital entrepreneurship ecosystem, or a network of engagement between digital entrepreneurs, designers and potential investors" (Frontier Economics, 2018, p. 7). Tech hubs are promoters of digital entrepreneurship, provide accelerator services, incubator services, mentoring assistance, workspaces, digital infrastructures, digital entrepreneurs collaboration and provide access to finance by connecting digital tech start-up founders with partners like angel/seed investors and venture capitalists during gestation (David-West *et al.*, 2018; Quinones, Heeks, & Nicholson, 2021; Roshan Kokabha, Hekkala, & Tuunainen, 2018; Taura *et al.*, 2019). Most of the tech hubs are located in Lagos (Disrupt Africa, 2022), the commercial city of Nigeria, because most third-party application developers and digital start-ups are situated in Lagos Nigeria.

4.2 Negotiating entry to technology hubs in Nigeria's digital start-up ecosystem

Gaining access to suitable digital start-up founders for this investigation is critical, it requires formal approval from the technology hub (tech hub) management (Walsham, 1995, 2006). The researcher sent an official email to different tech hubs, informing them of his intention to carry out a research study on their premises, detailing the content of the research, and the expected benefit of the research outcome. A response from the tech hubs requested further details regarding the expected research, which include the reason for the research, the expected role of the researcher, the tech hub level of involvement in the research to be conducted, the confidentiality of digital start-up founders/co-founders to be selected, kind of information to be provided and the duration of the research study. Having responded to the

above request from the tech hub management, an approval email was received, granting the researcher access to the tech hub's premises. Following the approval, an office space was given to the researcher and the researcher was further introduced to the tech hub management team. This process was carried out in different tech hubs; however, due to funding needed to visit many tech hubs, only three tech hubs were selected as empirical situations for investigation.

4.3 Data collection

When conducting scientific research studies that involve human activities, the primary source of data collection is the participants who are purposefully selected to take part in the investigation (Layder, 1998; Naderifar, Goli, & Ghaljaie, 2017). In this study, interview participants are the primary source of data collection and they are chosen based on specific criteria that are relevant to the research question being investigated. Only founders of digital start-ups who were third-party developers and eventually transitioned to digital entrepreneurs were considered for the interview. The participants are the selected portion representing the whole population that is been investigated (e.g. Marton, 2013; Naderifar *et al.*, 2017; Onwuegbuzie & Collins, 2007; Onwuegbuzie & Leech, 2007). Therefore, a sampling technique known as purposeful sampling/snowball technique or even "gradually determined sampling structures" (Marton, 2013, p. 20) was adopted by the researcher to conduct this qualitative study (Naderifar *et al.*, 2017). This method of data collection offers the right selection of appropriate/relevant participants who possess the right knowledge and experience about the investigated phenomenon within our investigative context of interest (Flyvbjerg, 2006; Onwuegbuzie & Collins, 2007). A snowball method of sampling is described as a process where "[t]he researcher first identifies a group of people, and after gathering data, he/she asks them to recommend similar cases for the study" (Naderifar *et al.*, 2017, p. 2).

Thus, the researcher recruited participants who demonstrate maximum variation in experiences by involving different third-party application developers who are pursuing digital entrepreneurship development and are situated in technology hubs (i.e. tech hubs). These participants cut across different sectors, to help achieve heterogeneity in the data collected. As such, earlier selected participants who were recommended by the tech hub management help to introduce the researcher to other participants with relevant knowledge and experience within the investigative context to ensure the right sampling with target characteristics is accessed (Naderifar *et al.*, 2017). As part of the interview process, a group of 10 third-party application developers were carefully chosen through snowballing to participate in the study. These individuals are the founders and co-founders of a range of digital start-ups that were investigated. The selected number of participants was recorded to be 10 because the researcher experienced saturation when the tenth respondent was interviewed. This point of saturation is a point at which the inclusion of additional data from new participants does not yield any further relevant information (Braun & Clarke, 2019; Francis *et al.*, 2010; Fusch & Ness, 2015; Lowe, Norris, Farris, & Babbage, 2018). In this study, the researcher interviewed 10 participants; each of the interviews took an average of 46 minutes. The questions asked during the interview were open-ended. The nature of the questions encouraged the interviewees to express in detail their experiences, views and challenges encountered. They gave an account of their engagement with digital platform boundary resources in the development process, as a series of actions were taken and tasks were executed continuously (Walsham, 1995). Some of the questions asked include:

What motivates you to engage in the process of creating a digital start-up? What role/impact did the digital platform play in the development process? How did you handle the complexities and uncertainties that ravage the development process? How were you able to develop an acceptable digital product/service that represented your digital start-up in the market? How did you acquire the

necessary resources needed for the development of the application that represented your product/services? What are the challenges experienced in the process of developing digital products/services? How did you resolve these challenges to enhance the development process? How has digital technology impacted the decision to engage in digital entrepreneurship?

Hence, at the point of saturation, sampling more participants to further stretch data collection makes no difference to the already collected but could be counterproductive to the themes/categories of the descriptive evidence already developed (Francis *et al.*, 2010; Fusch & Ness, 2015). However, “[f]ailure to reach data saturation has an impact on the quality of the research conducted and hampers content validity” (Fusch & Ness, 2015, p. 1408). Therefore, the researcher ensured that while collecting data, the data collection exercise reached a point where no new data was discovered from the next participant interviewed. Table 1 depicts the participants interviewed in the investigation. However, the names of the third-party application developer and their digital business name were replaced with letters for participants’ privacy.

4.4 Data analysis

The study aimed to gain insights from different perspectives offered by third-party developers who are interested in pursuing digital entrepreneurship. The researcher focuses specifically on actions, practices and experiences of the third-party developers with digital platform boundary resources, and their interactions with other application developers. Hence, voice recording and detailed notes and memos were taken throughout the interview process, which requires a rigorous and thorough analysis of data, having triangulated the written and voice data collected. To commence the data analysis, the researcher first transcribed the collected interview audio data into English and then made sure to get it validated by the interview participants to ensure that there were no errors or misunderstandings. This

Respondent details	Third-party digital applications	Primary role of respondent	Number of years	Number of meetings for interview & clarification	Time used during interview
B1	Gaming Application	Founder	3	2 meeting	48min & 25min
B2	Aggrotech Application	Founder	4	2 meeting	43min & 27min
B3	E-commerce Application	Founder	4	1 meeting	55min
B4	E-Health Application	Founder	3	2 meetings	35min & 40min
B5	Digital Media Application	Co-Founder	4	1 meeting	40min
B6	Fintech Application	Founder	4	1 meeting	58min
B7	Advertising Application	Founder	3	2 meetings	43min & 33min
B8	Prop-Tech Application	Co-founder	2	2 meetings	38min & 20min
B9	E-Health Application	Co-founder	3	1 meeting	50min
B10	Fintech Application	Founder	4	2 meetings	46min & 30min

Table 1.
Sample respondents of third-party application developers in the empirical situation

Source(s): Table 1 developed from Ajah’s fieldwork

approach enables the researcher to completely understand the data collected. Then, the transcribed data is triangulated with the notes and memos that were taken during the interview.

To analyse the data collected from the empirical situation, the researcher employed a rigorous methodology, which involved a series of structured coding procedures (Charmaz & Belgrave, 2018; Corbin & Strauss, 1990; Glaser & Strauss, 1967). These structured procedures consisted of open coding, which allowed for the initial exploration and identification of patterns in the data, thereby creating labels representing different patterns identified in the data collected. Axial coding was then used to establish the relationships between these patterns, while selective coding helped to refine the analysis by focusing on the most significant concepts and themes representing the patterns (Corbin & Strauss, 1990; Glaser & Strauss, 1967). Throughout the analysis process, the researcher made sure to constantly switch back and forth between the data and the emerging propositions, to ensure that the analysis was firmly grounded in the evidence that was collected. During the analysis, to achieve abstraction and generalization (Klein & Myers, 1999), the researcher skilfully highlighted similar descriptions and meticulously coded the descriptions using the NVivo analytic tool to identify clear explanations for the various codes that were used. This is illustrated in Figure 1.

To begin with the coding process, the researcher openly coded the interviews, identifying 87 codes that represented various instances and practices of the third-party developers' engagement with digital platform boundary resources. These codes were then grouped into 23 subthemes for different digital entrepreneurship development activities through axial coding. The next step involved selective coding, which involved integrating different activities of the third-party developers that were presented as sub-themes to form the themes. This process continued until an overarching theme, the core theme that best represents the phenomenon under investigation was identified and depicted in Figure 1. Throughout this process, the researcher iterated between the identified codes to ensure that higher-level codes (i.e. themes) were identified and aligned with the underlying data. This thorough approach allowed the researcher to gain a comprehensive understanding of the third-party developers' engagement with digital platform boundary resources and their implications for digital entrepreneurship development activities. Overall, this analysis provides valuable insights into the behaviour of third-party developers in the digital entrepreneurship space, shedding light on their experiences and interactions with digital platform boundary resources.

5. Findings

This section provides a detailed result of the analysis of the data, revealing a fascinating pattern that sheds light on the role of digital platform boundary resources. The findings demonstrate how these resources influence, motivate and attract multiple third-party developers to help navigate the ambiguities, disorientations and uncertainties experienced during digital entrepreneurship development. With the help of these platform boundary resources, such as APIs, SDKs, IDEs, Libraries and Platform policies, third-party developers could navigate the complex and often disoriented landscape of digital entrepreneurship development, ultimately leading to successful outcomes. This is discussed following.

5.1 Access to resources and flexible control influencing new business opportunity and ideation

Our research findings suggest that digital platforms offer third-party application developers a high degree of autonomy, ensuring access to resources and enabling loosely coupled engagement with various tasks, ultimately resulting in the co-creation of new business

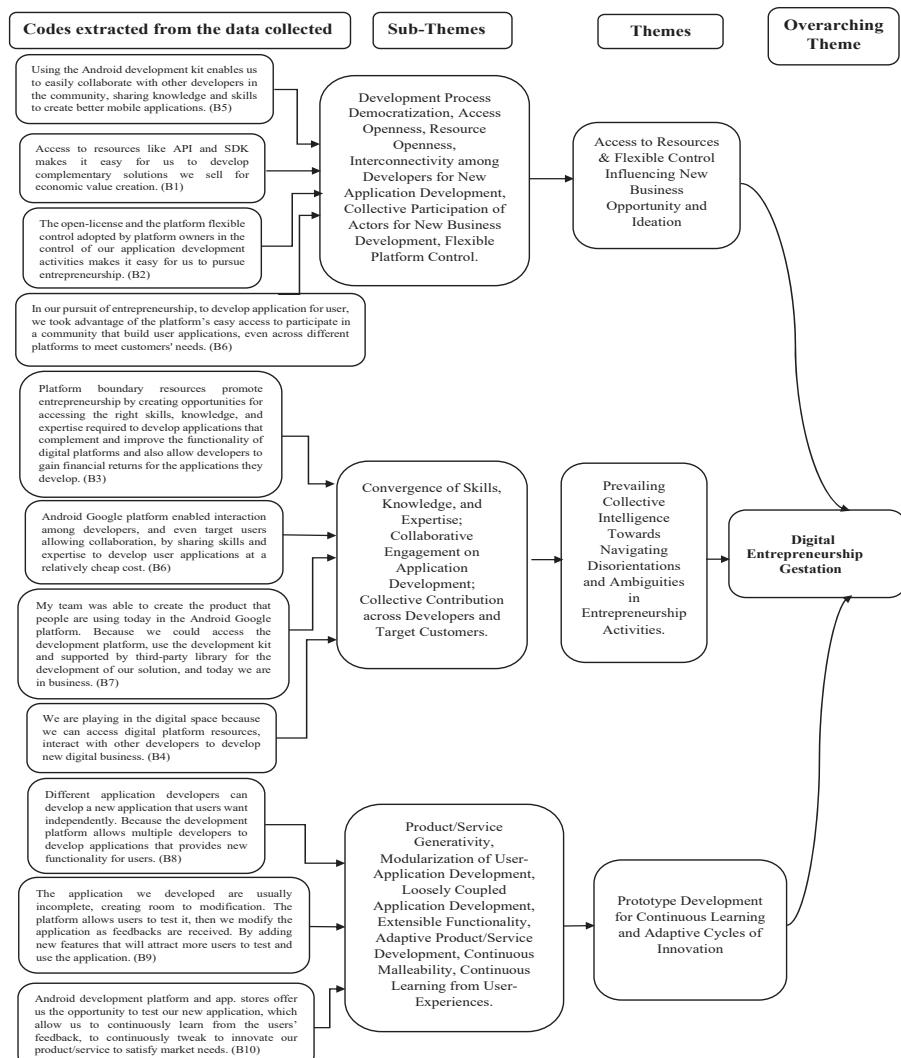


Figure 1.
Coding and theme development process

Source(s): Developed from Ajah's field work

products and services. This autonomy motivates third-party developers to pursue new business ideas and entrepreneurial activities by creating modular complements that meet the immediate needs of a specific market. The emergence of digital platforms and open access to its boundary resources has transformed traditional entrepreneurship from an individual-based approach to a group-based model. It has created opportunities to mitigate various forms of challenges encountered during new business development. Digital platforms changed the dynamics of entrepreneurship by altering the behaviour of entrepreneurs from thinking individually to having a collective imagination of different actors who are in collaboration. This technological infusion has revolutionized the way entrepreneurs develop

and conduct new business activities, as digital platforms offer open access and provide loose or flexible control among multiple actors, such as third-party application developers during their engagement.

The digital platform creates a complex web of interactions among different actors and can be challenging to navigate. As a result, third-party developers have a high degree of autonomy in their activities but often face ambiguity in their decision-making processes. They are required to consider multiple factors and perspectives during the process. Also, technological advancements introduce new forms of uncertainties, which keeps third-party developers continuously seeking collaborative support to resolve such uncertainties. Third-party developers continuously interact with the platform boundary resources, as user demands keep changing, which makes them develop applications with functional diversification to ensure that products and services developed meet the requirements to conduct new digital businesses.

Despite these challenges, digital platforms offer significant opportunities for third-party developers to operate as entrepreneurs and to expand their reach and access to new markets, making it an essential tool for success in today's business landscape. This unique feature encourages the development of new business ideas and the co-creation of products/services that can foster success for digital entrepreneurs. The platform owners guarantee flexible control among third-party developers as a key feature and are predominantly practised among the founding team in our investigated context. This control pattern empowers every team member to make independent decisions that contribute to the effective development of digital business applications (software products). Our findings suggest that practising flexibility in the control and coordination of the platform activities enhances internal complexity among third-party developers and platform owners and plays a crucial role in influencing the contribution of each participating actor as new business ideas are developed and transformed into viable products/services. By embracing this approach, third-party developers imbibe new behaviour that makes them transform into digital entrepreneurs who leverage the potential of the platform to foster collaborative, innovative and successful new digital business development. Participants B4 and B10 noted

Digital platforms are very important; it has offered big benefits to developers of applications. For instance, a digital platform used for application development is easily accessible to us, and it allows us to have the opportunity to interact with other actors who support the development of new business ideas.

Today, digital platform boundary resources have allowed us to tap into a vast resource used for application development, and has made it easy for us to develop our products.

During the interview, the participant discussed how digital platforms play an important role in providing support for entrepreneurial activities, particularly, in the face of challenges and uncertainties. The participant highlighted how such platforms offer boundary resources that help individual actors personalize the tasks of the application developed for the new digital business. This personalization enables entrepreneurs to make adaptive decisions as they encounter opportunities and challenges during task execution, especially in the presence of environmental uncertainty. The participant explained that the personalization of tasks allows entrepreneurs to tailor their approach to the specific needs of their business, adapting to changing circumstances and leveraging the unique strengths of their team. This approach also enables third-party developers to participate in decisions independently, promoting collective involvement, unity and a shared purpose without undermining the established goals of the digital platform. Overall, the participant emphasized how digital platforms can serve as powerful tools for entrepreneurs, providing them with the resources and flexibility they need to drive innovation, growth and success in their ventures.

5.2 Prevailing collective intelligence toward navigating disorientations and ambiguities in entrepreneurship activities

The feedback received from the participants interviewed has provided valuable insights into the crucial role played by digital platform boundary resources in promoting entrepreneurship. These resources have facilitated the connectivity of application developers from different geographical locations and as a result, allow them to collaborate and share their expertise and knowledge. This collaboration has led to the acquisition of essential human resources such as intelligence, skills and expertise, which are critical for the development of digital products and services. Hence, the digital platform served as a meeting point for these actors, providing a space for the aggregation and sharing of resources, ultimately leading to digital business development and the success of numerous digital ventures. As participant B7 noted

As a digital entrepreneur, you focus on platform boundary resources to enable you to have access to resources and the right developers, especially to gather critical skills and knowledge needed to carry out tasks that will drive successful product/service development.

In the digital age, entrepreneurs face significant challenges when trying to establish new businesses due to the unpredictability of the business environment, commonly referred to as environmental uncertainty. This challenge can be reduced by collective intelligence and expertise gathering from various stakeholders. This means involving different actors, including programmers, entrepreneurship experts and end-users during the development process. By leveraging the knowledge and expertise of these actors, entrepreneurs can gather critical insights and information to make informed decisions about their business development process. This is exceptionally important as feedback obtained from application users provides valuable information about the specific needs of the market and the performance of the new product or service in the market. Digital platforms play a crucial role in facilitating this process by providing third-party application developers with access to vital resources required for the development process. These resources include development tools, software libraries, APIs and app stores, enabling them to develop and experiment with the prototype of a product/service for gathering feedback from application users. By having access to these resources, third-party application developers can develop new digital businesses more efficiently and effectively, thus increasing their chances of success during market entry.

5.3 Prototype development for continuous learning and adaptive cycles of innovation

Digital platforms have revolutionized product and service development by enabling adaptive cycles of innovation through the creation of prototypes that undergo regular testing by application users. This is driven by digital technology's generative and specificity characteristics. Thus, it facilitates the modification of the prototypes based on user feedback to cater to the immediate specific needs of the market. The generative and malleable nature of digital platforms motivates third-party application developers to pursue entrepreneurship, even making them experiment with new ideas, as it allows them to learn from user feedback to determine the actual need for adjustments. As a result, digital applications remain intentionally incomplete in their development to cater to the ever-evolving user needs. Our research confirms that digital technology, particularly, digital platforms, relies on its generative and specificity characteristics to drive and guarantee the adaptability and malleability of new market offerings in any market of interest. This feature enables application developers to modify, streamline and expand value propositions from time to time, to meet the needs of a specific market. Therefore, digital entrepreneurs continuously push to modify prototypes based on user feedback, ensuring that their products meet market needs and remain relevant.

Developers have the opportunity to experiment with new applications in the market by utilizing app stores and other digital platforms, which allows them to gather direct information from users' reviews. This enables continuous experiential learning and further development of the application to easily meet user needs. As an aspiring entrepreneur, it is critical to remain agile and adaptable when it comes to your product/service offerings. Gathering feedback from users and analysing the competitive landscape can help you make informed decisions about how to improve your market position. According to the participants in this research, digital entrepreneurs consider the testing phase as a crucial aspect of the application development and digital entrepreneurship processes. Building a prototype allows for modifications and adjustments, which can help you navigate any challenges that arise. Utilizing app stores can also speed up the process of adapting your application to meet your users' needs. By consistently gathering feedback and analysing performance, you can identify opportunities for growth and address any potential roadblocks. This enables ongoing strategic decision-making that can help ensure the continued success of your new digital business. For instance, Participant B1 and B9 noted,

To understand the mind of our target customers towards our new application that is being developed, we usually engage App. Stores to test our MVP (i.e. minimum viable product).

With the introduction of our MVP in the app. store, we presented our application prototype in the market. Application users engage with the review system to convey the merits or defects of our new application, they sometimes ask for new features. Also, they report any bugs noticed and even ask for support when necessary. Then, we recorded lots of responses from the target users, which has helped our decision-making process.

Therefore, this research highlights how third-party developers are encouraged to pursue entrepreneurship development processes. It explains how important it is for developers to seek feedback from application users through ongoing experimentation of incomplete prototypes. This feedback provides valuable insights needed to refine prototypes and optimize the expected products/services for a first sale in a target market. Digital platform boundary resources serve as a crucial tool for third-party developers to stay informed about the latest information and enhance their knowledge and expertise to continuously innovate their offerings. Moreover, these resources equip them to proactively address external challenges and contingencies arising from stakeholders and market force dynamics.

6. Discussion

This study investigated the entrepreneurship behaviour of third-party developers influenced by digital platform boundary resources, as they transition through the disoriented and ambiguous processes of digital entrepreneurship development (Garrigos-Simon *et al.*, 2021; Hanesch & Schallmo, 2022; Zaheer *et al.*, 2019). Thus, the findings from the study support existing studies (e.g. Mainela & Puhakka, 2008; Naudé & Liebregts, 2020; Sanz-Velasco, 2006; Standing & Mattsson, 2016). However, the outcome of the study extends knowledge by identifying and providing a liminality perspective on how digital platform boundary resources influence the behaviour and experiences of third-party developers as they digitally engage in different entrepreneurial activities. They do it by simplifying tasks through the collaborative input of multiple actors. So, having identified an opportunity and further confirming its viability, collaborative third-party developers subsequently develop an innovative business model that represents a feasible hypothesized assumption of the value proposition to be developed and experimented. This is a supportive finding that corroborates some past studies (e.g. Standing & Mattsson, 2016).

The outcome of the present study indicates that the development of digital entrepreneurship is a transitional process, where third-party developers shift their focus

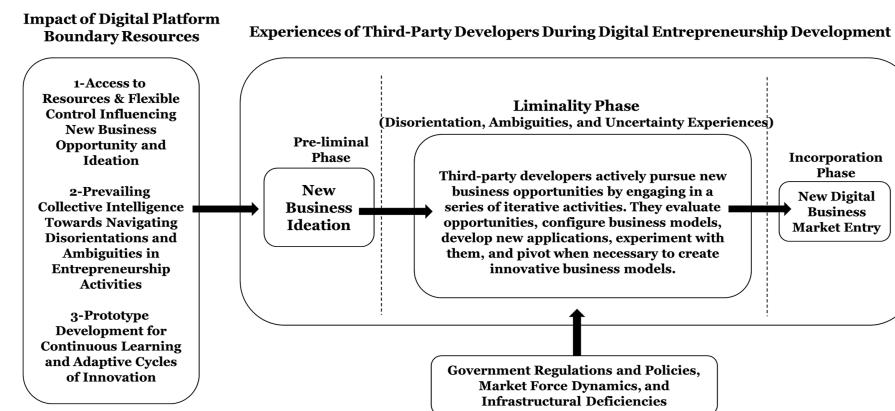
from developing complementary applications for digital platforms to becoming digital entrepreneurs who are interested in pursuing entrepreneurship. The researcher discovered that this shift is driven by the interaction between third-party application developers and digital platform boundary resources. The process involves third-party developers identifying market needs, creating a new business idea, evaluating it and eventually transforming it into a product or service that they can sell in a specific market. This process involves multiple actors and typically includes several recursive events, such as ideation, configuring a business model, acquiring resources, developing a product or service and entering the market for the first sale. Thereby corroborating earlier studies in entrepreneurship development (e.g. Chen, Cui, Hunt, & Li, 2020; Davidsson, 2015; Davidsson, Recker, & von Briel, 2020; Nzembayie & Buckley, 2022). However, the current study extended the literature by presenting a view that explicates how digital platform boundary resources influence the interest and behaviour of third-party developers who pursue entrepreneurship. The current study elaborates on the process by describing the development process as occurring in a liminal space, involving many complications characterized by ambiguous activities, hence, it is a period of crisis for third-party developers who became entrepreneurs (Daniel & Ellis-Chadwick, 2016).

Third-party application developers emphasize that the period involves making risky decisions, where structure and orderliness remain suspended, however, digital platform boundary resources enable third-party developers to navigate through these complexities. So, the process of digital entrepreneurship development exists in a liminal space, whose activities involve a complex and multifaceted process, characterized by creativity and innovative performances that are not bounded by any traditional bureaucratic structures or controls that cause the emergence of a new viable digital business. Therefore, application developers pursuing digital entrepreneurship are considered to be operating in a space of uncertainty and chaos. They engage with the perceived affordance of digital platform boundary resources to enable them to transition from being application developers who develop complementary applications for the extension of digital platform functionality to becoming digital entrepreneurs who develop and launch a new product or service through a digital platform for a target market for financial returns. The study reveals that throughout the development process, third-party developers find themselves in a transitional space where they must make important decisions regarding entrepreneurial actions and practices. These developers must overcome the challenges of this transitional phase by creating innovative and attractive products or services that meet the demands of the market and are financially viable (Stenner & De Luca Picone, 2023; Turner, Abrahams, & Harris, 1969).

The study emphasizes the challenges faced by third-party developers during the process of digital entrepreneurship. These challenges arise when new business ideas are being explored, refined and tested, which can create uncertainties and risks. This experience can be stressful for application developers as they try to validate their business model, target market and product/service offering. To navigate through these challenges successfully, they need to be agile, responsive and adaptive to changing market conditions and customer needs. Digital platform boundary resources make navigation easy by providing a platform where a talented and dedicated team can work collaboratively to achieve their goals. The study suggests that third-party application developers should explore the openness of digital platform boundary resources to attract and collaborate with multiple third-party developers to enable them to navigate the complexities, limitations and uncertainties experienced in conducting application development activities for entrepreneurship. Digital platform boundary resources enable third-party application developers pursuing entrepreneurship to navigate the challenges that arise when operating in an environment that lacks orderliness, structures and bureaucracies. By taking continuous action to resolve various complexities and

dynamics, such as government regulations and policies about the market offering (e.g. fintech solution), market forces and technological advancements. Digital platforms help to create a more constructive and supportive environment for developers pursuing entrepreneurship. This ultimately leads to a more efficient and productive digital entrepreneurship ecosystem for all stakeholders involved. In the liminal space of digital entrepreneurship development, the activities are spontaneous and challenging, yet, drive a rewarding experience, as they offer immense opportunities that can create a viable and innovative product/service that is attractive to the market (Wels *et al.*, 2015; Willson, 2019). Figure 2 illustrates the three phases of liminality experienced by third-party application developers who are pursuing digital entrepreneurship development. These three phases are the pre-liminal phase (separation), the liminal phase (liminal space) and the post-liminal phase (incorporation/aggregation). Figure 2 is a visual representation of the constructive journey that a third-party application developer takes to become a successful digital entrepreneur. It details the different stages starting from the conception of a new business idea to the development of a viable digital business in a specific market niche.

The framework in Figure 2 shows that digital entrepreneurship development is characterized by iterative activities that arise from the actions and practices conducted through the interaction of third-party developers with the digital platform boundary resources within a given environmental conditions (Bianco *et al.*, 2014; Bonina *et al.*, 2021). Especially as the third-party developers who participated are loosely controlled by the platform owners. In this process, new applications developed to meet users' needs are usually influenced by the flexible platform governance structure offered by the digital platform, in addition, the ease of access to application users (i.e. target users) helps third-party developers in gathering information about the current needs and expectations of the market (Ghazawneh & Henfridsson, 2012). For individuals aspiring to become digital entrepreneurs, it is crucial to develop applications that cater to the needs of their intended audience and adapt to the regulations and policies guiding such market offerings. The current study further extends knowledge in literature by revealing that while creating an application can enhance the functionality of a digital platform, it alone does not suffice to establish oneself as an entrepreneur. Entrepreneurs should consider the market forces and the product/service suitability by prioritizing the modelling and creation of a sustainable and gratifying application for particular market conditions. To overcome the hurdles of digital entrepreneurship especially in an uncertain and complex environment experiencing unstable regulations and policies, third-party developers take advantage of the digital



Source(s): Developed from Ajah's field work

Figure 2.
Liminal space
experience of third-
party developers
during digital
entrepreneurship
development

platform by utilizing the resources available on the platform to collaborate with others. This cooperation fosters uncertainty mitigation, innovative products/services, ingenuity and the emergence of new applications, ultimately leading to exciting entrepreneurial prospects for value generation and capture. The following sub-sections elaborate on the different phases experienced by third-party developers as they engage in digital entrepreneurship development.

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6.1 Pre-liminal phase (ideation)

The pre-liminal phase is considered a period where third-party developers get disjointed with their personalities and the primary task of developing new applications that will extend the functionality of a digital platform. In this phase, they focus on exploring the prospects of pursuing entrepreneurial activities. This new pursuit keeps the developers conducting non-routine activities (Söderlund & Borg, 2017) because they no longer focus on the task of enhancing the features and functionality of a digital platform's extendible core architecture and performance. They are brainstorming a new business idea and figuring out how to make it profitable. Hence, third-party developers become inclined towards identifying or creating ideas that can solve specific market problems and developing applications as a product/service to solve identified needs. So, third-party developers take advantage of platform boundary resources to pursue entrepreneurship. This is that phase where some critical questions are asked and answers are sought. The questions include "*What is a pressing market unmet need that needs to be solved? What is a solution to this problem? What has to be done for this solution to work? What are the minimum resources or possible effort required? What is the simplest way to gather resources and capture value? Who is the target market or customer segment? What is the channel needed to deliver this market offering? Who is my competition?*" These questions are pondered upon by the third-party developers to help prepare them for the task ahead and the validation of the market needs.

Interestingly, third-party developers continuously shape their experience and behaviour for entrepreneurship through the digital platform boundary resources, which help them collaborate with other developers and experienced entrepreneurs to evaluate new business ideas. They also expand their reach and attract other actors through the boundary resources. Further, third-party developers explore the possibilities of developing applications that can be utilized seamlessly across multiple digital platforms by taking advantage of the freedom to engage in multi-homing. These new proposed applications are expected to serve as complementary products/services, ultimately providing a more enriching experience for users who patronize different platforms (Constantiou, Eaton, & Tuunainen, 2016; Hein *et al.*, 2020). In this phase, the developers carefully analyse the pressing needs of application users across platforms. Then, evaluate current market issues to identify and create new and innovative business ideas that can be pursued and transformed into profitable products/services. This is a motivation that attracts third-party developers to pursue entrepreneurship and drives their intention to develop an application that prioritizes the needs of an application user over the platform's core functionality extension and evolution (Constantiou *et al.*, 2016; Hein *et al.*, 2020; Rubleske, 2020).

6.2 Liminal phase (third-party application developers' entrepreneurial actions and practices)

The process of developing digital entrepreneurship can be described as a process that occurs in a liminal space (Söderlund & Borg, 2017). This is because the activities conducted are transitional, though recursive and move from ideation to commercialization in a target market (Daniel & Ellis-Chadwick, 2016; Kraus *et al.*, 2018; Willson, 2019). During these liminal space activities, third-party developers conceive a new business idea, refine it, develop a product/service and finally launch it in the market for its first sale (Kraus *et al.*, 2018;

Paternoster, Giardino, Unterkalmsteiner, Gorschek, & Abrahamsson, 2014). However, we need to know that “[in] practice, [digital entrepreneurship] gestation is not an easy process, but a difficult period in the life of a new business; it is full of uncertainties, and concerns, continuously faced with an alarming resistance to stakes, and characterized by a phase where risky decisions are continuously made” (Ajah, 2023, p. 1). Then, to better understand the phenomenon investigated, the researcher draws from the liminal space perspective, as he adopts the view of some scholars who consider certain situations as a liminal experience. A scholar described “liminality as the process of going in between two states and the time spent in that transitional zone when one is neither one nor the other but in the process of becoming” (Leeming, 2014, p. 1033). Third-party application developers, who engage in business development activities, become digital entrepreneurs when they introduce new applications to the market.

This view helps to elaborate third-party developers’ experiences during digital entrepreneurship development, as product/service is being developed and continuously tested and modified for market fit. In this context of the investigation, Figure 2 depicts the two states that boundary the liminal space of digital entrepreneurship development. The phases bounding the liminal space include ideation (pre-liminal phase), and the new digital business market entry (incorporation phase) (Leeming, 2014; Mueller-Greene, 2022). What happens between these two boundaries describes the entrepreneurial actions, practices and experiences of third-party developers who seek to develop and refine products/services to meet the needs and demands of the market. However, the actions and practices are seen to happen in a non-structured and unguided liminal space, a space where structure, norms and control are suspended. A space where platform owners do not determine or exhibit full control of the decisions and actions of third-party developers who use the digital platform boundary resources to pursue digital entrepreneurship development and operation.

The liminal space represents an iterative sequence of processual activities engendered by third-party developers who interact with digital platform units that are loosely coupled but engage the affordances of digital platform boundary resources for the transformation of a viable business idea to a new digital business in a target market. This is a threshold region where multiple third-party developers seek collaboration to drive actions and practices necessary to create and transform new innovative business ideas into new applications that represent the product/service of an emerging digital business that is expected to satisfy the needs of the target market. So, it is a period where a flux of entrepreneurial activities is triggered by digital platform boundary resources, where third-party developers lose their identity from being application developers for digital platforms to becoming digital entrepreneurs who are pursuing entrepreneurship for value creation and capturing (Daniel & Ellis-Chadwick, 2016; Gibbons *et al.*, 2014). Figure 2 shows the emerging digital business that arises from the iterative entrepreneurial actions of the actors coordinated by the resource openness of the digital platform, making third-party developers incentivized to undertake actions that foster new digital entrepreneurship development.

The capabilities of digital platforms are inspiring new venture ideas and opportunities, which influences third-party developers. Third-party developers leverage these capabilities to develop application software that can provide innovative solutions for unmet market needs. Thus, the rise of digital technology has provided a valuable platform for the development and testing of the viability of new business ideas, concepts and business models. Most often, application developers can seek input from their intended customers and other stakeholders via social media platforms, app stores and websites. Though the process can be challenging due to inherent ambiguities, it empowers digital entrepreneurs to be resourceful and innovative in addressing feedback, ultimately earning the market’s trust, confidence and support.

Today, the process of building digital entrepreneurship involves a series of iterative steps that are subject to uncertainties and various dynamics that arise with the process as continuous efforts are engaged to guarantee the needs of the target audience are met. These steps ultimately lead to the creation of innovative digital products/services through a sequence of emerging events. The dynamic nature of the digital platform, with its open access to its resources, creates a certain level of ambiguity and uncertainty that further complicates the process. However, this experience provides ample opportunities for third-party developers to experiment with and refine the developed prototype of the market offerings. The adjustments made to these offerings reflect the third-party developers' response to complexities and even to customer feedback. Throughout this process, third-party developers track the outcomes of their efforts from target application users' responses, then pivot and reconfigure the business models and value proposition accordingly. Nevertheless, it is important to note that digital entrepreneurship is also influenced by the environment in which it operates, as the conditions of this environment create instabilities that further shape the course of events. Various environmental structures and enabling conditions affect activities in the liminal space, influencing the decision-making and actions of third-party developers. This suggests that liminal space represents a transitional rite of passage that requires careful attention, which every third-party developer must navigate to pursue entrepreneurship development for digital business (i.e. start-up) emergence in a target market (Gibbons *et al.*, 2014).

The outcome of the study demonstrated a critical and significant role played by digital platforms in entrepreneurship. It shows how it changed the way entrepreneurs conduct their activities and enables collaboration among different individuals located in different places. This finding aligns with the views of other scholars in previous studies who emphasized digital technology offers collaborative and co-creation activities for new digital products/services development (e.g. Giones & Brem, 2017; Kraus *et al.*, 2018; Nambisan, Lyytinen, Majchrzak, & Song, 2017; Nambisan, Wright, & Feldman, 2019; von Briel *et al.*, 2021). From the findings of the study, it is evident that the digital platform boundary resources' fluidity and openness are responsible for and drive the activities that led to the interactive actions and practices that culminate in new digital start-up emergence. The influence of platform boundary resources keeps the involvement of multiple actors, empowering entrepreneurs to take steps that overcome certain known challenges like a limitation of required skills and other resource deficits and mitigating the consequences of uncertainties that arise from the government regulations, policies and market forces. Hence, the role played by digital platform boundary resources to mitigate challenges against the progress of the development process becomes especially important in an environment experiencing constrained resources, market force dynamics and unfavourable and inconsistent government policies and regulations that tend to limit the entrepreneurs' performance and success.

Finally, third-party developers look for various resources to turn their business ideas into reality. They frequently use digital platforms to find the expertise and financial resources needed to create new products or services. Thus, crowdsourcing and crowdfunding platforms are especially popular among these entrepreneurs, as they provide access to resources that may not be readily available locally. In an environment with limited investors and few skilled professionals, as we have in our investigation context (i.e. Nigeria's digital start-up ecosystem), these platforms can have a significant influence by helping entrepreneurs overcome resource constraints. Therefore, it enables third-party developers to develop new business ideas and bring them to life. This finding supports prior studies that describe such platforms as critical to new venture development and resource acquisition (e.g. Garrigos-Simon *et al.*, 2021; Nambisan *et al.*, 2019; Smith & Smith, 2021). Therefore, digital platforms play a crucial role in the development and experimentation of new market offerings. Further, digital platforms offer lean start-up/agile methods for product/service development, which enables the co-creation of products/services, and as a result, they can mitigate every

uncertainty and resource limitation experienced. This approach also prioritizes user-centred design, ensuring that application users are involved in every step of the product/service development process. Through experimentation and feedback, third-party developers gain a deeper understanding of their customers' needs. Feedback informs the iterative process of pivoting and modifying the product/service until it perfectly aligns with the market. As the offering becomes more refined, new digital businesses emerge in the market, gaining traction and generating revenue as users become increasingly satisfied. Therefore, the findings from the study corroborate the lean start-up principle, whose approach is to "[c]reate value for the customer . . . Identify the value stream . . . Create flow . . . Produce only what is pulled by the customer . . . Pursue perfection by continuously identifying and eliminating waste" (Ghezzi & Cavallo, 2018, p. 3).

6.3 Incorporation phase (emerging new digital business)

In the current phase of the digital entrepreneurship journey, the efforts of the individuals and parties involved have resulted in the emergence of a thriving digital business. This business boasts a promising product/service that is capable of generating consistent revenue and can rapidly gain momentum and traction in the market. At this point, the third-party developers involved have successfully transitioned from being third-party developers to becoming established players in the digital market as digital entrepreneurs. In addition, their applications are actively fulfilling the needs and wants of their intended users, effectively meeting the demands of a rapidly evolving digital landscape.

7. Conclusion

This research paper presents an in-depth empirical analysis of how digital platform boundary resources impact the entrepreneurial behaviours of third-party application developers, especially as they transition from third-party application developers of a digital platform to thriving digital entrepreneurs. The research study highlights the ability of these developers to demonstrate resilience in the face of ambiguity, disorientation and uncertainties that are inherent in the digital platform and environmental context. The primary aim of the study is to develop a conceptual framework that explains the role of digital platform boundary resources as third-party developers experience liminality during the process of digital entrepreneurship development. The study examines the various boundary resources provided by digital platforms, such as application programming interfaces, software development kits, integrated development environments, libraries and access to platform data. The research findings demonstrate that digital platform boundary resources play a significant role in the development of digital entrepreneurship in today's market. The study highlights how these resources enable third-party developers to create new applications that expand the functionality of the digital platform, leading to increased user engagement and revenue generation. Therefore, this study contributes significantly to the advancement of theoretical conceptualization and practice in the literature. It provides a better understanding of the role of digital platform boundary resources in promoting digital entrepreneurship and highlights the importance of these resources for both theory and practice.

7.1 Theoretical contribution

This study contributes to theory, its outcome is a conceptualization of the role of digital platform boundary resources in the promotion of digital entrepreneurship. The outcome of this study responds to the call from some scholars who lamented the absence or limited conceptualization of digital platform impact on digital entrepreneurship processes in the existing literature (Anim-Yeboah *et al.*, 2020; de Reuver *et al.*, 2017; Foisal *et al.*, 2023;

Rubleske, 2020). So, this study delves into the experiences of third-party developers involved in digital entrepreneurship development by adopting the theory of liminality. The developed conceptual framework extends the current literature by providing a theoretical elaboration of third-party application developers' experiences and the factors that impinge on them. The framework identifies several factors that contribute to the uncertainties and ambiguities experienced during the process of digital entrepreneurship development. First, digital platform boundary resources play a crucial role in shaping the experiences of third-party developers. Second, government organizational institutions also impact the experiences of these developers. Third, market structures characterized by unmet needs and competitive landscapes also affect the experiences of third-party developers. Finally, the interactions with other stakeholders such as investors, customers and suppliers also play a significant role in shaping the experiences of third-party developers. Hence, the study is distinct from other studies (e.g. Davidsson & Gruenhagen, 2020; McMullen & Dimov, 2013; Moroz & Hindle, 2012; Selden & Fletcher, 2015; Servantie & Rispal, 2018; Zaheer, Breyer, Dumay, & Enjeti, 2022) because it extend literature by demonstrating with a framework in Figure 2 how digital platform boundary resources mediate to provide the resources and context that enables third-party developers to succeed during liminal space activities and experiences. The framework takes into account the contextual dependencies of a specific environment (Gudi & Chinta, 2020; Steininger, 2019) and provides an account of the role of digital platform boundary resources, environmental structures and enabling conditions. These factors have a significant influence on the behavioural actions and activities of third-party developers who are pursuing entrepreneurship in the investigated context. Importantly, the framework developed in this study promotes an un-deterministic perspective on digital entrepreneurship development, which means that it recognizes the importance of various factors that can influence the emergence of new digital businesses in a target market. Hence, the study develops new concepts that explain the role of digital platforms in promoting digital entrepreneurship. The framework provides a deeper understanding of the experiences of third-party developers involved in digital entrepreneurship development and can help in developing policies and strategies that support digital entrepreneurship. Therefore, the framework in Figure 2 provides a new background insight for further studies, which scholars who are interested in the investigation of the role of digital platforms in the process of digital entrepreneurship development research can pursue.

7.2 Practical implication

This research study is a valuable contribution to the field of digital entrepreneurship, especially in regions like the global south where entrepreneurs often face resource constraints, environmental uncertainties and complexities. The study focuses on Nigeria and can be a guide for similar countries where third-party developers interested in digital entrepreneurship development will find it helpful. The study provides a comprehensive guide for practitioners on how to drive different dimensions of events during the development process of digital entrepreneurship. It identifies key roles that digital entrepreneurs should focus on to ensure success in the development process. Therefore, it offers actionable steps that practitioners need to follow to ensure the right actions and practices during digital entrepreneurship development. The outcome of this study reveals three critical impacts of digital platform boundary resources that drive the behaviour of third-party application developers. These impacts include resources and control openness for new business ideation, collective intelligence to navigate disoriented and ambiguous entrepreneurial activities and prototype application development for continuous learning and adaptive cycles of innovation. These impacts promote the activities and practices of the third-party developers as they interact with one another to promote the desire to pursue entrepreneurship processes.

Therefore, the outcome of this study will enlighten and guide third-party developers and other entrepreneurs who intend to pursue the development of new digital businesses on how to engage with the platform boundary resources to make the most of its usefulness.

The framework in Figure 2 guides how to navigate the complexities of the digital entrepreneurship landscape, enabling entrepreneurs to focus on the most critical factors for success. Overall, this research study is an essential resource for anyone interested in digital entrepreneurship because its practical insights and theoretical framework offer a roadmap for success in this challenging field. Next, the study provides an in-depth analysis of the impact of policies and regulations on digital entrepreneurs' activities during digital entrepreneurship development, offering policymakers and regulators valuable insights into how their decisions affect the digital start-up ecosystem in Nigeria. The study shows that creating policies and regulations that support digital entrepreneurs is essential to promoting nascent entrepreneurial activities in the country. Based on its findings, the study recommends that the government provide tax holidays as support to new digital entrepreneurs who are seeking to engage in digital entrepreneurship development. Such incentives will encourage more entrepreneurs to venture into the digital space and help grow the digital economy in Nigeria. Moreover, the study emphasizes the need for government institutions to develop laws that support the activities of the digital start-up ecosystem, for instance, reducing barriers to entry, these policies will help create a conducive environment for digital entrepreneurs to thrive. Hence, it is important for the Nigerian government to fully implement the Nigeria Start-up Act, 2022, to guarantee support, incentives and programs that will encourage digital start-up founders to pursue digital entrepreneurship in Nigeria's digital start-up ecosystem. Overall, the study highlights the importance of developing appropriate policies and regulations and implementing programs to support digital entrepreneurs. Through these measures, Nigeria's digital economy can be revolutionized, and the country can become a hub for digital innovation and entrepreneurship.

7.3 Limitations and future research directions

The findings of this study are highly specific to the experiences of third-party developers who operate in Nigeria and may not be directly transferable to other contexts. Economic policies, regulations and cultural differences can all play a significant role in shaping the opinions and decisions of third-party developers and may have different effects in other environmental contexts. It is important to note that this study was restricted to the perspectives of third-party developers who have digital entrepreneurship experience, and this was achieved through the use of a snowball sampling technique. While useful insights were obtained through this approach, it is important to recognize that other digital business players, such as support service providers, may have different perspectives that could be useful to consider in future research. In addition, it is worth mentioning that due to resource constraints during field visitation, this study focused solely on technology hubs located in Lagos Yabacon. To obtain a more heterogeneous view of the impact of digital platform boundary resources, future research may benefit from broadening the sample to include technology hubs in other Nigerian states. Taken together, it is clear that there is a need for further research to build on the insights obtained in this study and to gain validation or a more comprehensive understanding of the impact of digital platform boundary resources on third-party developers in Nigeria and beyond.

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eXplainable artificial intelligence (XAI) in business management research: a success/failure system perspective

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Abstract

Purpose – eXplainable artificial intelligence (XAI) is an evaluation framework that allows users to understand artificial intelligence (AI) processes and increases the reliability of AI-produced results. XAI assists managers in making better decisions by providing transparency and interpretability in AI systems. This study explores the development of XAI in business management research.

Design/methodology/approach – This study collects and analyzes business management research related to XAI using common management keywords as the basis. We used the success/failure system to explore its research guidelines XAI in business management.

Findings – The study found significant growth in XAI research within business management. This research will be discussed from various management disciplinary perspectives to help scholars understand the current research directions. Additionally, we utilize a success/failure system to explore how this theory can be applied to artificial intelligence and business management research.

Originality/value – The success/failure system offers a comprehensive framework encompassing the evolution of the cosmos, nature, and ecology. This theory can offer valuable insights for business management in XAI and competitive societies, governments, and enterprises, enabling them to formulate effective strategies for the future.

Keywords eXplainable artificial intelligence (XAI), Success/failure system, Business management research

Paper type Conceptual paper

1. Introduction

Artificial intelligence (AI) research and technology began to gain traction following the Dartmouth Workshop in 1956, during which researchers deliberated the possibility of creating machines that could mimic human minds (Howard, 2019). In the 1970s and 1980s, AI development garnered minimal attention. However, since 2010, advancements in computer hardware efficiency and the emergence of algorithms and deep learning have spurred significant improvements in learning from data and handling complex tasks. These advances have fostered a proliferation of AI applications, encompassing image and speech recognition and the rapid generation of various data types to meet user needs.

The AI generates outcomes based on the input provided by individuals in the form of ideas or queries. As the user provides more detailed descriptions of their conditions, the AI response typically becomes more precise and comprehensive, meeting the user's expectations.



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Generative AI can greatly enhance work productivity for businesses and organizations by significantly reducing the time and cost associated with manual content creation and writing (Wu, Mou, Li, & Xu, 2020; Korzynski *et al.*, 2023; Zarifhonarvar, 2024).

Nevertheless, many issues surround the information currently generated by AI. Some scholars argue that generative AI-produced content lacks accuracy and rationality, with specific information being outdated compared to what individuals can access through internet searches (Dwivedi, Kshetri, *et al.*, 2023; Gupta, Akiri, Aryal, Parker, & Praharaj, 2023; Zarifhonarvar, 2024). Therefore, to demystify AI's operations as a black box, there is an increasing emphasis on eXplainable Artificial Intelligence (XAI) concepts and principles.

The XAI aims to enhance AI by providing results through a transparent and explainable decision-making process, which may encompass visualizations, data sources, statistics, and more. The distinction between XAI and traditional AI lies primarily in the transparency and interpretability of the decision-making processes. While traditional AI often operates as a "black box," providing little insight into how decisions are made, XAI focuses on making these processes understandable and transparent to users (Rai, 2020). Some more mature machine learning algorithms provide interpretable analysis, such as Shapley additive explanations (SHAP) and Local Interpretable Model-Agnostic Explanations (LIME). These techniques help in explaining the reasoning behind AI decisions, making them more accessible to human understanding (Černevičienė & Kabašinskas, 2024; Dwivedi, Dave, *et al.*, 2023). The additional information provided by XAI empowers users to comprehend the context of the content, ensures the integrity of the AI's analyses, and instills confidence in the content generated by the AI (Langer *et al.*, 2021). For instance, in the context of a student or academic research report, software tools such as AI Text Classifier and Hive moderation can be employed to ascertain whether generative AI was used in the article.

Additionally, Turnitin AI detection can utilize to identify instances of plagiarism. The Turnitin system will furnish the user with a list of similar sources, enabling them to discern the extent of relevance between their articles and others, pinpointing any issues precisely. The results generated by this tool are persuasive and supported by detailed information. The XAI offers users information on "interpretation", "transparency", and "explainability" (Bunn, 2020; Von Eschenbach, 2021). These three terms belong to distinct categories in their definitions, ranging from basic to advanced. Various arguments exist for explainability and transparency, but their common purpose is augmenting individual decision-making and use patterns.

In today's business environment, data-driven decision-making is essential for effective management (Paschek, Luminosu, & Negruț, 2020). Traditional data analysis tools, however, no longer suffice to address the growing complexity and uncertainty in modern business operations. XAI presents a transformative opportunity for businesses by automating and optimizing decision-making processes, enhancing transparency, and providing clear insights into AI-generated outcomes. XAI enables organizations to harness AI for evaluation and planning while equipping employees—even those with limited experience—to make more accurate judgments based on explainable AI content (Albahri *et al.*, 2023; Karyamsetty, Khan, & Nayyar, 2024). This capability proves crucial in improving the quality of managerial decisions across various business domains such as supply chain management, production, and customer service. By cultivating a deeper understanding of task-related contexts and potential risks, XAI strengthens decision-making reliability and offers businesses increased flexibility and a competitive edge in tackling future challenges.

Currently, business management employs bibliometrics, reviews, and meta-analysis to analyze the evolution of the AI research field. For instance, Han *et al.* (2021) extensively reviewed the literature to assess AI's role in business-to-business marketing. Sestino and De Mauro (2022) conducted text mining on the Elsevier and Scopus databases, summarizing 3,780 AI-related studies in business and marketing. Their study categorized these studies into three themes: implications, applications, and methods, through a systematic literature review. Cubric (2020) combined bibliometrics and meta-analysis to scrutinize AI-related studies,

evaluating the quality of papers published between 2000 and 2019 in the context of business management and AI.

However, it is worth noting that there needs to be more discourse on XAI, with most scholars still exploring traditional AI applications. Some experts posit that XAI possesses the potential to spearhead the next generation of AI and should warrant academic attention (Ali *et al.*, 2023; Arrieta *et al.*, 2020; Minh, Wang, Li, & Nguyen, 2022). Consequently, this study aims to investigate the current state of XAI within the academic realm of business management. We will leverage recent literature statistics on XAI to assess its status. Furthermore, we will employ the success/failure system theory to appraise the XAI and business management research.

The success/failure system, introduced by Bau (2018a), differs from conventional business theories in a key way: it views failure factors, reasons, and events not merely as setbacks, but as strategic opportunities for development and the creation of new business activities. The success/failure systems do not assume any specific factor as inherently correct or indicative of success. Instead, it treats successful and failed outcomes as valuable sources of insight, offering a balanced perspective on organizational decision-making.

From the past model of human decision-making, it is found that even information is transparent and explainable. However, human decision-making often leads to varying interpretations, both positive and negative. For instance, a scholar specializing in technology adoption behavior and stock price prediction might apply for a university position. Some may view this individual as a multidisciplinary talent, while others may perceive a lack of focus, potentially leading to a rejection. In the context of XAI, where transparency and interpretability are critical, however, the final decision-making still relies on human judgment. Thus, the theory allows us to explore how organizations can integrate AI-driven insights while remaining aware of potential risks.

We hope this theory can offer a novel perspective and serve as a reference for future studies. We will explore the following two research questions to achieve our research objectives.

- RQ1. What is the current situation of studies between XAI and business management research?
- RQ2. How can success/failure systems serve as an academic basis between XAI and business management research?

2. XAI in business management research

This section elucidates the data collection process and presents the results. We collected the data from the web to elucidate the current state of research at the XAI (applied/used) in business management. Explore the importance of XAI and business management research, which can help scholars develop future research directions.

2.1 Data collection process

Due to the limitations and resource constraints in our research, we examined two distinct databases: Elsevier ScienceDirect and EBSCO-Business Source Corporate Plus. We conducted separate evaluations for the results obtained from each database. This study data was collected on October 1, 2023, representing a static record. Given that XAI is an emerging AI topic, our observation period spans from 2016 to 2023. There is no information before 2016.

We searched for specific keywords because “Business” is our discussion. According to the Journal Citation Reports, the business and management categories fall under the broader economics and business group. Therefore, we employed “business,” “economics,” and “management” as the three keyword combinations for our search and statistical analysis.

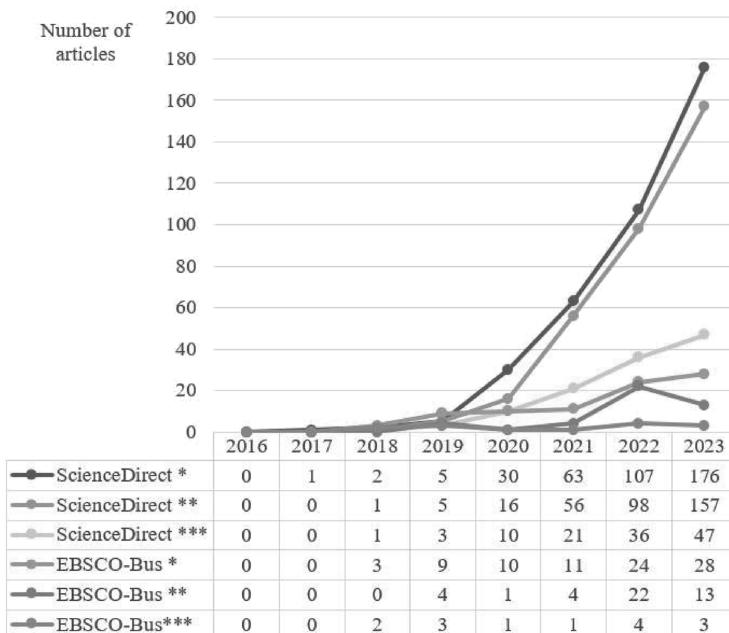
Initially, we used “business management” as a keyword. However, it yielded few results. We additionally used the keyword “management” to bring in research from various unrelated fields, such as engineering, complicating the dataset. Similarly, using “XAI” as a keyword introduced many specialized terms, leading us to avoid simplified keywords to prevent the inclusion of irrelevant articles. Our final keyword combinations were: “Explainable Artificial Intelligence” and “business,” “Explainable Artificial Intelligence” and “economics,” and “Explainable Artificial Intelligence” and “marketing.” Among these, marketing represents the most established and widely studied field within business management.

To perform content analysis, we initially classified the journals into major recurring publication types and their corresponding disciplines, including Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). We cross-check the content to ascertain their associated research areas. Subsequently, we sought confirmation from three professors in the Faculty of Management to ensure the absence of categorization bias.

2.2 Number of XAI studies in business management

Figure 1 displays the number of papers on XAI in business management, encompassing 2016 to October 2023. In 2020, the topic of XAI gained increased attention. While there is not an explosive surge in the volume of studies, the first keywords combination in average annual growth rates of papers between 2021 and 2023 are strikingly high at 110, 69, and 64%, respectively. These figures signify the emergence of XAI as a significant and noteworthy trend in scientific research.

When searching Elsevier ScienceDirect for the keyword “Explainable Artificial Intelligence” in isolation, we find 2,770 studies employing this term in 2016, followed by 7,910 until 2020, 11,643 in 2021, and 15,315 in 2022, with a further increase to 17,740 in 2023. The trend in



Note(s): *:XAI, Business; **:XAI, Economic; ***:XAI, Marketing

Source(s): Authors' own work

Figure 1. Number of XAI studies in business management

EBSCO-Business Source Corporate Plus is also ascending annually. After conducting a time trend analysis, we estimate that by 2025, the number of articles will surpass 20,000 per year. Compared to all studies, there are few studies on XAI in business management, possibly due to the absence of mature products supporting corporate activities and the scarcity of indicative cases.

Current XAI Topics in Business Management Studies.

While we employed keywords to conduct the literature search, it was unavoidable that specific papers related to computer science would surface. Therefore, we observe the first keyword combination as a content analysis. Table 1 provides a summary of the outcomes. In summary, the predominant types of current research encompass bibliometrics, reviews, conceptual exploration, and trend discussions. These articles guide scholars in XAI's future directions (e.g. Angelov, Soares, Jiang, Arnold, & Atkinson, 2021; Brasse, Broder, Förster, Klier, & Sigler, 2023; Islam, Ahmed, Barua, & Begum, 2022).

In business management, finance, and accounting emerge as XAI's most explored research areas. These studies encompass the utilization of AI in finance, stock market forecasting, risk analysis, and related topics, offering direct assistance to supervisors in enhancing financial management effectiveness (Lachuer & Jabeur, 2022; Zhang, Cho, & Vasarhelyi, 2022). For example, Zhang, Wu, Qu, and Chen (2022) propose an XAI approach that integrates an ensemble method and an interpretation framework for financial distress prediction. The LightGBM model achieved the highest AUC (0.92), providing explanations that help individual companies identify key factors leading to financial distress, while counterfactual explanations offer strategies for improvement. Second, researchers have conducted numerous studies on business operations, particularly in digital transformation, work productivity, and supply chain management, exploring how XAI can assist enterprises in addressing current challenges (Johnson, Albizri, Harfouche, & Tutun, 2023; Senoner, Netland, & Feuerriegel, 2022). Such like Bhatia and Albarak (2023) propose a model called XAI-based Faster RCNN (Regions with Convolutional Neural Networks) to evaluate the contents of food items using web systems and QR codes. The system retrieves detailed nutritional information and uncovers hidden details embedded in QR codes, enhancing food safety and quality by ensuring the accuracy of food security information.

Furthermore, our findings reveal a significant body of research that employs XAI to facilitate sustainable business operations, assisting organizations in managing resources such as electricity, water, and waste (Ha, Sah, Park, & Lee, 2022; Maarif, Saleh, Habibi, Fitriyani, & Syafrudin, 2023). Other studies include information systems research, analyzing social network sites, and embracing the potential of XAI are crucial for staying ahead in today's

Table 1. Basic statistics of the disciplines classification

Disciplines	EBSCO	Science direct	Total
Information systems and E-commerce	6	20	26
Management and decision sciences	7	10	17
Finance and accounting	14	21	35
Marketing, customer service, and retail	6	10	16
Bibliometrics, reviews, and trend discussions	18	29	47
Travel, leisure and hospitality	3	7	10
Business operations, B2B, and digital transformation	8	21	29
Sustainability and energy	4	23	27
Knowledge management, innovation management, and human resources	6	10	16
Healthcare and biotech	2	26	28
Computer science	6	180	186
Others – transportation, law, ethics, education, government, and agriculture	5	27	32

Source(s): Authors' own work

digital landscape (Leichtmann, Humer, Hinterreiter, Streit, & Mara, 2023; Yilmaz Benk, Badur, & Mardikyan, 2022). Conversely, we observed a comparatively lower volume of research papers on XAI in marketing, retail, and customer service. This trend may be attributed to the fewer innovative XAI applications in these business activities. XAI can be applied in different business activities. We have compiled some current technologies and potential business applications in Table 2.

Table 2. Examples of XAI methods and success/failure system in commercial applications

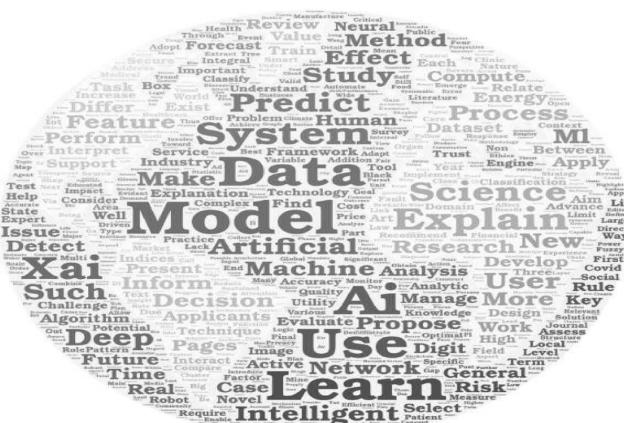
XAI method	Explanation approach	Business example	Success/Failure system perspective
SHAP (shapley additive explanations)	Based on game theory, SHAP attributes the contribution of each variable to the model's prediction, providing an interpretation of the output	In the financial sector, SHAP is used in credit assessment models to explain why a customer was rejected for a loan	SHAP identifies critical success (loan approval) or failure (loan rejection) factors, allowing for a granular analysis of each variable's impact, helping to improve decision-making and risk management processes
LIME (local interpretable model-agnostic explanations)	LIME simplifies the model locally, offering users insights into how the AI operates on a specific prediction point	LIME explains why AI has diagnosed a patient with a disease in healthcare	The success/failure system helps to analyze success (correct diagnosis) and failure (misdiagnosis) factors, guiding the refinement of diagnostic models to improve accuracy and interpretability
Decision tree	Decision trees utilize a series of binary (yes/no) questions to split data and generate predictions, offering high interpretability	Decision trees predict customer purchasing behavior in retail, helping optimize product sales strategies	The success/failure system helps analyze which decision paths led to success (increased sales) and failure (lost sales), enabling companies to refine their strategies and improve customer satisfaction and profitability
Large language models (LLMs)	While powerful, LLMs are challenging to interpret due to their opaque reasoning process, requiring additional tools for explanation and transparency	In customer service, LLMs are used to respond to customer inquiries automatically	The success/failure system can analyze successful (effective responses) and unsuccessful (ineffective responses) LLM outputs, helping businesses adjust and improve response quality, thereby enhancing customer experience
Deep learning explanation models (e.g. Grad-CAM)	Visualization techniques like Grad-CAM highlight focus areas in image recognition, revealing how deep learning models operate internally	In manufacturing, deep learning models detect product defects, and visualization tools show which areas the model focuses on for defect detection	The success/failure system helps analyze which parts of the defect detection are successful and which fail, allowing manufacturers to optimize defect detection models and improve quality control processes

Source(s): Authors' own work

Regarding other research paper categories, transportation topics dominate, followed by law and ethics. It is worth noting that these patterns emerge because specific categories unrelated to business management were excluded based on keyword criteria. Although the number of papers in this survey is small, it does not mean that the number of research papers in this field in XAI is small.

We utilized Python to conduct semantic analysis on the gathered research, encompassing paper titles, abstracts, and keywords. We categorized significant terms and visualized them in word clouds (see Figure 2). Among these terms, “Model” is the most frequent, occurring 846 times, followed by “Learn” with 665 instances and “Data” with 637 occurrences. Notably, we observed that several words are more closely linked to business management within these texts. Specifically, “Predict” appears 448 times, “Decision” 344 times, “Technology” 177 times, “Manage” 147 times, and “Industry” 134 times. “Risk” is mentioned 118 times, “Market” and “Trust” appear 74 times, “Financial” 73 times, “Privacy” 68 times, and “Ethics” 46 times.

In addition to the data described above, we observe several key discussions in the existing literature. First, there are relatively few empirical studies on XAI in business management. Recent studies, such as Masialeti, Talaei-Khoei, and Yang (2024), analyze portfolios of AI applications, while earlier research remains limited in scope. Most current academic discussions focus predominantly on generative AI, likely due to the limited adoption of XAI products within organizations. Second, numerous studies propose potential future developments for XAI in specific management fields, such as smart cities (Javed *et al.*, 2023) and supply chain management (Mugurusi & Oluka, 2021). These studies identify potential research directions based on scholars' experiences and existing literature but lack solid theoretical foundations. Although they guide future scholars on relevant topics, they fail to provide a specific theoretical framework to support these directions. Third, much of the existing literature remains focused on technical discussions, with limited exploration of XAI's practical applications in business management. While technical details are essential, solely focusing on technology overlooks the broader value of XAI in enhancing decision-making processes and management efficiency. Technology-oriented studies often fail to thoroughly examine how XAI influences organizational decision-making or improves operational performance.



Source(s): Authors' own work

Figure 2. Word cloud from semantic analysis result

In sum, the current literature on XAI's application in business management is still in its early stages. Future research should explore applying XAI technology effectively within business environments and expand the theoretical framework to offer more concrete guidance for scholars and practitioners. Additionally, further empirical research on XAI applications across various management domains will drive the advancement of theory and practice in this emerging field.

3. Success/failure system perspective

This section introduces the success/failure system and explains why this theory has been used to explain the development of XAI and business management research. We will use the success/failure system to present different propositions for XAI and business management research, which will serve as a reference for future scholars and researchers.

3.1 Success/failure system

The success/failure system is a concept proposed by Bau (2018a). In his research (Bau, 2018b, 2019a), this system (theory) can explain the evolutions across ecology, nature, and the cosmos. This theory is mainly derived from Einsteinian science. Einstein (Einstein & Calaprice, 2011) believed that "nature [the universe] is a perfect structure, seen from the standpoint of reason and logical analysis." Einstein's principle theory aims to uncover universal laws in biology, addressing crucial questions in the field. One significant contribution of this hypothesis is clarifying humanity's position in the universe teeming with life and the subsequent imperative to preserve and sustain our planet, Earth. Additionally, the hypothesis catalyzes the realms of physics and biology, presenting a scientific breakthrough. This integration has the potential to ignite interdisciplinary curiosity, bringing science closer to its ultimate goal of unity.

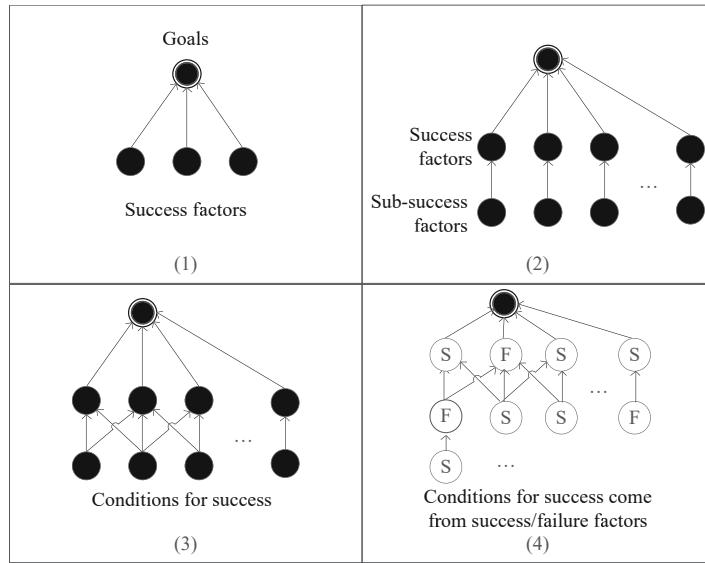
Due to the rigorous nature of Einsteinian science in revealing the laws of nature, any alteration or deviation from the fundamental principles is deemed incorrect. In other words, when applying the principle theory to study the mesocosmos, an individual will eventually and consensually reveal the success/failure system as the law of nature at the mesocosmic level we live in. The success/failure system holds great significance as it represents a natural law that governs the mesocosmic level within our vast universe (Bau, 2019a). Thus, the primary contribution of the success/failure system in Einsteinian science forms a part of a theory of the universe. Whereas the success/failure system governs the mesocosmoc level, cosmic inertia is a law of nature that accounts for the universe as a single significant whole.

The success/failure system is a theoretical concept that can offer valuable insights and methods for exploring research in business management and XAI. In the realm of business management, this system allows for the evaluation of a business or organization's performance. Managers can better understand their business's functioning and make more informed decisions by analyzing various factors contributing to success and failure.

3.2 Success/failure system and XAI

In order to develop the success/failure system hypothesis as a principle theory, it is crucial to consider a wide range of complex and interconnected facts, collectively known as general facts. This general fact encompasses various mathematical concepts, including the interdependence of conditions for success and causes of failure. By treating this general fact as an axiom and employing discrete mathematical reasoning, we can construct a hypothetico-deductive system to establish the principle of the success/failure system, which can be described as follows (see Figure 3):

- (1) Suppose we acknowledge the general fact that various factors influence the success of a business.
- (2) In the case of a successful enterprise, there are typically multiple critical success factors at play. These factors, in turn, can be attributed to other sub-factors influenced



Source(s): Authors' own work

Figure 3. Sketches illustrating the success/failure system

by success. All of these factors contribute to the success of the business. The same is true for artificial intelligence. The results generated by iteration are composed of one layer after another. We cannot fully believe that the result of AI is an absolute answer (value).

- (3) As we observe these key success factors, we realize that their usefulness and effectiveness stem primarily from their interdependencies with other success factors. Consequently, these factors form a network system that enables the company to achieve its goals. Similarly, mechanical learning and deep learning have many algorithms and iterations, which is a network evolutionary derivation process, and the number of these iterations and variations should be able to be returned to the user.
- (4) The principle of the success/failure system can be explained using mathematics (Bau, 2019b): Partial Ordering (PO) conditions for success = Partial Ordering (PO) causes of failure. Therefore, we assume that an XAI or firm's success is solely the result of the presence of success factors. It is also plausible that certain failure factors shape the outcomes, thereby establishing a complex success/failure system. For an organization, the occurrence of either failure or success factors is a fact of life that is difficult to correct. However, XAI should be able to correct this by making system adjustments to realize the logic of the success or failure system.

In summary, in traditional AI responses, users only get their answers, making it challenging for users to assess the credibility of those answers. AI generates results that users can accept (success) or discard (failure). The XAI transforms the black box within which machine learning and deep learning operate into a white box, revealing the evidence and the reasoning source. The XAI's outcome is contextual and data percentage evaluated, and empowers users to directly assess correct (success) factors they accept or reject.

Considering the success/failure system, we advocate reporting AI results and provider users directly recalibrating the untrustworthy (failure) or success factors. This system supports

the adjustment of different factors, as outlined in point 4, empowering users to enhance the effectiveness of AI in aiding and facilitating tasks. This concept we call “Calibration of XAI.”

Calibration in XAI describes how individuals interpret the output information of XAI results. They subsequently adjust, correct, and test, hoping to obtain better results from artificial intelligence. The efficacy of calibration is not solely determined by artificial intelligence. When people encounter interpretable and transparent information, they may feel inclined and need to retrain and execute XAI, and this leads to repeated Calibration behavior in pursuit of the optimal solution. Thus, we recommend that AI software provides services for interpreting data. It does not require confirmation of the correctness or failure of its content. Instead, it should inform the user about the weight of these factors in forming the result, allowing them to assess the content’s correctness and significance independently. The system must offer functionality enabling users to reapply interpretable data as calibrated artificial intelligence.

This study proposes to utilize the success/failure system to analyze or explain business management and XAI applications. Additionally, we provide directions for further academic development. Our objective is to enhance contributions to the evolution of social science by employing this system concept or law.

3.3 Success/failure system in business management

Early research in business management extensively examined the factors contributing to success and failure. For example, Belassi and Tukel (1996) researched project management activities to investigate critical factors contributing to project success or failure. Their study objective was to develop a framework that facilitates project evaluation. Malik and Khan (2021) discuss the key factors for the success and failure of enterprise resource planning (ERP) systems in developing countries. However, these studies revealed negative effects on the discussion of failure factors, and few studies have explored its importance to success.

Most theories in business management, such as the Technology Acceptance Model, Resource-based Theory, Dynamic Capabilities, and Innovation Diffusion, generally promote a positive outlook. They offer valuable insights and frameworks for understanding and analyzing various social phenomena. Thus, many business management studies mostly explore those success factors that will bring about favoring performance in terms of research objectives. Only a few studies consider failure, such as Toots’ case study of the Estonian e-participation portal Osale.ee. Researchers discovered that e-participation systems face three challenging factors (Toots, 2019). The inherent complexity of these challenges renders e-participation systems susceptible to failure. Kaur, Dhir, Singh, Sahu, and Almotairi (2020) adopted the Innovation Resistance Theory to explore barriers to user mobile payment and study negative predictors.

The achievement of business goals should consider the coexistence of success and failure factors. We may consider that the term failure factors will not bring success. Therefore, it is easy to overlook its importance. Cecez-Kecmanovic, Kautz, and Abrahall (2014) mentioned that success or failure factors may cause the success or failure of project product development. Some scholars also mention the existence of this phenomenon (Fowler & Horan, 2007; Rese & Baier, 2011; Luo & Chang, 2023). Some scholars attribute failure factors to the formation of key factors (Bennett & Snyder, 2017; Say & Vasudeva, 2020). Concerning the success/failure system, certain success factors can exert an influence on the failure system.

The success/failure system is a theory that can integrate positive and negative factors. However, regarding negative factors, there will be a negative relationship in the construction model. In recent years, reports that use failure as a factor in developing academic research have received increasing attention, such as Castro-Arce and Vanclay (2020) and Nambisan, Wright, and Feldman (2019). The failure factor is a key that positively affects success, which may affect other success factors, thus triggering a chain reaction. For example, during the pandemic of Covid-19, supply chain disruptions occurred worldwide (Moosavi, Fathollahi-Fard, &

Dulebenets, 2022). However, some companies can obtain new orders because of the production disruption in regional countries. When examining the cases of technological development, it becomes evident that factors such as high technology costs and the absence of government support often lead many technologies to take an interest in other technologies. In short, some companies' success is due to the problems/failures of certain factors, and only through such opportunities can companies succeed.

Building on the concepts discussed above, we examine the development of Kentucky Fried Chicken (KFC) in Asia as an illustrative example. KFC's decision to sell Portuguese-style egg tarts was a strategic move to align its offerings with local tastes in various Asian markets. This story originates from Lord Stow's Bakery in Macau, where British expatriate Andrew Stow crafted a unique version of the Portuguese "pastel de nata" in 1989. Stow's version gained significant popularity, sparking an egg tart trend throughout East Asia (St Cavish, 2017; Tong, 2017). At the same time, KFC introduced roasted chicken to appeal to Asian consumers. However, the production process differed substantially from their signature fried chicken, requiring significant investment in new equipment. Unfortunately, the sales of roasted chicken did not meet expectations, jeopardizing the return on investment in this new infrastructure (Li, 2024; Lichtenberg, 2012). KFC Asia sought alternative products that could leverage the existing equipment more effectively. The introduction of egg tarts capitalized on the product's rising local popularity and allowed KFC to use its existing equipment without further capital expenditure. In 1999, Margaret Wong, Andrew Stow's ex-wife, sold the recipe rights to KFC, initially launching the egg tarts in Hong Kong and Taiwan before expanding to mainland China and other regions (St Cavish, 2017). The egg tart quickly became a signature dessert for KFC across Asia, prompting the chain to build a dedicated egg tart factory in China to meet growing demand. By 2010, KFC had sold millions of egg tarts, reinforcing the brand's connection with local consumers who appreciated freshly baked goods.

In the academic development of business management, the success/failure system can be conceptualized as illustrated in Figure 4. This framework is beneficial for research that examines how organizations achieve their business goals. We propose a three-tiered structure incorporating various sub-factors influencing success and failure. These sub-factors provide deeper insights into the underlying causes of success or failure within an organization, allowing researchers and practitioners to identify critical areas that impact organizational performance and outcomes. The first level is sub-factors, a new system that should not directly relate to goals. The first level explains the formation factors that affect

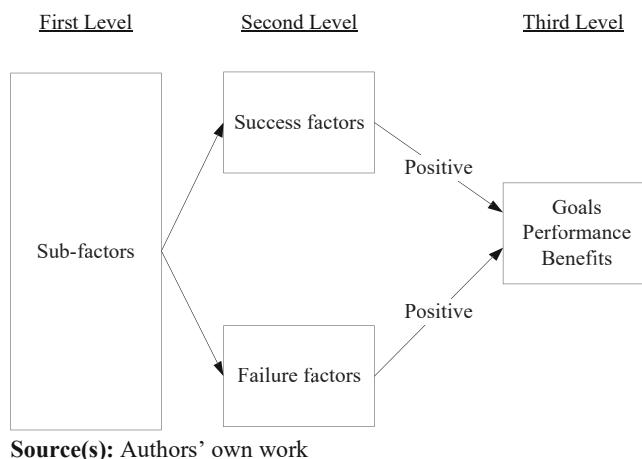


Figure 4. Basic construct model of the success/failure system

the core success and failure factors, and there may be positive or negative relationships between the facets in this level. Moreover, a construct can impact different factors within the second level.

The second level is the core success/failure system. Unlike other theories, it must positively affect the third level. While there may be a relationship between success and failure factors, the success/failure system primarily focuses on the dependency relations within a system. It considers both the system's overall success or failure and its individual components' performance. Thus, we suggest that in the construction of the second level, the relationship between these two factors should not be explored, which will make the model more complicated to explain the relationship between success and failure. In addition, adding confounding factors is acceptable.

The third level involves discussing the enterprise's (organization) goals, which typically revolve around performance, profitability, and value creation. Constructing this model can support the formulation of operational and management strategies and enable adjustments to the operational framework. This model can be applied to various research topics, including marketing, strategy, information systems, organization, and policy, providing fresh insights for academic advancement.

According to the success/failure system construction model, it is advisable to refrain from formulating hypotheses with a mediation effect, as this can lead to confusion. On the other hand, including a moderator effect is acceptable, and it is recommended to situate it between the second and third levels.

The three-tiered structure of the success/failure system is unlike existing frameworks; this model incorporates both factors (success/failure) and their underlying causes, offering a holistic view of organizational dynamics. This innovative perspective allows researchers to capture more complex relationships within organizations and provides fresh avenues for academic inquiry. By incorporating organizational goals at the third level, the model can inform strategic decision-making and the development of operational frameworks. Researchers can apply this model to investigate how businesses adjust strategies to enhance performance and value.

4. Success/failure system to evaluate XAI in business management

From a business perspective, XAI enables enterprises and financial institutions to provide clear and transparent explanations throughout the analysis and decision-making process; this allows both customers and internal decision-makers to understand the AI model's decision-making logic and predictive outcomes, helping organizations effectively manage and mitigate risks. For instance, in Japan's financial sector, XAI technology is widely utilized in credit scoring and loan approval processes. According to research by The Japan Research Institute (2022), the system explains the underlying risks when a customer's loan application is declined. It provides a predictive model recommending how the customer can reduce those risks. By submitting an appropriate improvement plan, customers still have an opportunity to pass the review. This transparency enhances customer satisfaction and strengthens trust in the bank's decision-making process. Additionally, Hitachi Consulting applies XAI in enterprise data analysis to help companies identify potential success and risk factors (Generative AI Media, 2024; Hitachi, 2020). XAI's visual and transparent inferences reveal risks and fail factors that traditional analysis tools often overlook, thus improving corporate decision-making accuracy and risk control capabilities. This study examines the three levels of an organization, from top to bottom, in order of decision-making, management, and operations.

Business management regularly faces intricate decisions encompassing market strategy, supply chain management, and human resources. It is feasible for AI to facilitate automated corporate decision-making to support corporate operations and management. However, it is noteworthy that many of these decisions tend to address structural issues. XAI technology

offers the potential for enhancing decision-making and evolving a new generation of quantifiable, evaluated, and scenario-simulating decision support systems and business intelligence tools. Moreover, XAI requires Calibration to ensure its credibility within the context of a success/failure system. To achieve this, XAI must undergo quantitative evaluation, simulate diverse scenarios, and execute Calibration procedures. Analyzing XAI's performance across various decision-making scenarios allows us to identify its success and failure factors, ultimately enhancing decision support systems and management efficiency.

At the management level, XAI can assist in various tasks, including production, marketing planning, financial forecasting, alerting, and customer relationship management. With XAI's guidance and promptly addressing task requirements, gaining a more precise understanding of the core issue becomes crucial. For instance, companies utilize big data to analyze customer reviews and social media discussions. They employ semantic analysis to categorize text, which necessitates recategorization and interpretation. Typically, negative words are disregarded. In fact, analyzed and compared with negative language to assess customer sentiment. Employing this principle, companies can design their responses to customers more in alignment with their expectations.

Regarding operation, the application scope of XAI can be more diversified, encompassing emerging enhancements in production management, equipment maintenance, real-time customer service, membership management, and more. However, in current applications, the integration of XAI technologies often lacks comprehensive implementation strategies and sufficient customization to meet the specific needs of each business. This limitation makes it challenging to deliver innovative management solutions and services that can effectively bring added value to the enterprise.

For example, consider the inventory management of a retail store. In the past, when the system indicated the need for restocking, it would commence restocking early. According to the success/failure principle of the system, it assumed that the product was out of stock, presenting consumers with roughly three choices: first, to purchase a substitute; second, to visit another store; and third, to abandon the purchase. For both the second and third behaviors, the store would not benefit. Consequently, a store employing an intelligent inventory system can provide restocking information promptly, evaluate potential product substitutes, and determine whether implementing price reductions could attract consumers to make a purchase. Furthermore, companies can leverage the XAI concept in marketing management to design innovative experiential services.

Based on strategy management, how could failure be a contributing factor? Because this failure factor can affect the original success factors or the existing environment to create opportunities. Kakkar and Chitrap (2021) proposed that successful innovation is a factor based on the failure of consumers' acceptance of innovation. The story of "The Hare and The Tortoise" is an example of a simple explanation. Assuming the enterprise plays the role of the tortoise, it can succeed by causing the hare to fail. As for how to make hare fail, it is the principle of competition.

In addition, the black box problem remains a significant challenge for XAI, but it is not entirely insurmountable. By integrating existing XAI technologies, such as SHAP, LIME, and Grad-CAM, a certain level of interpretability can be achieved in business applications, allowing for the identification of key success and failure factors that impact performance. However, the design of this framework should prioritize addressing specific practical objectives, rather than attempting to fully resolve all black box concerns. Future research should further investigate how this framework can adapt to various challenges and propose potential solutions to the black box problem, ultimately enhancing its practical value and effectiveness.

Observing the historical context, the industry will always face a recession or a considerable challenge. In the past 30 years, the development of the Internet and information technology has caused many large enterprises in the 20th century to encounter problems today (e.g. Barnes &

Noble, Kodak). Enterprises are in an environment of continuous competition, and the wrong choice of strategy may lead to failure. The choice of expansion strategy is a method to avoid entry failure, including the extension of technology, product, and market, as well as the reframing of existing product fields.

Several studies have proposed future directions for XAI and how it can lead business activities. Some proposals are based on past research themes and suggest future research directions. We propose a success/failure system and new strategic thinking that expects artificial intelligence to reshape new business activities.

5. Conclusion

This study contributes as follows: First, it provides a comprehensive review of current research papers in business management, offering insights into the volume of research output in this domain. With XAI emerging as a significant trend, we map the trajectory of its integration into business management research. Second, this study explores business management and the case of XAI in business management. The success/failure system framework offers a novel perspective beyond traditional methodologies. It allows for a different structured analysis of dependency relations, providing a novel method to identify the interactions between success and failure factors.

Future research on the success/failure system could focus on expanding its application across various industries, especially in areas where failure is not typically seen as a strategic opportunity, such as technology adoption and crisis management. Empirical validation through case studies or surveys would help confirm its effectiveness. Integrating the success/failure system with established business theories, like innovation resistance or organizational learning, could offer a broader theoretical framework. XAI could optimize its application in business contexts, such as financial distress prediction, by enhancing its interpretability and real-time decision support capabilities. Additionally, exploring the effectiveness of XAI across different fields, including supply chain management and innovation resistance, would further validate its utility. Moreover, adapting XAI models to meet the cultural and market-specific demands across different regions would improve global applicability. Finally, future studies should emphasize how XAI can enhance transparency and build trust among external stakeholders, such as regulators and customers. These directions would further strengthen the role of XAI in business applications and extend its impact.

This study's limitations are as follows: First, we could not access an extensive array of databases due to Internet resource constraints, and we cannot conduct a comprehensive journal survey. Nonetheless, it is essential to note the number of papers on XAI in business management research, which has witnessed a notable increase. Second, the content analysis of the papers in this study relies on the authors' past experiences and the perspectives of other scholars, potentially introducing personal bias into the analysis. Third, this study observed that articles in the database exhibited similarities and were published in different journals. These articles were still included in our count, as we found no justification for excluding them solely based on their diverse sources. Although such instances were not frequent, they did impact the statistical results. Fourth, this study's keywords did not include alternative terms such as "company," "firm," or "corporate," which could have expanded the search results. As a result, the number of relevant papers may have been higher. Fifth, this study systematically examines the potential advancement of XAI in business research, considering both success/failure systems. Depending on the different theoretical frameworks applied, different outcomes may be expected. The success/failure system theory builds upon the concept proposed by Bau (2018a, b). However, this concept needs more empirical support. We anticipate that future research in business management or XAI will construct new research models based on the concepts outlined in this study, thereby establishing a solid academic foundation.

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Unveiling how consumers accept digital-only fashion: an empirical examination building upon the functional theory of attitudes

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Abstract

Purpose – Digital-only fashion represents an ideal fusion of sustainability and fashionability, garnering growing interest among fashion professionals. However, there is a noticeable gap in research focusing on digital-only fashion acceptance among consumers. Hence, this study aims to empirically examine consumers' motivations, evaluations and acceptance of digital-only fashion based on the Functional Theory of Attitudes.

Design/methodology/approach – A US-based research agency was hired to collect data, resulting in 247 completed survey responses. Data analysis was conducted using the Partial Least Squares Structural Equation Modeling (PLS-SEM) approach.

Findings – Testing results highlight that consumer acceptance of digital-only fashion is directly influenced by both overall attitude and self-expressive attitude. Self-expression is particularly pivotal in digital-only fashion acceptance. Adorning avatars and dressing realistic on-screen bodies are distinct yet complementary aspects of using digital-only fashion. Consumers with positive environmental beliefs about digital-only fashion are concerned about how well digital-only fashion items allow them to express such beliefs.

Originality/value – This study innovatively applied the functional theory of attitudes to the emerging domain of digital-only fashion and identified consumers' four functional attitudes toward digital-only fashion, along with the underlying motivations served by each functional attitude. Furthermore, this study provides valuable practical insights across the digital-only fashion value chain.

Keywords Digital fashion, Digital-only fashion, Sustainability, Self-expression, Functional theory of attitudes, Generative artificial intelligence, Partial least squares structural equation modeling (PLS-SEM)

Paper type Research paper

Introduction

The intersection of sustainability and fashionability has spurred significant interest in digital fashion among scholars and fashion industry stakeholders (Baek *et al.*, 2022; Casciani, Chkanikova, & Pal, 2022; Schauman, Greene, & Korkman, 2023; Zhang & Liu, 2024). Embracing dematerialization, digital fashion provides a sustainable alternative to traditional practices by reducing resource-intensive processes (Casciani *et al.*, 2022). This approach, especially in product design and development, decreases material resource consumption, shortens lead time to market, and lowers costs and waste linked with physical sampling (Wagner & Kabalska, 2023). As virtual end-products, digital fashion typically



encompasses two primary forms: digital-twins fashion, which replicates physical garments in virtual spaces, and digital-only fashion, which exists exclusively within digital environments and is not intended for physical production (Chan, Henninger, Boardman, & Blazquez Cano, 2024; Wagner & Kabalska, 2023). Particularly noteworthy, digital-only fashion, a distinct subset of digital fashion, completely bypasses physical production and paves the way for a promising nonphysical economy (Särmäkari & Vänskä, 2021; Schauman *et al.*, 2023).

Digital-only fashion enables designers to unleash their creativity and innovation, resulting in visually stunning and imaginative designs (Särmäkari, 2021; Särmäkari & Vänskä, 2021; Zhang & Liu, 2024). Accordingly, digital-only fashion provides consumers with unparalleled freedom of expression, transcending constraints like material limitations, craftsmanship, size, and societal norms (Baek *et al.*, 2022; Schauman *et al.*, 2023). It can be used to adorn avatars in virtual spaces and to dress realistic on-screen bodies like individuals' images and videos, effectively showcasing diverse identities, fashion preferences, individuality, and social statuses (Chan *et al.*, 2024; Mogaji, Dwivedi, & Raman, 2023). Beyond aesthetic appeal, digital-only fashion offers immersive experiences, heightening hedonic enjoyment (Venturini & Columbano, 2023). Digital-only fashion epitomizes sustainability and fashionability, increasingly appealing to fashion practitioners. For instance, Fabricant, a burgeoning digital fashion enterprise, partnered with blockchain companies, facilitating the auction of the digital-only Iridescence dress for cryptocurrency valued at \$9,500 (Särmäkari & Vänskä, 2021). Established fashion brands such as Balenciaga, Jimmy Choo, and Dolce & Gabbana are introducing exclusive digital-only garments (Mogaji *et al.*, 2023). The emergence of image-generation-systems based on generative artificial intelligence, such as Midjourney and Stable Diffusion, has also provided unprecedented chances for advancing digital-only fashion (Zhang & Liu, 2024). Overall, digital-only fashion holds significant potential to address the environmental challenges posed by physical fashion, while still meeting consumers' fashion preferences and desires.

Existing research largely focuses on digital fashion's role in supporting physical fashion practices, such as 3D apparel design and sampling and virtual try-on services for retail fittings (Baek *et al.*, 2022; Wagner & Kabalska, 2023). A few studies have explored digital fashion as end products for virtual use, particularly for dressing avatars, but have not distinguished digital-only fashion that involves no physical production from general digital fashion. For instance, Zhang, Liu, and Lyu (2023) confirmed that consumers' evaluation of digital fashion influences their intent to purchase luxury brands' digital fashion collections, but this research considered both digital replicas of physical items and virtual designs that may lead to physical production, not purely digital-only fashion. Moreover, Park and Kim (2023) found that consumers' purchase intentions for virtual products can significantly impact their interest in buying the corresponding physical products, indicating that some digital fashion products may ultimately lead to physical production. Thus, it is unclear whether prior studies that focus on digital fashion either as a tool for physical production and consumption or as a kind of general digital product, can meaningfully address physical fashion-related environmental concerns. To date, there is a noticeable gap in research specifically focusing on digital-only fashion, which involves no physical production or consumption, despite its potential significance. This study aims to fill that gap by empirically investigating consumers' motivations, evaluations, and acceptance of digital-only fashion.

The Functional Theory of Attitudes, widely applied in consumer studies, emphasizes that attitudes serve various functions beyond mere evaluation, including utilitarian, value-expressive, social-adjustive, and hedonic functions, to meet individuals' diverse needs (Cho, Kim-Vick, & Yu, 2022; Grewal, Mehta, & Kardes, 2004; Katz, 1960). This theory aids in understanding people's psychological motivations for attitude formation and alteration,

linking underlying motivations to the evaluation and subsequent responses (Katz, 1960). Building upon the Functional Theory of Attitudes, we identified four functional attitudes toward digital-only fashion and their underlying predominant functions. Through an extensive literature review, a research model comprising multiple attitudes and purchase intention in the digital-only fashion context, along with corresponding hypotheses, was proposed. Subsequently, we used the Partial Least Squares Structural Equation Modeling (PLS-SEM) approach to test this model and the predictivity of all identified attitudes.

This study offers both theoretical and practical contributions in three key areas. First, it is among the first to empirically examine how consumers perceive and evaluate digital-only fashion. We differentiate digital-only fashion from general digital fashion, highlight its unique value, and identify four key applications of digital-only fashion as end-products. Second, we applied the Functional Theory of Attitudes to the emerging field of digital-only fashion. Through this theoretical lens, we identified consumers' four functional attitudes toward digital-only fashion, along with the underlying motivations. Our findings confirm the importance of both evaluative and functional attitudes in shaping consumer acceptance of digital-only fashion. Third, this study provides practical guidance for professionals throughout the digital-only fashion value chain and offers important insights to relevant stakeholders. Overall, these contributions establish our study as a seminal piece in the digital-only fashion field, with the potential to help address sustainability issues in traditional fashion production and consumption.

Literature review

Digital-only fashion

The existing literature lacks a precise definition of digital-only fashion for consumer use, but three key characteristics can clarify it. Firstly, digital-only fashion items are dematerialized, existing solely in digital realms without physical production or associated practices (Casciani *et al.*, 2022). This sets digital-only fashion end-products apart from digital twins or 3D digital design models, which simulate physical fashion products either transitioning from physical to virtual or from virtual to physical (Wagner & Kabalska, 2023). Secondly, digital-only fashion is typically visually captivating, showcasing creativity, imagination, and high aesthetic value (Särmäkari & Vänskä, 2021). Thirdly, consumers can acquire and utilize digital-only fashion to adorn their avatars (digital identities) and realistic on-screen bodies (physical identities) within virtual reality environments (Zhang *et al.*, 2023). Therefore, digital-only fashion can be defined as virtual apparel and accessories exclusively existing in virtual environments, designed to dress avatars or realistic on-screen bodies, presenting visually appealing effects.

In today's fashion landscape, consumers face a dilemma: the desire for ever-changing fashion choices for self-expression and communication clashes with growing concerns about the textile industry's environmental harm (Schauman *et al.*, 2023). Digital-only fashion emerges as a promising solution to alleviate this conflict. With the rapid advancement of digital technologies, online activities like work, study, shopping, and entertainment have become increasingly integrated into daily life (Mogaji *et al.*, 2023; Willcocks, 2024). Digital-only fashion enables consumers to express themselves freely in virtual reality by offering unlimited creative possibilities, meanwhile reducing physical fashion consumption (Casciani *et al.*, 2022; Chan *et al.*, 2024; Särmäkari, 2021).

By dressing avatars that typically represent digital identities in 3D gaming realms or metaverse-related social platforms, individuals can present multiple personas, protect privacy through anonymity, and assume desired forms, even as fantasy characters (Park & Chun, 2023; Patruti, Zbuc̄ea, & Pinzaru, 2023). On the other hand, digital-only fashion facilitates the styling of consumers' realistic on-screen bodies through techniques such as virtual try-ons using Augmented Reality (AR) filters and direct alterations of clothing in

images or videos using Generative Artificial Intelligence (GAI) technologies (Venturini & Columbano, 2023; Zhang & Liu, 2024). When shared on social media, individuals dressed in digital fashion attire on their realistic on-screen bodies can be easily recognized by their peers and families, enhancing their real-world identities. By embracing digital-only fashion, consumers can reduce their reliance on physical fashion consumption and express themselves freely in virtual worlds; thereby enjoying guilt-free excitement (Schauman *et al.*, 2023). The key distinction between avatars and realistic on-screen bodies lies in the degree of resemblance to users' physical appearances. Specifically, the term "avatar," whether in 2D or 3D form, refers to a representation distinct from the user's actual appearance, while "on-screen body" denotes a depiction closely resembling an individual's physical attributes, particularly focusing on facial features, indicating a high degree of fidelity or realism. In summary, there are four typical applications of digital-only fashion: enhancing avatars (Patruti *et al.*, 2023), styling realistic on-screen bodies (Zhang *et al.*, 2023), enabling self-expression (Venturini & Columbano, 2023), and advancing environmental sustainability (Schauman *et al.*, 2023).

Most previous research has not distinguished between digital fashion as end products and digital tools that support physical fashion practices until the term "Metaverse" gained widespread attention in 2021 (Chan *et al.*, 2024). Metaverse refers to an evolving network that integrates various virtual environments and features a unique interconnection between digital spaces and the physical world (Barrera & Shah, 2023; Cheng *et al.*, 2022; Lee *et al.*, 2021). As the Metaverse progresses, virtual environments for presenting and disseminating digital fashion have expanded beyond gaming worlds to include various social platforms such as Roblox, Animal Crossing, Minecraft, and Sandbox, among others (Park & Kim, 2023; Venturini & Columbano, 2023). As such, digital fashion products designed for consumer use have drawn increasing scholarly interest. For example, a qualitative study using semi-structured interviews identified five key consumption values associated with fashion in the Metaverse: utilitarianism, social identity, personification, hedonism, and personal beliefs (Venturini & Columbano, 2023). Additionally, an empirical study using an online survey revealed that dressing avatars and realistic on-screen bodies are two central ways consumers engage with digital fashion products (Zhang *et al.*, 2023).

However, existing literature reveals seemingly conflicting findings regarding consumers' perceptions of digital fashion. For instance, Luong, Tarquini, Anadol, Klaus, and Manthiou (2024) found that consumers expressed concerns about the aesthetics and perceived value of digital fashion products based on an analysis of YouTube comments. In contrast, Schauman *et al.* (2023) identified four emerging consumer expectations of digital fashion, particularly from a sustainability perspective. A recent literature review research traced the development of digital fashion from tools supporting physical fashion design and retail to virtual products sold to consumers, identifying six types of digital fashion products: digital skins for gamified environments, digital skins for virtual influencers, image-based superimposed fashion, AR filter-based fashion, fashion NFTs, and digital twins (Chan *et al.*, 2024). While these products may be sold entirely in digital formats, they cannot all be classified as digital-only fashion since some, like digital twins, are digital replicas of physical garments. These highlight the need for research that focuses specifically on digital-only fashion from the consumer perspective. Since digital-only fashion is still in its early stages, it is critical to comprehend how consumer acceptance is influenced by underlying motivations and evaluations regarding the applications of digital-only fashion.

Theoretical background and research framework

According to the Functional Theory of Attitudes, individuals' attitudes are formed, shaped, or altered by the perceived functions of the relevant attitudinal objects, which are believed to

satisfy their needs or desires (Katz, 1960). This theory aims to understand the underlying psychological motivations that drive individuals to form or change attitudes (Katz, 1960). Scholars in consumer studies have confirmed four typical functions served by attitudes, including utilitarian, value-expressive, social-adjustive, and hedonic functions (Cho *et al.*, 2022; Grewal *et al.*, 2004; Katz, 1960). These underlying functions contribute to individuals' evaluative outcomes, satisfying their needs and preferences, consequently exerting a profound influence on subsequent cognitive and emotional responses and behaviors (Cho *et al.*, 2022; Katz, 1960).

The Functional Theory of Attitudes aids in identifying and understanding underlying dynamics that may impact consumers' acceptance of digital-only fashion. Guided by this theory, we identified four key functional attitudes toward digital-only fashion and developed a conceptual model with corresponding hypotheses. First, adorning avatars using digital clothing and accessories has been long well-received among gamers (Chan *et al.*, 2024). This represents a fundamental application of digital-only fashion, particularly catering to consumers' hedonic needs, as digital-only fashion is known for its visually striking designs, allowing users to express a variety of desired identities and immerse themselves in fantasy environments (Särmäkari & Vänskä, 2021; Venturini & Columbano, 2023). According to the Functional Theory of Attitudes, the hedonic function relates to the positive emotions generated by an attitudinal object (Grewal *et al.*, 2004). As a result, we identify the attitude toward dressing avatars (ADA) as one of the functional attitudes regarding digital-only fashion, mainly serving the hedonic function. ADA denotes the assessment of utilizing digital-only fashion to adorn avatars distinct from users' physical appearances.

Second, the emerging application of dressing people's realistic on-screen bodies in digital-only fashion has garnered increasing popularity, especially among young consumers who enjoy receiving likes and comments on their digital outfits through social media (Chan *et al.*, 2024; Mogaji *et al.*, 2023). Resembling physical fashion presentation, this application could enhance people's real-world identities and social statuses (Casciani *et al.*, 2022; Schauman *et al.*, 2023). The Functional Theory of Attitudes indicates that the social-adjustive function focuses on gaining social approval or fitting into social groups (Cho *et al.*, 2022). The social-adjustive function may be the primary motivator for this application of digital-only fashion. As such, we identified the attitude toward dressing on-screen body (ADO) as a functional attitude toward digital-only fashion, denoting the evaluation of using digital-only fashion to adorn individuals' realistic on-screen bodies that closely resemble their physical appearances.

Third, according to the Functional Theory of Attitudes, the utilitarian function concerns the effectiveness of attitudinal objects in fulfilling specific needs, often achieved by maximizing external rewards and minimizing related punishments (Katz, 1960). The leading utilitarian function of digital-only fashion lies in its potential for environmental contributions due to its fully dematerialized nature (Casciani *et al.*, 2022; Särmäkari & Vänskä, 2021). Thus, we identify environmental attitude (EA) toward digital-only fashion as a functional attitude, representing consumer evaluation of the extent to which digital-only fashion can contribute to environmental protection.

Fourth, digital-only fashion allows consumers to express themselves freely by showcasing various identities, enhancing their real-life personas, and communicating their core values (Chan *et al.*, 2024; Särmäkari, 2021). Self-expression has emerged as a key motivation for consumers across various uses of digital-only fashion. The Functional Theory of Attitudes suggests that the value-expressive function refers to the positive expression of personal values, beliefs, and self-images (Katz, 1960). Accordingly, we identified self-expressive attitude (SA) toward digital-only fashion as a crucial functional attitude, mainly serving the value-expressive function. SA represents consumers' assessment of using digital-only fashion to convey self-images, values, and beliefs.

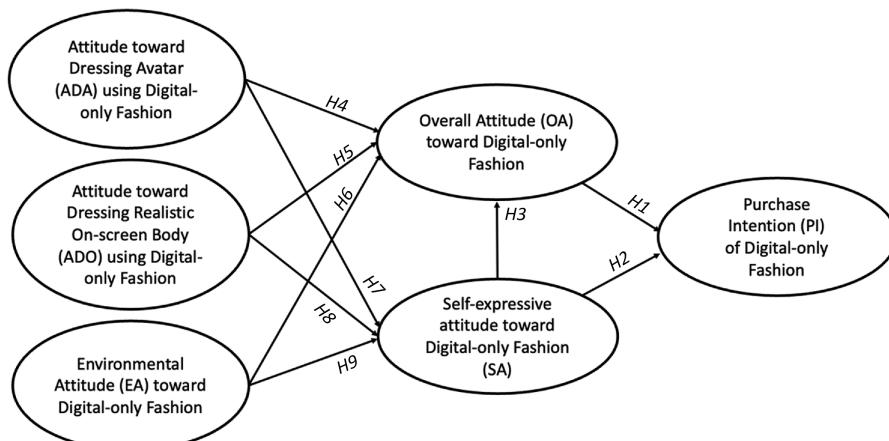
Figure 1 illustrates our proposed research model, which examines four functional attitudes, overall attitude, and purchase intention related to digital-only fashion. In this conceptual framework, three of the identified functional attitudes, each linked to one key application of digital-only fashion, act as antecedents, as they likely influence consumers' overall evaluations of digital-only fashion based on distinctive predominant motivations. Self-expression plays a dual role, functioning as both a motivation and an outcome in virtual consumption (Park, Ko, & Do, 2023; Venturini & Columbano, 2023). Consequently, the functional attitude, SA, is considered both an independent and dependent variable in this model. Overall attitude also functions as both an independent and dependent variable, while purchase intention is the ultimate dependent variable.

Hypotheses development

Purchase intention, a subset of customer behavioral intention, signifies consumers' conscious willingness to engage in specific acceptance behaviors (Spears & Singh, 2004). The attitude commonly refers to an individual's predisposition to evaluate specific objects either favorably or unfavorably (Katz, 1960). Numerous studies across diverse domains have consistently confirmed the positive link between evaluative attitude and purchase intention, including the fashion industry (e.g. Cho *et al.*, 2022; Park, Jeon, & Sullivan, 2015; Spears & Singh, 2004). In this study, purchase intention (PI) specifically denotes consumers' intent to acquire digital-only fashion products, while overall attitude (OA) reflects consumers' evaluative attitudes toward digital-only fashion products. Consequently, we proposed the following hypothesis:

- H1.* Overall attitude (OA) toward digital-only fashion influences purchase intention (PI) of digital-only fashion.

Consumers aim to affirm their self-concepts and convey core values by acquiring items that align with their goals (Stuppy, Mead, & Van Osselaer, 2020). In traditional fashion consumption, consumers buy and utilize apparel and accessories as communicative tools to express and refine a unified self-concept, embodying either an ideal or authentic self and conveying cherished beliefs and values (Anand & Kaur, 2018). Similarly, in virtual environments, purchasing digital fashion items can also serve as a means to express



Source(s): Authors' own work

Figure 1.
Proposed
research model

consumers' consistent self-images and communicate their beliefs (Patruti *et al.*, 2023; Schauman *et al.*, 2023). According to the Functional Theory of Attitudes, the value-expressive function of attitudes plays a crucial role in shaping consumer behavior (Katz, 1960). Hence, self-expression is likely a crucial factor motivating consumers to purchase digital-only fashion, driven by their value-expressive motivations. Accordingly, individuals with positive self-expressive attitudes toward digital-only fashion may be inclined to purchase digital-only fashion items, leading to the following hypothesis:

H2. Self-expressive attitude (SA) toward digital-only fashion impacts purchase intention (PI) of digital-only fashion.

As per the Functional Theory of Attitudes, while attitudes may serve multiple functions, a certain functional attitude primarily aligns with a specific motivational process context (Katz, 1960). In other words, a primary psychological factor tends to guide the motivation process for each functional attitude (Cho *et al.*, 2022). In this study, the four identified functional attitudes are associated with key applications of digital-only fashion: adorning avatars, dressing people's on-screen bodies, reducing environmental harms of physical fashion, and self-expression. While each functional attitude may address different consumer needs, one predominant function behind a specific attitude typically drives the motivation process for how consumers engage with digital-only fashion.

Self-expression is a key application for consumers of digital-only fashion. While the self-expressive attitude may fulfill various functions, the value-expressive function, centered on expressing self-images and conveying beliefs, is likely to be the main driver motivating consumers to use virtual attire for self-expression. The hedonic function, which emphasizes the enjoyment of pleasurable experiences, is expected to be the primary motivation for consumers' attitudes toward using digital-only fashion to dress avatars. The major reason lies in avatars allow users to customize their appearance to reflect any desired identity. Similar to physical fashion consumption, individuals using digital-only fashion to dress their realistic on-screen bodies can enhance their real-world identities (Casciani *et al.*, 2022; Schauman *et al.*, 2023). In this case, the social-adjustive function, which is concerned with gaining social approval, tends to be the primary motivator behind consumer attitudes toward dressing on-screen bodies in digital-only fashion. Additionally, to support environmental protection and sustainability, consumers may shift their fashion habits by reducing physical purchases and favoring expressive and creative digital-only fashion (Särnäkari & Vänskä, 2021; Schauman *et al.*, 2023). As such, the utilitarian function tied to environmental protection may serve as the primary motivation behind consumers' environmental attitudes toward digital-only fashion.

In certain contexts, consumers may form multiple attitudes that coexist in a hierarchical structure (Bian & Forsythe, 2012). When faced with these different attitudes, consumers mentally activate them in a prioritized sequence, with attitudes toward specific targets being more prominent (Harben & Kim, 2008). According to the Functional Theory of Attitudes, consumers' overall evaluation could be shaped by their functional attitudes, which address their particular needs and desires, within a particular context (Katz, 1960). Therefore, the four identified functional attitudes, each driven by distinct primary motivations, are likely to collectively influence consumers' overall attitudes toward digital-only fashion.

Specifically, consumers with favorable self-expressive attitudes toward digital-only fashion may tend to hold a positive overall assessment of it, mainly driven by value-expressive function. Consumers who hold satisfactory attitudes toward accepting digital-only fashion for avatar dressing may also maintain a positive overall attitude toward digital-only fashion, primarily motivated by hedonic function. Consumers' attitudes toward dressing their on-screen bodies in digital-only fashion attire may impact their overall attitude toward digital-only fashion, particularly propelled by the social-adjustive function.

Consumers who perceive the environmental benefits of digital-only fashion positively are likely to have a favorable overall attitude toward it, driven by its perceived utilitarian function. The following hypotheses are accordingly proposed:

- H3.* Self-expressive attitude (SA) toward digital-only fashion affects overall attitude (OA) toward digital-only fashion.
- H4.* Attitude toward dressing avatar (ADA) using digital-only fashion affects overall attitude (OA) toward digital-only fashion.
- H5.* Attitude toward dressing realistic on-screen body (ADO) using digital-only fashion affects overall attitude (OA) toward digital-only fashion.
- H6.* Environmental attitude (EA) toward digital-only fashion affects overall attitude (OA) toward digital-only fashion.

Utilizing fashion items to express either ideal or real selves and convey core values is crucial for individuals engaging in fashion consumption (Casciani *et al.*, 2022; Mogaji *et al.*, 2023; Orzada & Kallal, 2021). In the context of digital-only fashion, self-expression can serve both as a motivation and an objective across various scenarios, such as showcasing different personas, highlighting social status, and communicating core values, fashion tastes, and preferences (Casciani *et al.*, 2022; Chan *et al.*, 2024; Särmäkari, 2021). According to the Functional Theory of Attitudes, the perceived functions of the attitudinal objects play a pivotal role in influencing and altering consumers' attitudes (Katz, 1960). Consequently, if consumers tend to primarily express themselves or their core values through various applications of digital-only fashion, the predominant motivator behind the three functional attitudes (ADA, ADO, and EA) may shift to the value-expressive function.

Dressing avatars using digital-only fashion items not only enhances hedonic experiences but also enables users to socialize and express their cherished concepts and values freely (Park & Chun, 2023; Patruti *et al.*, 2023). This includes representing underrepresented and marginalized cultures through diverse identities that diverge from mainstream voices (Särmäkari, 2021). Hence, consumers who appreciate dressing avatars with digital-only fashion may tend to hold favorable self-expressive attitudes toward it, leading to the following hypothesis:

- H7.* Attitude toward dressing avatar (ADA) affects self-expressive attitude (SA) toward digital-only fashion.

Previous studies indicate that consumers have a preference for sharing photos or videos showcasing their realistic on-screen bodies dressed in digital fashion attire on social media platforms and seeking comments or compliments similar to those received when displaying physical fashion items (Chan *et al.*, 2024; Schauman *et al.*, 2023; Venturini & Columbano, 2023). This suggests a tendency to use digital-only fashion items to enhance consumers' real-world self-images. As such, consumers who hold a positive attitude toward dressing their on-screen bodies in digital-only fashion may also shape satisfactory self-expressive attitudes toward digital-only fashion. Accordingly, the succeeding hypothesis is proposed:

- H8.* Attitude toward dressing realistic on-screen body (ADO) impacts self-expressive attitude (SA) toward digital-only fashion.

Existing research has shown that environmentally conscious consumers tend to adopt sustainable consumption practices (Cheng, Chang, & Lee, 2020). Nowadays, consumers show increased awareness of the environmental harm associated with the fashion industry (Casciani *et al.*, 2022; Wagner & Kabalska, 2023). They acknowledge and advocate for collective efforts in addressing sustainability concerns (Schauman *et al.*, 2023). Accordingly,

consumers who perceive the environmental benefits of digital-only fashion positively may seek to express these beliefs and garner more public attention. Thus, spurred by the reinforcement of self-images and the efficient communication of values and beliefs, consumers who positively perceive the environmental advantages of digital-only fashion may tend to hold favorable self-expressive attitudes toward it. As a result, the following hypothesis is formulated:

- H9. Environmental attitude (EA) toward digital-only fashion influences self-expressive attitude (SA) toward digital-only fashion.

Research method

Research instrument

An online survey was developed and administered via Qualtrics. The survey started with the institutional review board (IRB) approval information and an introduction to digital-only fashion, comprising the definition, the salient attributes, and the difference between avatar and on-screen body, along with a set of digital-only fashion visual references. This section aims to ensure that survey participants can comprehend and distinguish digital-only fashion products and their associated applications. To confirm participants' understanding of the key concepts, we then utilized true-or-false filtering questions. One example was: "Digital-only fashion refers to a type of fashion that typically features visually appealing effects and is not intended for physical production. Is this statement True or False?" The subsequent section included multi-item scales to assess research constructs. The final part of the survey included questions to collect demographic information.

All six research constructs were assessed through multi-item scales either adopted or adapted from previous research (see Table 1). In this study, self-expressive attitude (SA) refers to how consumers evaluate using digital-only fashion to express their self-image and core values. To measure this, we adapted the fashion self-congruity scale developed by Anand and Kaur (2018), which has been extensively employed to empirically assess how well consumers perceive fashion items or brands align with their actual and ideal self-images (e.g. Kaur & Anand, 2021; Legere & Kang, 2020; Xue, Caiguo, Yi, & Chenxia, 2022). SA was measured using eight items, based on this established scale. SA employed a 7-point Likert scale, with 1 indicating "strongly disagree" and 7 denoting "strongly agree". Environmental attitude (EA) represents consumer evaluation of how much digital-only fashion can contribute to environmental protection. This concept aligns with a well-established and widely verified measurement scale of consumer involvement, which gauges the extent of consumers' engagement with specific objectives (e.g. Hollebeek, Glynn, & Brodie, 2014; Zheng, Li, & Na, 2022). Consequently, we adapted the EA scale from Zaichkowsky (1985), utilizing a 7-point bipolar semantic scale to assess this variable. The semantic differential scales for measuring attitude and purchase intention, developed by Spears and Singh (2004), have been widely utilized and validated by researchers in the fashion industry, including both physical and digital fashion consumption contexts (e.g. Gomes, Marques, & Dias, 2022; Johnstone & Lindh, 2022; Zhang *et al.*, 2023). Therefore, the other four constructs—overall attitude (OA), attitude toward dressing avatar (ADA), attitude toward dressing realistic on-screen body (ADO), and purchase intention (PI)—also utilized a 7-point bipolar semantic scale and were adopted from Spears and Singh (2004).

Sample and sampling

A U.S.-based research firm was hired to manage participant recruitment and data collection. Our survey link was disseminated to individuals within this firm's consumer panel. Out of 333 responses, 247 participants completed the survey after passing attention-check

Construct	Indicators	Coding	References	Journal of Electronic Business & Digital Economics
Self-expressive attitude toward digital-only fashion (SA)	<p><i>How do you evaluate the self-expression function of digital-only fashion?</i></p> <p>Digital-only fashion style can be consistent with how I see myself</p> <p>Digital-only fashion style can be a part of my identity</p> <p>Digital-only fashion clothing can be an important tool to express my self-image</p> <p>Using digital-only fashion items could enhance my self-image before others</p> <p>Digital-only fashion clothes could reflect how I feel about myself</p> <p>Digital-only fashion clothes could help me become the person I want to be</p> <p>Digital-only fashion clothes could help me achieve the identity I want to have</p> <p>Digital-only fashion clothes could help me narrow the gap between what I am and what I try to be</p>	<p>SA1</p> <p>SA2</p> <p>SA3</p> <p>SA4</p> <p>SA5</p> <p>SA6</p> <p>SA7</p> <p>SA8</p>	Anand and Kaur (2018)	
Overall attitude toward digital-only fashion (OA)	<p><i>How do you evaluate digital-only fashion in general?</i></p> <p>Unappealing..... Appealing</p> <p>Unlikable..... Likable</p> <p>Bad..... Good</p> <p>Unpleasant..... Pleasant</p> <p>Unfavorable..... Favorable</p>	<p>OA1</p> <p>OA2</p> <p>OA3</p> <p>OA4</p> <p>OA5</p>	Spears and Singh (2004)	
Attitude toward dressing avatar in digital-only fashion (ADA)	<p><i>How do you evaluate using digital-only fashion to dress avatars that are different from your real appearance?</i></p> <p>Unappealing..... Appealing</p> <p>Unlikable..... Likable</p> <p>Bad..... Good</p> <p>Unpleasant..... Pleasant</p> <p>Unfavorable..... Favorable</p>	<p>ADA1</p> <p>ADA2</p> <p>ADA3</p> <p>ADA4</p> <p>ADA5</p>	Spears and Singh (2004)	
Attitude toward dressing realistic on-screen body in digital fashion (ADO)	<p><i>How do you evaluate using digital-only fashion to dress your realistic on-screen body?</i></p> <p>Unappealing..... Appealing</p> <p>Unlikable..... Likable</p> <p>Bad..... Good</p> <p>Unpleasant..... Pleasant</p> <p>Unfavorable..... Favorable</p>	<p>ADO1</p> <p>ADO2</p> <p>ADO3</p> <p>ADO4</p> <p>ADO5</p>	Spears and Singh (2004)	
Purchase intention of digital-only fashion (PI)	<p><i>Describing your intention to purchase digital-only fashion items in the future</i></p> <p>Definitely not buy it..... Definitely buy it</p> <p>Very low..... High purchase interest</p> <p>Probably not..... Probably buy it</p> <p>Definitely do not intend to buy.....</p> <p>Definitely intend to buy</p>	<p>PI1</p> <p>PI2</p> <p>PI3</p> <p>PI4</p>	Spears and Singh (2004)	
Environmental attitude toward digital-only fashion (EA)	<p><i>How do you evaluate the environmental benefits of digital-only fashion?</i></p> <p>Unimportant..... Important</p> <p>Means nothing to me..... Means a lot to me</p> <p>superfluous..... vital</p> <p>Does not matter to me..... Matters to me</p>	<p>EA1</p> <p>EA2</p> <p>EA3</p> <p>EA4</p>	Zaichkowsky (1985)	
Source(s): Authors' own work				

Table 1.
Constructs and
corresponding
measurement

questions. The majority of participants were females (75.3%, $n = 186$), followed by males (23.9%, $n = 59$), with a few choosing not to disclose their gender (0.8%, $n = 2$). The age groups were distributed as follows: 18–25 years (66%, $n = 163$), 26–34 years (4.9%, $n = 12$), 35–54 years (15.8%, $n = 39$), and 55–64 years (13.4%, $n = 33$). The ethnicity breakdown showed: Caucasian/White (68.4%, $n = 169$), African American (12.1%, $n = 30$), Asian (8.9%, $n = 22$), Hispanic (6.9%, $n = 17$), American Indian (0.8%, $n = 2$), and Other (2.8%, $n = 7$). In terms of education, 77% ($n = 190$) held a bachelor's degree, 15.4% ($n = 38$) had a high school diploma, and 7.3% ($n = 18$) had a graduate or professional degree, with one participant (0.4%) choosing not to disclose.

Data analysis

Data analysis, including both exploratory factor analysis (EFA) and Partial Least Squares Structural Equation Modeling (PLS-SEM), was conducted using the R programming language and RStudio software. Compared to covariance-based SEM, PLS-SEM offers greater statistical predicting power without stringent assumptions of multivariate normality (Hair, Hult, Ringle, Sarstedt, & Ray, 2021). PLS-SEM provides greater statistical predictive power than Covariance-Based Structural Equation Modeling (CB-SEM), making it especially useful for identifying relationships in smaller sample sizes and intricate models without needing distributional assumptions (Hair *et al.*, 2021). Dissimilar to CB-SEM, which uses confirmatory factor analysis (CFA) for construct assessment, PLS-SEM evaluates construct reliability and validity by assessing the measurement model.

Results

Exploratory factor analysis

Harman's Single-Factor Test was conducted to address the concern of common method bias. The result shows that a total variance of 0.46 was extracted by one factor, below the recommended threshold of 0.5. Therefore, no common method bias was found (Fuller, Simmering, Atinc, Atinc, & Babin, 2016). Exploratory Factor Analysis (EFA) identified six constructs with 31 items, explaining approximately 85% of the total variation. Communalities extraction loadings range from 0.74 to 0.95, and the Kaiser–Meyer–Olkin measure of sampling adequacy (KMO) is robust at 0.94, indicating that the data dataset is appropriate for factor analysis. Additionally, EFA indicator loadings range from 0.79 to 0.90, indicating the reliability of the research constructs. Key results of EFA analysis are summarized in Table 2.

Assessment of the measurement model

Evaluating reflective measurement models involves assessing measurement reliability at both the indicator (indicator reliability) and construct (internal consistency reliability) levels (Hair *et al.*, 2021). Convergent validity is examined through the average variance extracted (AVE), while the heterotrait–monotrait (HTMT) ratio of correlations is employed to gauge discriminant validity among reflectively measured constructs (Hair *et al.*, 2021). The indicator loadings for all constructs, ranging from 0.80 to 0.98, surpass the threshold of 0.708 (Hair, Risher, Sarstedt, & Ringle, 2019), demonstrating satisfactory reliability. All Cronbach's alpha (between 0.93 and 0.98) and the composite reliability rho_A (between 0.96 and 0.98) values exceed the threshold of 0.70 (Hair *et al.*, 2019), indicating the internal consistency reliability of all construct measures.

Convergent validity is evidenced by the AVE values (ranging from 0.79 to 0.94) well above the 0.50 minimum requirement (Hair *et al.*, 2019). All HTMT values are significantly below the threshold of 0.85, supporting the discriminant validity (Hair *et al.*, 2021). The

Items	E-L	C-L	I-L	Alpha	AVE	ρ_A
OA1	0.84	0.88	0.94			
OA2	0.84	0.85	0.92	0.96	0.86	0.96
OA3	0.83	0.87	0.93			
OA4	0.83	0.86	0.92			
OA5	0.83	0.87	0.93			
EA1	0.90	0.84	0.93			
EA2	0.90	0.89	0.95	0.93	0.82	0.97
EA3	0.87	0.74	0.80			
EA4	0.85	0.87	0.94			
ADA1	0.90	0.93	0.96			
ADA2	0.90	0.93	0.96	0.98	0.93	0.98
ADA3	0.89	0.94	0.97			
ADA4	0.89	0.92	0.96			
ADA5	0.88	0.93	0.96			
ADO1	0.87	0.92	0.96			
ADO2	0.85	0.90	0.95	0.98	0.93	0.98
ADO3	0.85	0.95	0.97			
ADO4	0.85	0.93	0.96			
ADO5	0.83	0.93	0.97			
SA1	0.84	0.79	0.88			
SA2	0.84	0.78	0.88			
SA3	0.82	0.82	0.90	0.96	0.79	0.96
SA4	0.82	0.82	0.89			
SA5	0.81	0.79	0.88			
SA6	0.81	0.81	0.90			
SA7	0.81	0.82	0.90			
SA8	0.79	0.79	0.89			
PI1	0.86	0.93	0.96			
PI2	0.86	0.95	0.98	0.98	0.94	0.98
PI3	0.85	0.95	0.97			
PI4	0.85	0.94	0.97			

Note(s): E-L, EFA indicator loading; C-L, Communities extraction loading; I-L, Indicator loadings in the PLS-SEM analysis; AVE, average variance extracted value; alpha, Cronbach's alpha value; ρ_A , composite reliability ρ_A value

Source(s): Authors' own work

Table 2.
Key results of EFA
analysis and construct
assessment in
PLS-SEM

bootstrapping procedure (10,000 bootstrap samples) of the HTMT test further confirmed the discriminant validity, as the upper boundaries of confidence intervals consistently remain below the threshold of 0.85 (Hair *et al.*, 2021), indicating that all the research constructs are distinct. The major results of the measurement model evaluation are also presented in Table 2.

Assessment of the structural model

All Variance Inflation Factor (VIF) values in the structural model are well below the value of 2, indicating no collinearity issues among predictor constructs (Hair *et al.*, 2021). The coefficient of determination (R^2) values for the endogenous constructs were assessed, signifying the proportion of variance explained in each endogenous construct and serving as an indicator of the model's explanatory capacity (Hair *et al.*, 2021). The R^2 values for these three endogenous variables are respectively SA (0.342), OA (0.443), and PI (0.424).

The model's predictive power signifies its capacity to predict new observations out-of-sample (Hair *et al.*, 2021). To assess the predictive power of the structural model, the

PLS_{predict} procedure with $k = 10$ folds and 10 repetitions was employed. The assessment of prediction errors should focus on the model's key endogenous construct (Hair *et al.*, 2021), therefore, our attention centers on PI and its associated indicators. Examination of the prediction error distributions reveals their relative symmetry, justifying the use of the root-mean-square error (RMSE) for the assessment (Hair *et al.*, 2021). Results show that three out of four PI indicators in the PLS path model exhibit lower RMSE values compared to the Linear Modeling (LM) model benchmark: PI_2 (PLS, 1.615; LM, 1.621), PI_3 (PLS, 1.668; LM, 1.678), and PI_4 (PLS, 1.585; LM, 1.594). Therefore, this structural model exhibits a medium-to-high out-of-sample predictive power (Hair *et al.*, 2021).

Hypotheses testing results

Results reveal that eight out of nine proposed hypotheses are supported (see Figure 2). The significance and relevance of path coefficients were assessed using the bootstrapping (10,000 samples) procedure. All path coefficients in hypotheses, except for H6 (EA → OA), are significant, as the value zero lies outside the 95% confidence interval (Hair *et al.*, 2021).

Table 3 presents the detailed results of the hypotheses testing. Regarding the relevance of path coefficients, SA (0.58, $p < 0.001$, H2) exhibits a stronger influence on PI compared to OA (0.13, $p < 0.05$, H1). OA is most impacted by ADA (0.33, $p < 0.001$, H4), followed by ADO (0.30, $p < 0.001$, H5) and SA (0.17, $p < 0.05$, H3). SA is most influenced by ADO (0.35, $p < 0.001$, H8), followed by EA (0.25, $p < 0.001$, H9) and ADA (0.17, $p < 0.05$, H7).

Post hoc mediation analysis

We further conducted mediation analysis by using the bootstrapping (10,000 samples) procedure to examine and confirm the mediating role of OA and SA. Results show that OA mediates the relationship between ADA and PI ($t = 1.99$, $p < 0.05$) and the association between ADO and PI ($t = 1.79$, $p < 0.05$). Notably, SA demonstrates a significant mediating role in three relationships: ADA→SA→PI pathway ($t = 2.27$, $p < 0.05$), ADO→SA→PI pathway ($t = 3.89$, $p < 0.001$), and EA→SA→PI pathway ($t = 4.2$, $p < 0.001$).

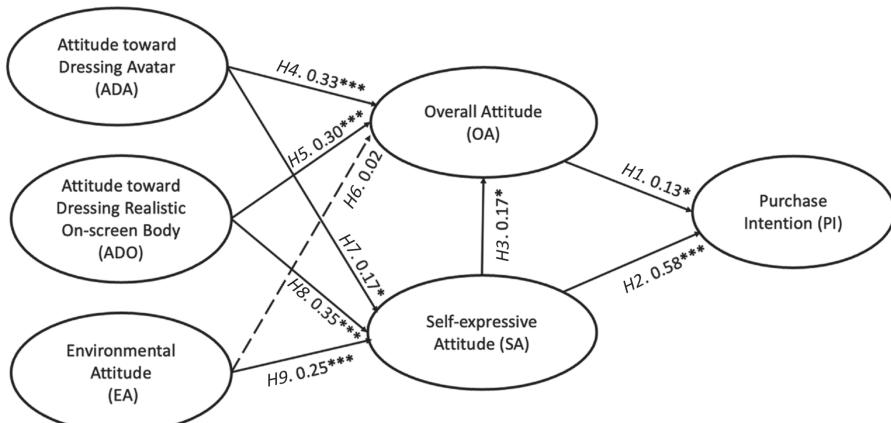


Figure 2.
Hypotheses testing
result overview

Note(s): *, $p < 0.05$; ***, $p < 0.001$; numbers, path coefficients; solid lines, supported hypotheses; dash line, rejected hypothesis

Source(s): Authors' own work

Table 3.
Results of hypotheses
testing

Hypotheses	O-Est	B-mean	B-SD	T-stat	2.50% CI	97.50% CI	Result
H1 OA → PI	0.130	0.129	0.059	2.215*	0.017	0.247	Supported
H2 SA → PI	0.581	0.581	0.054	10.681***	0.469	0.682	Supported
H3 SA → OA	0.174	0.175	0.068	2.560*	0.043	0.306	Supported
H4 ADA → OA	0.327	0.324	0.071	4.627***	0.182	0.459	Supported
H5 ADO → OA	0.302	0.302	0.074	4.079***	0.159	0.449	Supported
H6 EA → OA	0.021	0.023	0.056	0.387	-0.088	0.130	Not Supported
H7 ADA → SA	0.169	0.167	0.074	2.298*	0.021	0.311	Supported
H8 ADO → SA	0.346	0.347	0.076	4.555***	0.199	0.497	Supported
H9 EA → SA	0.254	0.257	0.059	4.313***	0.140	0.371	Supported

Note(s): O-Est, original values of the path coefficients; B-Mean, Bootstrap mean; B-SD, Bootstrap standard deviation; T-stat, t-values; CI, Confidence Interval; ***, p-value <0.001; **, p-value <0.01, *, p-value <0.05

Source(s): Authors' own work

Discussions and implications

Discussions on testing results

This study confirms the positive relationship between the overall evaluative attitude and purchase intention in the context of consumer acceptance of digital-only fashion. This finding is consistent with observations in both physical and digital contexts, including digital fashion consumption (Park *et al.*, 2015; Spears & Singh, 2004; Zhang *et al.*, 2023). Our testing results highlight the substantial influence of the self-expressive attitude on the intention to purchase digital-only fashion. This suggests that consumers' adoption of digital-only fashion largely hinges on the extent to which their self-expression including social-adjustive and value-expressive needs can be satisfied. This outcome resonates with existing literature indicating that self-expression is the primary motivator for consumers to purchase fashion apparel whether in physical or digital formats (Baek *et al.*, 2022; Casciani *et al.*, 2022; Schauman *et al.*, 2023).

Furthermore, this study reveals that three functional attitudes, including attitude toward adorning avatars, attitude toward dressing realistic on-screen bodies, and self-expressive attitude, collectively contribute to the formation of the overall evaluative attitude toward digital-only fashion. These results validate the propositions drawn from the Functional Theory of Attitudes within the emerging digital-only fashion domain, particularly consistent with the insight that consumer-perceived functions of attitudinal objects bridge the gap between specific attitudes and the overall evaluation in a given context (Cho *et al.*, 2022; Katz, 1960; Zhang *et al.*, 2023). Testing results also unveil that consumers' overall assessment of digital-only fashion is most impacted by their attitudes toward dressing avatars, followed by their evaluations of styling on-screen bodies. These findings may be attributed to consumers' greater familiarity with dressing avatars, which has a longer history compared to dressing realistic on-screen bodies (Chan *et al.*, 2024; Schauman *et al.*, 2023). Moreover, results indicate that consumers' environmental attitude toward digital-only fashion does not have a significant impact on their overall attitude toward it. This observation may be explained by consumers placing greater emphasis on fashionability rather than the environmental advantages of digital-only fashion.

Our study demonstrates that self-expressive attitude toward digital-only fashion is significantly influenced by three other functional attitudes: attitude toward adorning avatars, attitude toward dressing on-screen bodies, and environmental attitude. These findings highlight that while consumers may have varied motivations for how to use digital-only fashion products, their primary focus and ultimate goal lie in pursuing self-expression. These are consistent with previous research indicating that consumers value and prioritize the self-expression aspect of digital fashion (Baek *et al.*, 2022; Casciani *et al.*, 2022; Patruti *et al.*, 2023).

Mediation analysis results indicate that the overall evaluative attitude toward digital-only fashion serves as a mediator between the two functional attitudes (attitude toward adorning avatars and attitude toward dressing realistic on-screen bodies) and purchase intention. These discoveries underscore that embellishing avatars and donning realistic on-screen bodies are distinct yet complementary aspects of digital-only fashion consumption. They play crucial roles in shaping consumers' overall assessments of digital-only fashion and consequently influencing their purchase intentions. These findings align with recent research conducted in the context of digital fashion including virtual fashion items that can either be physically produced or exist solely in virtual environments (Zhang *et al.*, 2023). Furthermore, the self-expressive attitude toward digital-only fashion mediates the connections between three other functional attitudes and purchase intention. These results further emphasize the prominence of consumers' motivation and pursuit of self-expression in digital-only fashion consumption. Particularly, the mediation effect of self-expressive attitude on the relationship between environmental attitude and purchase intention is the most robust. This suggests that while consumers' positive environmental beliefs regarding digital-only fashion may be not directly translated into purchase behavior, consumers are concerned about how effectively digital-only fashion enables the expression of these beliefs.

Theoretical and managerial implications

This study serves as a seminal piece in the field of digital-only fashion. We distinguish digital-only fashion from general digital fashion, emphasizing that it exists solely in digital environments without any physical production or consumption. Our research identifies four key applications of digital-only fashion as end-products: adorning avatars, dressing people's realistic on-screen bodies, addressing environmental concerns associated with physical fashion, and enabling self-expression. We also clarified the difference between avatars and on-screen bodies within the context of wearing digital-only fashion. These set our research apart from previous studies on general digital fashion. Our study provides insights for future research on digital-only fashion, particularly how digital-only fashion consumption can effectively address environmental issues tied to physical fashion.

This study introduces an innovative application of the Functional Theory of Attitudes to the emerging field of digital-only fashion. Utilizing this theoretical framework, we identified four functional attitudes that consumers hold toward digital-only fashion and the underlying motivations associated with each attitude. Our findings confirm the importance of both the overall evaluative attitude and these functional attitudes in shaping consumer acceptance of digital-only fashion, particularly validating the predictive power of the identified functional attitudes. These results are consistent with existing research using the Functional Theory of Attitudes that emphasizes the role of motivational functions in influencing consumer attitudes and responses (Cho *et al.*, 2022; Grewal *et al.*, 2004; Katz, 1960; Song, Meng, Chang, Li, & Tan, 2021). Furthermore, our results reveal a dynamic hierarchical framework of attitudes in digital-only fashion consumption, in line with previous research demonstrating the coexistence and hierarchical relationships of multi-dimensional attitudes regarding the digital fashion context (Zhang *et al.*, 2023). These insights advance our understanding of both the Functional Theory of Attitudes and digital-only fashion consumption, contributing to the development of knowledge in attitude theories and fashion studies.

This study offers valuable practical insights for the entire digital-only fashion value chain and provides important guidance for key stakeholders involved in this domain. Specifically, in the design and production phases, designers could catch the opportunity to collaborate with consumers in developing highly customized digital-only fashion items that reflect individual personalities, fashion styles, and symbolic representations. This collaborative process allows consumers to gain a thorough understanding of the aesthetic value of digital-

only fashion and its various functional aspects such as value expression, social adjustment, hedonic, and utilitarian functions.

During the marketing and communication stage, marketers of digital-only fashion should prioritize delivering personalized messages to individual customers and assisting them in selecting suitable means of self-expression through digital-only fashion items. Marketing strategies may involve leveraging influencers and user-generated content to resonate with like-minded consumers. Establishing a digital brand ambassador who embodies the brand's image, strong personality, and unique fashion preferences might capture consumers' attention and foster their engagement. Furthermore, highlighting the environmental benefits of digital-only fashion and targeting consumers with a high environmental consciousness are essential strategies.

To cater to consumers' varied needs and preferences, practitioners should provide a comprehensive digital-only fashion product line, including dressing both avatars and on-screen bodies, along with enhanced services during the consumption stage. Collaboration with the gaming industry and other Metaverse-related platforms can yield immersive and visually appealing digital-only fashion items for dressing avatars, enhancing users' hedonic experiences. Many fashion brands have already embarked on such partnerships, resulting in significant achievements (Casciani *et al.*, 2022; Chan *et al.*, 2024; Mogaji *et al.*, 2023). Fashion brands could leverage advanced technologies, such as AR-based fashion filters and Generative AI-powered image generation systems, to facilitate consumers dressing their realistic on-screen bodies, bolstering consumers' real-world identities and meeting their diverse social needs. Moreover, fashion brands can consider curating avant-garde digital-only fashion editorial pieces, encompassing both photography and videography, to showcase consumers' uniqueness, fashion tastes, and vision. Sharing such editorials on social media platforms may generate significant attention, foster viral spread, and spark fashion trends.

Exploring the resale market of digital-only fashion has the potential to foster a circular digital business model, simultaneously enhancing environmental sustainability and economic feasibility. Importantly, this suggestion benefits both producers and consumers of digital-only fashion. To achieve this, practitioners could use Blockchain-based NFT technologies or other approaches like digital passports for physical products to track comprehensive information, including design copyrights, product features, ownership, and transactions, ensuring transparency and security (Schauman *et al.*, 2023).

Our study identified self-expression and environmental protection as key functional drivers for consumers selecting and utilizing digital-only fashion. Consequently, industry professionals in this field should focus on creating and collectively promoting content highlighting these two aspects, capturing public interest while encouraging a shift from physical to digital-only consumption. Such efforts may foster the public's more positive attitudes and increased purchase intentions regarding digital-only fashion. In turn, this shift could contribute to improving the overall quality of life by mitigating the environmental impact of the textile and apparel industry. In addition, policymakers should work closely with relevant stakeholders to establish a legal, robust, and sustainable environment that supports the growth of digital-only fashion.

Conclusion, limitations, and future research directions

Drawing from the Functional Theory of Attitudes, our study highlights that consumers' acceptance of digital-only fashion is influenced by both their overall evaluations and distinctive functional attitudes. Self-expression emerges as a crucial factor within digital-only fashion consumption. The practices of adorning avatars and dressing realistic on-screen bodies are distinct yet complementary aspects of shaping consumers' experiences with

digital-only fashion. Consumers who hold favorable environmental views regarding digital-only fashion prioritize how effectively digital-only fashion enables them to express these environmental values.

This research contributes to existing knowledge and offers practical insights for practitioners in the digital-only fashion realm. However, two key limitations of our study existed. First, the study utilized a correlational research strategy via an online survey, which limits the ability to investigate causal relationships among the key factors. Future research could employ experimental designs to explore these influencing factors and establish causality in digital-only fashion consumption. Furthermore, incorporating both quantitative and qualitative methods could offer a more comprehensive understanding of digital-only fashion and enhance generalizability. Second, our sample exhibited an imbalance in demographics, with a bias toward females and young individuals, potentially affecting the generalizability of results. Future research should aim for a more representative sample.

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From a learning to a smart nation: the rise of the digitalization megatrend and Singapore's development

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Abstract

Purpose – The purpose of this article is to discuss the “learning nation” concept and examine the characteristics and implications of using the “learning” premodifier in this nation-building program.

Design/methodology/approach – This article reviews how the “learning” aspect is inter-related to a series of national information and communication technology masterplans and includes a comparative analysis of the related premodifier “smart” as Singapore sets forth its ambition to become a “smart nation” as part of the digitalization megatrend. A print media indicator and Google Trends form part of the methodology to ascertain the rise of digital technology over a certain period. The former technique involves identifying relevant bibliographic databases and analyzing the volume of publications. The latter technique is a real time index of the volume of queries that users input into Google.

Findings – It is suggested that using the term “learning nation” previously and more recently “smart nation” is a consequence of the rise of the digitalization megatrend. The “smart-ness” involves learning about digital technologies, developing digital competencies and harnessing the benefits of these digital capabilities. From a public policy perspective, the article showcases how a city-state can transform itself through technology by riding on megatrends. Also, there is a need to be selective in developing specific areas for the application of digital technologies.

Originality/value – This article contributes to a better understanding on the frequent usage of the word “learning” as a premodifier and Singapore’s nation-building journey through human capital development and digitalization.

Keywords Nation-building, Human capital development, Digital transformation, Digital technology, Premodifier

Paper type Case study

Introduction

In 1997, the Singapore government launched the “Thinking Schools, Learning Nation” vision to complement a knowledge-based economy by creating a thinking and inquiring workforce (Singapore Ministry of Education, 1997). In 2014, with the advent and proliferation of digital technology, the “Smart Nation” initiative was announced in Singapore to harness digital technologies to beat competition and improve livelihoods (Lee, 2014). This article discusses the “learning nation” concept and examines the characteristics and implications of using the “learning” premodifier in this nation-building program. It reviews how the “learning” aspect is inter-related to a series of national information and communication technology masterplans. It



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also includes a comparative analysis of the related premodifier “smart” as Singapore sets forth its ambition to become a “smart nation” as part of the digitalization megatrend.

The genesis of this article arose from the frequent usage of the word “learning” as a premodifier in contemporary management and social sciences literature, for example, “learning organization” (Senge, 1990), “learning economy” (Lundvall & Johnson, 1994) and “learning nation” (Singapore Ministry of Education, 1998). A “premodifier” is “the part of a noun group, adjective group, or verb group that comes before the most important word and adds information about it” (Macmillan Dictionary, 2022). Consequently, it calls into question the definition and meaning of the word “learning” which leads to its popularity in usage as a premodifier in recent times. In this article, special attention will be paid to how the premodifier changes from “learning” to “smart” for the word “nation”.

The main purpose of this article is to explore and examine the usage of the word “learning” as a premodifier to the word “nation” and its subsequent change to “smart” as part of Singapore’s nation-building journey. Singapore as a nation has initially embraced the term “learning nation” in the 1990s and more recently adopted the “smart nation” initiative in the 2010s. Various interesting questions related to the usage of “learning” as a premodifier to “nation” and the subsequent change of the premodifier to “smart” arise – Why is “learning” such a commonly used premodifier? What triggered the use of “learning”? What does “learning” mean for Singapore as a “learning nation”? Why did Singapore replace “learning” with “smart” for the “smart nation” initiative? What can one learn from the frequent usage of “learning” as a premodifier? In the Singapore example, it is suggested that using the term “learning nation” previously and more recently “smart nation” is a consequence of the rise of the digitalization megatrend. The “smart-ness” involves learning about digital technologies, developing digital competencies and harnessing the benefits of these digital capabilities.

The remaining sections of the article are structured as follow: First, a write-up on premodifiers in English grammar and their association with other parts of the English language. A brief explanation of the key words including “learning”, “smart” and “nation” is presented. Second, the notion of a learning nation as proposed by Singapore in the 1990s and the idea of learning are explained. Third, the recent rise of the digitalization megatrend across the globe is highlighted which suggests an emphasis on using digital technologies to build future governments, businesses and societies across the globe. Fourth, Singapore’s journey towards a smart nation beginning in 2014 and riding on the digitalization megatrend. Then, there will be a discussion on the usage of the word “learning” and “smart” as premodifiers with an emphasis in the case of Singapore. The final section ends with some suggestions for future research work.

The usage of premodifiers in English grammar

Traditionally, English grammar classifies words based on the eight parts of speech, namely, the verb, the noun, the pronoun, the adjective, the adverb, the preposition, the conjunction and the interjection (Ives, 1957). For example, a noun is “a word that refers to a person, a place or a thing, a quality or an activity” (Oxford Learner’s Dictionaries, 2022a). An adjective word is one which “describes a person or thing” (Oxford Learner’s Dictionaries, 2022b). It gives more information such as traits and qualities about a noun. A “premodifier” is “the part of a noun group, adjective group, or verb group that comes before the most important word and adds information about it” (Macmillan Dictionary, 2022). In other words, a premodifier enhances the meaning of the key term. It is common practice to put two nouns together or an adjective before a noun to form a term, for example, “learning nation” and “smart nation”.

There are several key words that are covered in this article. They are “learning”, “smart” and “nation”. The word “learning” as a noun is “the process of learning something” (Oxford

Learner's Dictionaries, 2022c). In fact, the word "learning" may function as a noun, an adjective or other grammatical forms such as a present particle or a gerund subject to the context (Sun, 2003). It is interesting to note that as a verb or action word, to "learn" is "to gain knowledge or skill by studying, from experience, from being taught, etc." (Oxford Learner's Dictionaries, 2022d). In British English, the definition of the adjective "smart" generally denotes "people looking clean and neat or well-dressed in fashionable and/or formal clothes" (Oxford Learner's Dictionaries, 2022e). However, in a technological context, the word "smart" also suggests an impression of an object associated with electronic applications (Lutkevich, Rosencrance, & Cobb, n.d.). For example, a smart card is a small plastic card with a built-in microprocessor which information is stored in electronic form. Finally, the word "nation" is a noun that is defined as "a country considered as a group of people with the same language, culture and history, who live in a particular area under one government." (Oxford Learner's Dictionaries, 2022f).

This section introduced the various parts of the English language and the idea of premodifiers. It has also provided working definitions on the key words to be discussed subsequently in the article. This brief overview is to lay the groundwork on the discussion and examination on the usage of the word "learning" as a premodifier as part of Singapore's nation-building journey from a "learning nation" to a "smart nation".

The notion of a learning nation and the idea of "learning"

The notion of a learning nation was introduced in June 1997 by the then Prime Minister of Singapore Goh Chok Tong as part of the "Thinking Schools, Learning Nation" (TSLN) vision (Singapore Ministry of Education, 1998). The main rationale behind the initiative was to propel Singapore into becoming a knowledge-based economy with a thinking and inquiring workforce (Teo, 1999). As competition rises, the nation state needed to harness its human resources to build a workforce which can thrive in the 21st century. The well-being of the nation would depend on the people's capacity to learn and pursue innovative technologies (Singapore Ministry of Education, 1997).

An important aspect of the TSLN vision was how information technology (IT) could be used to support the education system (Koh & Lee, 2008). Specifically, the "Masterplan for IT in Education" was initiated in the same year to augment learning and teaching practices (Koh, 2004). The change was driven by the impact of globalization due to economic or technological factors and the relevance of education for a workforce to meet these challenges. The scope was nation-wide and covered both students who attended compulsory education at the various levels and workers who have left the education system. Both groups were expected to develop competencies to help the nation stay competitive. The entire education system was required to equip future and existing working population with critical thinking and IT skills.

The TSLN concept was applied at two levels. Beginning with the notion of thinking schools, students were taught critical skills to prepare them for the future. At the school level, young Singaporeans were encouraged to develop creative thinking skills (Tan, 2006). "Thinking schools" served to develop future generations with curriculums that promoted creative thinking skills and supported by IT. The stakeholders included students, teachers and parents (Singapore Ministry of Education, 1997). In the schools, students were assigned multidisciplinary projects covering subjects such as mathematics, science and English and supported by IT tools (Saravanan, 2005). Through the development of curriculum which incorporated IT as part of learning, teachers begin to realize that they were also participating in a process of lifelong learning (Low-Ee, 2001). Professional communities where teachers network, exchange information and collaborated on self-initiated projects, were formed (Hairom, 2020). For the working adults, they were expected to embark on lifelong learning to keep their skills relevant in the economy.

At the national level, lifelong learning programs for professional development and personal enrichment were also supported. The World Bank has referred to human capital as consisting of “the knowledge, skills, and health that people accumulate throughout their lives, enabling them to realize their potential as productive members of society” (World Bank, 2019). Thus, human capital development in the context of education and training would then mean improving the life-long knowledge and skills of the people as contributing members of society. From this perspective, the notion of a learning nation went beyond the traditional educational institutions to human capital development for the workforce in the form of continuous learning to ensure that their skills remained relevant to meet market needs. Thus, many stakeholders across the public and private sectors were involved.

On examination, the notion of a learning nation is clear and well-defined. The reason is because the narrative stipulated the target groups with specific outcomes. The school-level learning initiatives directed at the students were aligned with continuous learning effort at the workplace. The idea of TSLN explicitly stated that the result is a nation which must remain relevant and thrive in a global economy. Identifying both students and workers among the various stakeholders was a logical step as part of the overall progression to build a knowledge-based economy. Another important factor was the application of a series of information and communications technology (ICT) masterplans to enhance learning in schools (Natarajan, Lim, & Cheah, 2018). IT was earmarked as a key enabler to enhance the core skills to be developed. This addition elaborates on the definition of a learning nation by including an IT component. IT has always been an important tool to raise productivity and promote innovation. Thus, the idea of “learning” in Singapore’s context included key areas about who to learn, why to learn and the tools to help people to learn.

Essentially, “learning” involved students and workers with the purpose of growing the economy. IT was highlighted as an important factor to argument learning especially at the school-level. The close association between “learning” and technology is a result of the rise of the digitalization megatrend. Megatrends represent major patterns emerging in the macroenvironment that are likely to have significant impacts in the consumer and producer markets in the foreseeable future. Consequently, it is noted that whenever the word “learning” was used, for example, in “learning nation” it always includes some form of IT or ICT – both terms are used interchangeably in this article.

The rise of the digitalization megatrend

In recent years, the global economy has witnessed first-hand the transformative powers of digital technologies (Bienhaus & Haddud, 2018). Government, businesses and societies experienced tremendous disruptions and must relook at the way they operate because of the digitalization megatrend (Hoe, 2019a). For example, an organization which has been using manual processes to engage its customers will have to develop a digital platform and apply automation to improve user experience. However, such global technological forces are not new and have been around for quite some time. There were several major industry transitions that were brought about by changes in technology in recent times.

According to the World Economic Forum, the First Industrial Revolution arose because of the availability of steam power for production, the Second Industrial Revolution due to the application of electricity for mass production and the Third Industrial Revolution was signified by the conversion of analogue to digital means to automate production (Schwab, 2016). In the current Fourth Industrial Revolution, the interconnectivity of digital technologies blends the business applications across the physical and digital worlds. More recently, digital transformation has become a focus for organization in recent years mostly driven by rapid advancements in digital technologies. These digital technologies include but are not limited to Internet of Things (IoT), social media, mobile apps, artificial intelligence, augmented and virtual reality (Paul *et al.*, 2024).

There are many frameworks that have been developed to analyze digital transformation. For example, Elia, Solazzo, Lerro, Pigni, and Tucci (2024) proposed a digital transformation canvas covering key element such as strategy, operational pillars, value and pitfalls. Agostino and Costantini (2022) crafted a measurement framework for assessing digital transformation comprising of five main dimensions, namely, people, technology, process, customer and strategy and investment. Also, there are integrated frameworks which suggest that key enablers such as leadership, structures and culture can help industrial organizations achieve better collaboration, customer-centricity and agility as part of the digital transformation journey (Imran, Shahzad, Butt, & Kantola, 2021).

One quantitative approach to determine the rise of the digitalization megatrend is using print media indicators and Google Trends to discover the number of publications and searches related to digitalization among scientific and casual researchers over time (Hoe, 2019b). Such a combined method may be used as a proxy to shed some light on when this megatrend began. The aim is to identify the period when digitalization became popular around the world. A proxy measure which provides an indication of the popularity of the term by the frequency of searches on business databases and the internet can be found through ABI/INFORM and Google Trends respectively.

Using print media indicators as part of quantitative empirical research on “organization concepts” has been a popular choice among management scholars (Benders, Nijholt, & Heusinkveld, 2007). Essentially, the technique involves identifying relevant bibliographic databases and analyzing the volume of publications. In this study, the choice of bibliographic databases is based on the comprehensiveness of the records in its international coverage on the topic of business. ABI/INFORM is a business database that covers full-text journals, dissertations, working papers, key business and economics periodicals. It can be used to identify the number of publications related to a group of keywords and parameters.

The data from ABI/INFORM and Google Trends was collected in 2022. The keyword “digitalization” and publication types which include wire feeds, newspapers, reports, trade journals, scholarly journals, magazines, blogs, podcasts, websites, working papers, conference papers/proceedings, dissertations/theses and books were first selected as parameters in the ABI/INFORM database. Then, the period parameter was set between 1980–2021. Next, publication titles and abstracts were chosen as additional parameters. The search results produced based on the selected parameters on the number of publications related to digitalization was 76,872. On further investigation, the number of publications between 2010–2021 was 75,729. This figure suggests that there is a spike in the number of publications from 2010 onwards.

For the next step, data was collected and analyzed using Google Trends. This tool is a real time daily and weekly index of the volume of queries that users input into Google (Choi & Varian, 2012). Google Trends was selected as part of the combined method together with print media indicators to analyze megatrends because it presents the actual search requests made by users through the internet. These datapoints are also largely raw and unprocessed which give a somewhat more truthful picture of user choice and preference over time. The index is normalized to 100 for ease of reference. In technical terms, the maximum query share in the time period specified is normalized to be 100 while the query share at the initial date being examined is normalized to be zero. It can be used as a substitute to ascertain the level of interest on a particular topic of casual or general users. The keyword “digitalization” was input into Google Trends with the parameters set at worldwide, custom time range of January 2010 – December 2021, all categories, and web search. The Google Trends search results produced were the graphed (see Figure 1). It is interesting to note that keyword search results for “digitalization” spiked from around end of 2015 onwards. This result seems to suggest that there has been a sudden growth in interest on the topic worldwide from 2015 to 2021.

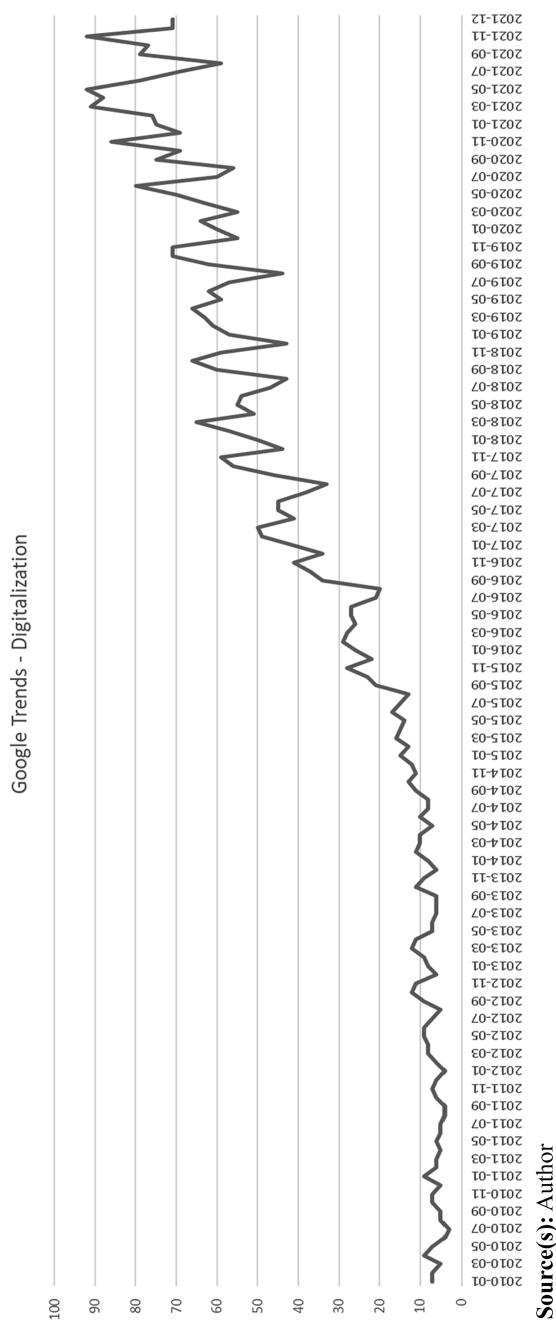


Figure 1.
Google trends search results for the word
“digitalization” from
2010 to 2021

Coincidentally, the World Economic Forum also launched the digital transformation initiative in 2015 (World Economic Forum, 2022). Briefly, the concept of digital transformation refers to the acceleration of applying current and emerging digital technologies and developing business models associated with such technologies (World Economic Forum, 2024). The idea is to use various digital technologies to augment business practices to enhance user experience. The group forecasted that there would be a significant impact of digital technologies across various sectors moving forward. Such technologies include 3D printing, artificial intelligence, autonomous vehicles, big data analytics, IoT and robots. Of course, many industries such as automotive, consumer, electricity, healthcare, logistics, media, travel, oil and gas, professional services, telecommunications and mining would be affected. To sum up, based on a bibliographic database and Google Trends search, the rise of the digitalization megatrend seems to happen around 2010 to 2015 and onwards.

A smart nation journey

Singapore has been a strong proponent in using information and communications technology to drive economic success. Technological innovations have helped to accelerate Singapore's growth. The various key milestones of Singapore's smart nation story include national IT masterplans and major public agency e-government projects to improve the lives of the citizens and develop the economy (Smart Nation and Digital Government Office, 2024). These digital initiatives demonstrate how the country transforms itself through technology over the years. The government aims to continue to drive the economy using technology as a key enabler (Tharman, 2015). The various national information IT masterplans that have been developed over the years as part of nation-building include the National Computerization Plan in 1980, National IT Plan in 1986, IT2000 plan in 1992, Infocom 21 plan in 2000, the Connected Singapore plan in 2003, the Intelligent Nation plan in 2010 and Infocomm Media 2025 plan in 2015 (Hoe, 2016).

A recurring theme and challenge for Singapore has always been maintaining its competitive advantage in the region and internationally. Thus, education plays a critical role in preparing students to excel in an increasingly complex environment and eventually thrive in the workforce. At the same time, IT has been recognized as a key enabler to fast-track economic growth. Consequently, IT in education has always been an integral part of the Singapore's national IT masterplans (Singapore Ministry of Education, 2002; Koh & Lee, 2008). A unique feature of the concept of a learning nation is how it is integrated into the state's IT masterplans. The IT initiatives aim to change the way teaching and learning are done in the classrooms (Natarajan & Laxman, 2021).

In 2014, the Prime Minister of Singapore Lee Hsien Loong revealed the city-state's smart nation vision (Lee, 2014). The vision sought to apply ICT to improve people's lives and create more opportunities to overcome the state's physical limits. Through the smart nation initiative, the government endeavors to co-create innovative people-centric solutions with industry and citizens. Ordinary citizens and individuals can also benefit from digital technologies and lead a better quality of life around work, education and healthcare (Poon *et al.*, 2017). There are three priority areas, namely, elderly, transportation and data which the initiative will specifically address (Lee, 2015). The rationale is because of the fast-greying population, traffic congestion and ease of data accessibility. The protection of digital assets would also feature prominently under the cybersecurity theme (Balakrishnan, 2014).

The smart nation initiative is a whole-of-nation approach to enhance the quality of living and increase productivity for the country (Smart Nation Programme Office, 2015). While the initiative is not about technology per se, digital technologies do play a key enabling role in many projects. The digital technologies employed are really a means to an end (Balakrishnan, 2015a). For example, some of the strategic national projects introduced

were National Digital Identity framework, E-Payments, Smart Nation Sensor Platform, Smart Urban Mobility and Moments of Life (Smart Nation and Digital Government Office, 2017). Essentially, these are platforms which utilize digital technologies such as big data analytics and artificial intelligence to engage an ecosystem of stakeholders. In addition, various other types of digital technologies such as IoT, 3D printing and robotics have also been highlighted as high potential areas (Balakrishnan, 2015b). Of course, with the introduction of these digital technologies, new jobs with new skills in these areas would be required (Ang, 2015).

With the formation of the Smart Nation and Digital Government Group within the Prime Minister's Office, it took on the digital government pillar to drive digitalization efforts in the public sector (Hoe, 2018). At the same time, the Ministry of Communications and Information led the digital economy and digital society pillars. Through the establishment of the Digital Government Blueprint, public sector agencies were encouraged to experiment with emerging digital technologies and incorporate them into their workplans. The public agencies have been very active in engaging the industry to realize a series of digital plans. These industry digital plans include the Singapore Payments Roadmap by Monetary Authority of Singapore in collaboration with KPMG (KPMG, 2016), Legal Industry Technology and Innovation Roadmap (Singapore Ministry of Law, 2020), Singapore Cybersecurity Strategy (Cyber Security Agency of Singapore, 2021), Industry Digital Plan for Social Services (National Council of Social Service, 2021) and Process Construction and Maintenance Industry Digital Plan by Infocomm Media Development Authority in partnership with Enterprise Singapore (Infocomm Media Development Authority, 2021). For the Singapore Budget 2024, the government continues to encourage works to re-skill and take on jobs in digitalization (Abu Baker, 2024).

Discussion

The intent of the article is to explore and examine the usage of the word “learning” as a premodifier as part of Singapore’s nation-building journey. Some key questions were raised at the beginning of the article. This discussion section will revisit these questions and to provide responses to better understand the features and characteristics of premodifiers such as “learning” and “smart” in English grammar.

The first question is “Why is ‘learning’ such a commonly used premodifier?” One possible explanation on its common usage in contemporary management literature could be that “learning” is closely related to knowledge. With knowledge, one can foster new and different ways of doing things which lead to innovation. The importance and significance of knowledge as a strategic resource in the production of new innovations and empowering new forms of work is undeniable (Lundvall, 1992; Florida, 1995). Very often, this general idea of “knowledge” leading to monetary success is discussed around the theme of “learning” (Hudson, 1999). This simply means that an outcome of knowledge creation is that an entity can increase its earning capacity to make more profits. An implicit assumption is that learning creates knowledge which enables new ways of doing things. Learning leads to new knowledge creation (Darling, 2014). Through various learning activities such as problem solving and reflection, knowledge is gained. In this instance, the relationship between learning and knowledge is closely connected where knowledge is a result or product of learning (Antonacopoulou, 2006). “Learning” as a premodifier becomes popular because it signifies this characteristic when it is put before another noun to form a new term. Of course, a natural question arises “Why is knowledge not used in the first place as a premodifier to nation?”. A simple Google Trends search on the words learning and knowledge and comparison of interest over time on these terms suggest that the former consistently lead the latter in popularity since 2004 in Singapore. This result partially explains why nation was

used together with learning instead of knowledge despite their close relation. One could also speculate that in coining the term “learning nation”, the emphasis was on the importance of the actions to be taken rather than the particular end. Learning is an active and constructive process (Sun, 2003). By stressing on the process instead of the product, the concept of the learning nation directs the effort towards the act of doing which may lead to different results as a better alternative to being fixated to an anticipated outcomes which may limit the scope of innovation.

The second question is “What triggered the use of ‘learning’?” In the case of the “learning nation”, Singapore adopted a pragmatic approach to overcome its natural constraints (Quah, 2018). In the formulation of economic policies, a key consideration is to attract multi-national corporations (MNCs) to set up bases in the country. For this to happen, MNCs must see the value in moving there. Being a small-sized nation with an open economy that is heavily reliant on international trade and finance, the nation is constantly faced with intense global competition. To stay ahead, “the learning nation” needs to have the best technologies and processes to produce goods and services at reasonable cost. Driven by such factors, Singapore needs to create breakthroughs and innovations. Thus, the word “learning” is triggered because its meaning suggests “the process to gain knowledge or skill by studying, from experience, from being taught” and so forth. This explanation also provides an answer to the third question “What does ‘learning’ mean in the case of a ‘learning nation?’” The “learning” implies that the nation will engage in a process to gain knowledge and skills. More specifically, Singapore as a “learning nation”, will continuously reskill and upskill the workforce to stay ahead of competition.

The next question is “Why replace ‘learning’ with ‘smart’ in the case of the ‘smart nation?’” In the case of Singapore using the term “learning nation” previously and more recently “smart nation”, the argument being put forth is that the change from “learning” to “smart” is a consequence of the rise of the digitalization megatrend. This “smart-ness” involves learning about digital technologies. While the world has always experienced global technological trends, such digitalization forces have become more distinct in recent years. As suggested by the print media indicator and Google Trends search results, the digitalization megatrend took off around 2010 to 2015 and onwards. This phenomenon suggests a significant shift towards digital technologies as a critical success factor for competitive advantage. At the same time, the word “smart” seems to suggest a greater emphasis on digital technologies with a more specific digital know-how and skills to be acquired compared to the premodifier “learning”. For example, smart technology may be broadly defined to cover groups of digital technologies which include IoT, connected devices and programmed devices (Nanowerk, 2022). “Smart” seems to indicate a broader set of more advanced digital skills beyond basic information skills. These advanced skills could cover areas such as cybersecurity, big data analytics and artificial intelligence. While the “smart nation” vision is not related to or a direct evolution of the “learning nation” vision, it appears to be a natural progression of the notion given the rise of digitalization megatrend or digital technologies. The replacement of the premodifier serves to broaden and deepen the application of digital technology to strengthen the country’s position regionally and internationally.

Finally, to the question “What can we learn from the frequent usage of ‘learning’ as a premodifier?” As mentioned, the word “learning” suggests a process of gaining knowledge or skills. This generally positive description of the word makes it a popular choice among management thinkers and writers to select it to add more meaning to certain terms. In doing so, the premodifier is useful in conveying a more favorable message across to the readers. Thus, to the casual reader, the frequent usage of “learning” seems to be harmless. On the other hand, the constant exposure to a particular word may dilute its importance and meaning. This may relegate the word into something that is generic and ordinary. The real downside is that readers are no longer able to derive its true meaning due to frequent and

unreflective exposures to the premodifier. An over-familiarity with the meaning of a word may lead to casual usage resulting in a failure to appreciate its true implications in different contexts.

From a public policy and management perspective, technology features very prominently as part of Singapore's national development journey. The practice of harnessing technology to spur economic growth in the past and present is evident in Singapore's effort to improve the well-being of its citizens. Policy implications-wise, the wide-spread adoption and application of technology does provide tangible economic and social benefits across both the public and private sectors. Singapore has recognized the tremendous economic potential of a digital economy (Lee, 2021). It is now championing digitalizing cross-border trade flows and facilitating flows of digital services around the region. Fast-forward to recent years, there are many examples of how emerging IT or digital technologies are changing the way work is performed (Le Blanc, Ulfert, Peeters, Rispens, & Scherer, 2024). An often-mentioned case is the deployment of ChatGPT in many areas of the business such as customer service and human resource to reinvent work activities and tasks. In next two years, digital technology trends are expected to grow even faster resulting in more changes to the public sector (Buchholz, 2024).

Singapore has been actively promoting the use of artificial intelligence in the public and private sectors. A key approach is to be selective in developing specific areas such as population health and climate change on the application of artificial intelligence. This is because national and local governments should be selective in introducing smart city practices and digital technologies in view of contextual variables (Noori, Hoppe, De Jong, & Stamhuis, 2023). To elaborate, adapting international best practices to meet local requirements is crucial for the successful integration of digital technologies into public services.

Limitations and future research

There are several limitations in this research study which need to be highlighted. Firstly, the overall approach adopted in the research design. The research design is framed around the novel idea of using English grammar as a starting point of analysis on the frequent usage some common words. Consequently, the discussion and arguments provided to explain Singapore's transition from a learning to a smart nation with a common technology theme is grounded using the approach. Furthermore, the "empirical evidence" provided were obtained from Google Trends to support the notion on rise of the digitalization megatrend. It is noted that this form of examination is but one approach to illustrate Singapore's national development policies and practices. Other qualitative and quantitative research designs could provide similar conclusions or otherwise. Secondly, researcher bias. As the evidence taken and conclusions drawn were mostly taken from ministerial speeches and publicly available government reports, there may exist certain bias due to how this information are interpreted and, thus, may be subjective.

The frequent usage of certain words is a common practice in modern times. Many such words appear in various forms in an English sentence. This article focuses on the premodifiers "learning" and "smart". The analysis and discussions have uncovered many opportunities for scholars to conduct further research. For example, some studies can concentrate on the meaning of "learning" based on certain concepts and disciplines. These theories can be from cognitive science, organizational behavior or critical studies. In addition, an examination to understand the nature of the actors who are "learning" may be necessary. This is because "learning" may happen at various levels, for example, individually, collectively, regionally or nationally. Finally, from a technological perspective, how governments are transforming their policies and processes because of the digitalization megatrend.

Digitalization, national development and digital government are relevant topics that are of interest among public policy makers and management in recent times. More thorough studies are required to improve one's understanding of their inter-relationships. Thus, for future research, scholars may wish to consider questions such as – What is the relationship between digitalization and national development?, What factors affect the rate of digital technology adoption among the citizens?, Which industries have evolved because of the transition from a learning to a smart nation? and What are the side effects of digital technology on society? to advance the body of knowledge.

Conclusion

The word “learning” is frequently used as a premodifier in contemporary management literature. This practice calls into question the definition and meaning of the word “learning” which leads to its popularity in recent times. One possible explanation of its common usage in contemporary management literature could be that “learning” is closely associated with knowledge. With knowledge, one can foster new and different ways of doing things which lead to innovation. Also, “learning” implies a process to gain knowledge and skills. More specifically, a “learning nation” will continuously reskill and upskill the workforce to stay ahead of competition. In the Singapore example, it is suggested that using the term “learning nation” previously and more recently “smart nation” is a consequence of the rise of the digitalization megatrend. The “smart-ness” involves learning about digital technologies, developing digital competencies and harnessing the benefits of these digital capabilities. From a public policy perspective, the article showcases how a city-state can transform itself through technology by riding on megatrends. Also, there is a need to be selective in developing specific areas for the application of digital technologies.

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Humanitarian organization culture and humanitarian organization usage of digital cash-based assistance: the mediating role of financial service providers' technology readiness

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Abstract

Purpose – The study examined the influence of humanitarian organizations' culture and financial service providers' technology readiness on the usage of digital cash-based assistance by humanitarian organizations, the influence of Humanitarian Organization Culture on Financial providers' technology readiness and the mediating role of financial service providers' technology readiness on the relationship between the culture in humanitarian organizations and their usage of digital cash-based assistance.

Design/methodology/approach – A quantitative cross-sectional survey design was used. The target population consisted of humanitarian organizations that were members of the Uganda Cash Consortium (UCC). The research hypotheses were tested using SMART PLS version 4.

Findings – The culture in humanitarian organizations and financial service providers' technology readiness positively influences the usage of digital cash-based assistance by humanitarian organizations during humanitarian crises, and humanitarian organizations' culture positively influences financial service providers' technology readiness. Financial service providers' technology readiness fully mediates the relationship between the culture of humanitarian organizations and the usage of digital cash-based assistance by humanitarian organizations during humanitarian crises.

Research limitations/implications – The study mainly focuses on culture in humanitarian organizations and financial service providers' technology readiness when examining the usage of digital cash-based assistance during humanitarian crises. Further, financial service providers' technology readiness is examined using a humanitarian organization, financial service provider and beneficiary/persons of concern's point of view rather than the government's point of view.

Originality/value – Research examining determinants for digital cash-based assistance usage in humanitarian crises is scarce. Further, empirical research examining the influence of the humanitarian organizations' culture and financial service providers' technology readiness in promoting the usage of digital cash-based assistance in humanitarian crises, the impact of humanitarian organizations' culture on financial service providers' technology readiness and the mediating role of financial service providers' technology readiness on the relationship between the culture of humanitarian organizations and usage of digital cash-based assistance in humanitarian crises are non-existent. The majority of research and grey literature focuses on how digital cash-based transfers can be used to enhance financial inclusion in refugee contexts.

Keywords Humanitarian organizational culture, Financial service providers' technology readiness, Usage of digital cash-based assistance, Humanitarian crises

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1. Introduction

The use of digital payments or e-transfers in humanitarian supply chains has increased significantly in recent years (Better than Cash Alliance, 2021). Digital cash payments were introduced by private telecommunication providers in several countries around the world, especially in Africa, Asia and Latin America (Must & Ludewig, 2010). Digital cash-based assistance refers to the transfer of money or vouchers from the implementing agency to beneficiaries that are in this case refugees or persons of concern (William, 2022). Such transfers provide access to cash, goods and/or services through mobile devices, electronic vouchers or cards (e.g. prepaid ATM, credit or debit cards) (William, 2022; Kajol, Singh, & Paul, 2022). The term E-transfer is an umbrella term for e-cash and e-vouchers. Card-based systems allow the beneficiary to access cash (or commodities) via ATMs or payment merchants, possibly without the need for a bank account. Mobile transfers are a form of cash transfer occurring over the mobile network (Organisation for Economic Co-operation and Development (OECD), 2018; William, 2022). However, the concrete design of digital money services may not be similar; the general idea is to enable cheap and reliable money transfers between people who have access to them. Despite its huge potential and the presence of various forms of digital payment modalities, mobile phone payment remains a normal practice most especially in a few countries (Khairun & Yasmin, 2010). Further, the effectiveness of digital cash-based transfers depends on the level of digitization in humanitarian organizations and financial markets, and the availability of digital cash-based assistance modalities by beneficiaries (Juntunen, Kalla, Widera, & Hellingrath, 2023).

Besides the above, it is believed that donors and humanitarian organizations are looking for organizations to provide cash digitally not only because it offers cost-efficiency, but also because it promises to be more transparent (World Bank, 2016; Maghsoudi, Harpring, Piotrowicz, & Kedziora, 2023). Furthermore, by using technology in humanitarian responses, organizations could detect needs earlier; and increase the speed of assistance. On top of that, using technology can improve accountability, while simultaneously it can reduce corruption (Smith, MacAuslan, Butters, & Tromme, 2011; Maghsoudi *et al.*, 2023; Maghsoudi & Abakar, 2024). Also, due to the lack of humanitarian aid workers on the ground, recipients of humanitarian aid are forced to become “owners of their own recovery” whilst “digital humanitarianism stands primed to provide a remote, cost-effective, online self-help solution” (Duffield, 2016). Despite its importance, empirical research examining the predictors of digital cash-based assistance is scarce. Further, whereas there is increased advocacy for using digital cash in the humanitarian field, little is known about the role of the humanitarian organization’s culture and the technology readiness of the financial service providers in enhancing the use digital cash transfers by humanitarian organizations during refugee crises. Besides, existing research on Digital Cash Based Assistance (DCBA) is majorly qualitative (Pinna, 2020; Kayastha, Shrestha, & Agung, 2022), and focuses on benefits, risks and implementation challenges or drivers and inhibitors (Maghsoudi *et al.*, 2023; Balakrishnan & Shuib, 2021). Other studies look at the relevance of digital cash (Mehta, Patel, & Mehta, 2016; Ford, 2017) while others examine mobile money transfers in contexts other than the humanitarian context with financial inclusion, household consumption and continuance intentions among others (Apeti, 2023; Odoom & Kosiba, 2020; Bongomin & Ntayi, 2020).

Uganda hosts the world’s fastest-growing refugee population – today, the country hosts over 1.5 million refugees (United Nations High Commission for Refugees (UNHCR), 2021). According to the Ugandan Protection Policy of 2015, the introduction of cash transfers in Uganda’s humanitarian programming was an outcome of a 2013 agreement between the World Food Programme (WFP), UNHCR and the Office of the Prime Minister (OPM) that cash transfers were appropriate and should be implemented on a pilot basis. Since then, humanitarian organizations have collaborated to deliver humanitarian assistance to refugees

via digital cash transfer platforms and committed time to navigate fast-moving regulatory environments and iterating projects along the way. However, despite that, and based on the interviews conducted with the cash-based assistance transfer managers in five humanitarian organizations; Finish Refugee Council (11/08/2022), Norwegian Refugee Council (10/08/2022), Uganda Red Cross (12/08/2022), Danish Refugee Council (2/08/2022), and World Food Programme (28/07/2022) on the uptake of the digital cash transfers, feedback still shows that there are still low levels of adoption of digital cash-based assistance. Scholars including Demir, Pesqu é-Cela, Altunbas, and Murinde (2020), Kajol *et al.* (2022), McLean, Osei-Frimpong, Al-Nabhani, and Marriott (2020), Talwar, Dhir, Khalil, Mohan, and Islam (2020) call for more research on the underlying causes of digital cash transfer usage due to the presence of low diffusion rates of digital cash-based transfers. Besides, Katutu in an interview held on 28th/07/2022, some staff and supervisors of humanitarian organizations in Uganda embrace the use of digital cash payments with laxity despite the contributions of Information Technology (IT).

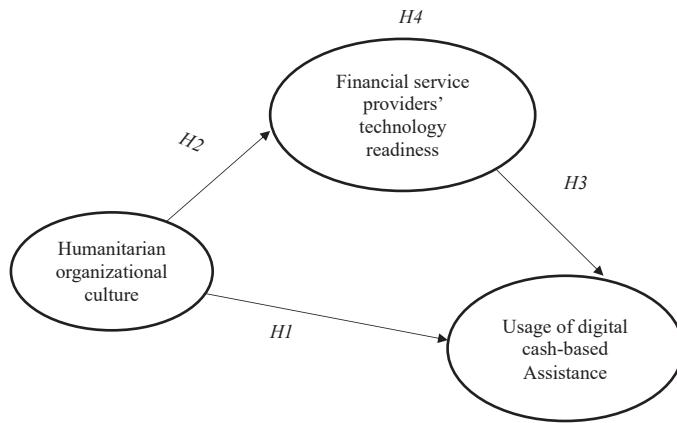
Besides the above, financial assistance is critical to meeting the basic needs of refugees, yet traditional forms of aid such as physical goods and services can be expensive, inefficient and unsustainable. One promising solution that has emerged to address the challenges of traditional aid is digital cash-based assistance, which not only offers a more efficient and cost-effective way to provide financial assistance to refugees, but also allows them to purchase the goods and services they need most to meet their basic needs. By leveraging technology to distribute financial assistance, humanitarian organizations can better tailor their support to the individual needs of refugees, ensuring that they receive the support they need to rebuild their lives and contribute to their communities. By enabling refugees to access financial resources digitally, digital cash-based assistance can provide a more cost-effective and flexible alternative to traditional aid. However, the successful implementation of cash-based assistance programs relies heavily on the technological capabilities and readiness of financial service providers (vendors) involved and the organizational culture inherent in humanitarian organizations.

Thus, the study aimed to examine the impact of humanitarian organizational culture and financial service providers' technology readiness on using digital cash-based assistance by humanitarian organizations in humanitarian crises. To address the research problem and achieve the intended objectives, four research questions are established that include:

- RQ1. Does organizational culture in humanitarian organizations impact the usage of digital cash-based assistance by humanitarian organizations in humanitarian crises?
- RQ2. Does financial service providers' technology readiness impact the usage of digital cash-based assistance by humanitarian organizations in humanitarian crises?
- RQ3. Does the organizational culture of humanitarian organizations impact financial service providers' technology readiness in humanitarian crises?
- RQ4. Does financial service providers' technology readiness mediate the relationship between humanitarian organizational culture and using digital cash-based assistance by humanitarian organizations in humanitarian crises?

2. Literature review

This section presents a review of the literature based on the four established hypotheses (see Figure 1). The section also presents the Theory used in explaining the variables in the conceptual framework.



Source(s): Figure courtesy of Dubey *et al.* (2022); Kiefer *et al.* (2021); Dhawan and Zollmann (2023); Abdelgawad *et al.* (2023); Reach (2022)

Figure 1.
Conceptual framework

2.1 Theoretical perspective: unified theory of acceptance and use of technology (UTAUT)

The Unified Theory of Acceptance and Use of Technology (UTAUT) is one of the Theories that have been used in explaining technology acceptance in the organizational culture context (Silic & Back, 2013; Borg & Hedlund, 2019); technology acceptance or adoption (Sarfaraz, 2017; Ojiaku, Ezenwafor, & Osarenkhoe, 2024; Nawafleh & Fares, 2024). In addition, the Theory has also been used in explaining technology readiness (Tsourela & Roumeliotis, 2015; Dube, Eck, & Zuva, 2020) although not in the humanitarian context. In addition, the use of digital cash-based assistance in humanitarian crises is a newly introduced approach where the UTAUT Theory hasn't been applied nor tested and the limited research available is majorly qualitative. Whereas there may be a huge body of literature on Information Technology adoption, the literature or research is for other contexts such as marketing. This research focused on the humanitarian contexts where the environment is completely different from other environments where earlier research on IT adoption has been done.

Besides using the Theory in explaining the variables, organizational culture is taken to be an antecedent of the UTAUT Theory that affects a firm's propensity to embrace and use technology (Dasgupta & Gupta, 2011).

2.2 Humanitarian organizational culture and usage of digital cash-based assistance by humanitarian organizations in humanitarian crises

Organizational culture is a concept that has been explored for more than a decade now. However, the majority of the research on organizational culture is covered in other sectors other than the humanitarian sector. A dearth or no research exists on the impact of humanitarian organizational culture on using digital cash-based assistance in humanitarian crises. Organizational culture refers to values, shared beliefs or symbolic ideals to which individuals in a given organization ascribe (Melitski, Gavin, & Gavin, 2010). Most of the literature relates to organizational culture and technology adoption. Organizational culture is an important factor in the implementation of new technologies (Dubey, Bryde, Dwivedi, Graham, & Foropon, 2022; Kiefer, Van Dinther, & Spitzmüller, 2021; Abtahi, Farhana, & Hasan, 2023). Similarly, a culture that values both an external focus and an internal focus maximizes the efficient use of digital innovations (Harvey, Palmer, & Speier, 1998). Besides, culture is a critical factor in digital transformation (Chehade, McConaghay, & Meier, 2020) and

enhancing digital or technology usage (Dahabreh, 2023). Thus, organizations create a digital culture by adapting their culture to the digital payment format (Chehade *et al.*, 2020). Further, organizational cultures shape how organizations choose to use technology (Manoharan, Melitski, & Holzer, 2023). A change in culture in organizations involved in humanitarian supply chains is required to enhance technology adoption (Kabra, Ramesh, Jain, & Akhtar, 2023). In addition, Yusof, Hariri, Taheer, and Omar (2018) argue that organizational culture impacts the adoption rate of electronic payment systems. Thus, given the above discussion, it can be hypothesized that:

H1. Humanitarian organizational culture positively influences the usage of Digital cash based assistance by humanitarian organizations in humanitarian crises.

2.3 Humanitarian organizational culture and financial service provider's technology readiness

Humanitarian organizations experienced a gradual shift in their cultures from the use of physical cash to digital cash-based assistance (Akbari, Swift-Reeves, Goodman, & Barca, 2023). These cultures stem from the mission of the humanitarian organizations (Dubey *et al.*, 2019) which focuses on enhancing the adoption of digital cash by beneficiaries and financial service providers. Such a change in culture places pressure on the financial service providers to revisit their operation strategies in the settlements. This is because humanitarian organizations deliver digital cash transfers by working closely with financial service providers that have the required networks and expertise to deliver cash in this way (Ford, 2017). Further, previous research shows that culture has an impact on technology readiness when it influences participants' technology readiness (both the financial service-providing firms and refugees) (Lu, Wang, & Hayes, 2012). Also, Dubey *et al.* (2019) advance that organizational culture is critical for information technology (IT) adoption and diffusion and is found to have a significant role in the success of technology implementation (Samsie, Rahman, Ibrahim, & Layuk, 2021), and affects a firm's propensity to embrace and use technology (Govender and Pretorius, 2015). Similarly, Mishra and Maheshwari (2024) argue that organizational culture is among the key determinants for technology readiness. Also, a culture having both an external focus and an internal focus may maximize its efficient use of innovation such as digital innovations (do Carmo Caccia-Bava *et al.*, 2006). Whereas the culture of humanitarian organizations may enhance technology readiness in financial service-providing firms, empirical research examining the impact of the culture of humanitarian organizations on technology readiness of financial service-providing firms is non-existent. Thus, given the above discussion, it can be hypothesized that:

H2. Humanitarian organizational culture positively influences Financial service providers' technology readiness.

2.4 Financial service providers' technology readiness and usage of digital cash-based assistance by humanitarian organizations in humanitarian crises

Research examining the impact of financial providers' technology readiness and usage of digital cash-based assistance by humanitarian organizations in humanitarian crises is non-existent. Existing research focuses on technology readiness and technology acceptance, technology readiness and adoption and technology readiness and e-commerce adoption (Al Nahian Riyadh, Akter, & Islam, 2009; Damerji & Salimi, 2021). Although conducted in contexts other than the humanitarian contexts, earlier researchers including Jain and Singh (2024), Hong and Park (2024) and Damerji and Salimi (2021) argue that technology readiness enhances technology adoption. From the grey literature, Financial Service Providers (FSPs) deliver cash electronically through banking or mobile money services (Reach, 2022). Mobile

money payment firms looking to improve their services consider optimization of their applications to accommodate technology readiness and acceptance factors. Financial providers' Technology readiness and Acceptance factors for the use of digital cash-based assistance by humanitarian organizations include beneficiary preferences, the inclusion of all vulnerable refugee groups, safety and security, transaction costs and speed of delivery are key for the use of digital cash-based assistance (Reach, 2022). Further, assistance is increasingly provided using digital financial services that include mobile money because it enables persons of concern to receive cash assistance in an efficient and timely manner (Uganda Refugee Response Plan (RRP), 2023). With the above discussion, it can be hypothesized that:

- H3. Financial service providers' technology readiness positively influences the usage of Digital cash-based assistance by humanitarian organizations in humanitarian crises.*

2.5 The mediating role of financial providers' technology readiness on the relationship between humanitarian organization's culture and the usage of digital cash-based assistance by humanitarian organizations in humanitarian crises

Research examining the mediating role of financial service providers' technology readiness on the relationship between humanitarian organizations' culture and usage of digital cash-based assistance by humanitarian organizations in humanitarian crises is non-existent. The majority of the work done on digital cash-based assistance is located in the grey literature and focuses on the contribution of digital cash-based assistance to financial inclusion in refugee contexts (ACODE, 2021; Dhawan & Zollmann, 2023; Abdelgawad, Khan, & Baharmand, 2023). Grey literature shows the presence of a link between humanitarian organizational culture and financial providers' technology readiness. Digital Cash transfer programs in humanitarian organizations pressure financial service providers to improve their technology readiness in various refugee settlements (USAID, 2019). The operating capacity of the financial service providers is assessed before involving them in digital cash-based transfers. Besides, financial service providers view humanitarian cash programs as attractive business opportunities worth investing in thus improving their technology readiness (Cash working group, 2022). Technology readiness of financial service providers results in the use of digital cash-based transfers. The use of digital cash-based transfers may be limited when the speed of the digital cash transfer transactions is low, digital cash transfer systems are not accessible, and inconvenient to beneficiaries, and when financial service providers are experiencing liquidity problems among others (Bommart, 2021).

Besides the humanitarian field, research conducted in other contexts such as SME manufacturing firms shows that both organization culture and technology readiness may impact information technology usage in e-commerce transactions (Abtahi *et al.*, 2023). Further, Mishra and Maheshwari (2024) advance that the culture in an organization determines its technology readiness and the level of readiness enhances technology usage or adoption. Thus, it can be hypothesized that:

- H4. Financial service providers' technology readiness mediates the relationship between humanitarian organizational culture and the usage of Digital cash based assistance by humanitarian organizations in humanitarian crises.*

2.6 Construct measurement development for financial service providers' technology readiness

Earlier research advances, Coverage, Speed and Timeliness, Cost Effectiveness and the User Friendliness of digital payment technology (Sandvik, Van Daal, & Adèr, 2014); User

Friendliness, Security and Compliance and Speed and Timeliness (Di Domenico, 2006) and speed, reliability, enjoyment of use, control and awareness of risks associated with technology (Trachuk & Linder, 2017) as measures for technology readiness.

Grey literature in the humanitarian field points to the capacity of the technology to meet program objectives, the level of market functionality, transactional costs, implementation capacity and financial infrastructure, and the ability to manage risks (World Bank, 2016); cost effectiveness, coverage, safety and timeliness (Maghsoudi & Abakar, 2024); interoperability and network coverage (Perdomo & Buzurukova, 2023); flexibility for the beneficiary to withdraw their cash at a time they choose (UNCHR, 2019); accessibility and network coverage, convenience, privacy, agency density, transaction costs, interoperability and security (U-Learn, UKaid and Cash working group, 2022); agent network, network coverage, regulatory environment, speed and convenience, security and partnership (GSMA, 2023); easiness to use, speed and security (OXFAM, 2022) and liquidity, interoperability and compliance (German cooperation, UKaid, & Social Protection, 2020) as key factors for a technologically ready financial service provider. Despite the suggested digital payment interventions, Abdelgawad *et al.* (2023) show that current research provides no evidence-based feasibility requirements for measuring financial service providers' technology readiness in refugee contexts.

3. Method

This section presents the research design, study population, sample size, sampling methods, data collection and preliminary analysis results.

3.1 Research design

A quantitative and qualitative cross-sectional survey design was used. Cross-sectional surveys are when information has to be gathered at a single point in time. The study involved testing research hypotheses; thus a quantitative study was also employed. Further, the study involved developing and testing measures for financial service providers' technology readiness thus an inductive approach had to be used.

3.2 Population of the study, sampling and sample size

The target population consisted of humanitarian organizations that were members of the Uganda Cash Consortium (UCC). A total of 77 humanitarian organizations were considered (Uganda Cash Working Group Report, 2023). The unit of analysis was International and local humanitarian organizations that subscribe to the Uganda Cash Consortium. The unit of inquiry consisted of five members of the program team and five on the logistics team who were directly involved in cash distribution. This was because these members had adequate information about the usage of digital cash-based assistance in humanitarian crises, making a total of ten respondents from each organization. The respondents were selected purposively. Because ten people were selected from each organization, the data collected was aggregated to the unit of analysis.

Out of 77 Humanitarian organizations, a sample size of 65 humanitarian organizations was considered. The sample size was determined using Krejcie and Morgan (1970). The firms were selected using the rand() function in Excel. Random values were generated for each firm and the firms were arranged in ascending order beginning from the smallest to the biggest whereafter the data was collected.

3.3 Qualitative data collection and analysis

Qualitative data used in the development of the measurement constructs for financial service providers' technology readiness was collected through interviews from 9 humanitarian

organizations, 4 financial service-providing firms serving refugees in the settlements and refugees/beneficiaries/persons of concern from 13 settlements. Collected data was recorded and transcribed and later analyzed using Atlas ti version 23. The recordings were transcribed verbatim and the spoken words were converted into written text, the research ensured that data remained accessible and ready for rigorous analysis. The reliability and validity of the collected data were ensured by focusing on data credibility, understandability, dependability and consistency among others. Besides that, interviews were conducted till a saturation point was reached.

Code trees were developed by connecting dots. The code trees were essentially hierarchical structures of codes, drawing relationships and identifying underlying patterns. The derived code trees later acted as pillars for the financial service providers' technology readiness measures, thus providing a scaffold upon which the research's conclusions were built.

Once developed (see Table 1), quantitative data was collected on the developed measures and a factor analysis was run to obtain the true measures for the financial service providers' technology readiness based on the factor loading. All identified measures were found relevant to the financial service providers' technology readiness variable.

3.4 Quantitative data collection and analysis

Quantitative data were collected through a drop-off and pick-up method using a questionnaire. The items were plotted on a 5-point Likert scale. The usage of digital cash-based assistance by humanitarian organizations was measured using bank money transfers, mobile money transfers and cheques using Venkatesh, Morris, Davis, and Davis (2003) while humanitarian organizational culture was measured using vision and goals, values, norms and beliefs using measures of Bettinger (1989), and Parida, Raina, and Narayan (1990). For the case of financial service providers' technology readiness, measures were developed and tested in this research.

Quantitative data were entered in the Statistical Package for Social Scientists software (SPSS). Using both the SPSS and SMART PLS software, preliminary tests for normality, collinearity, reliability, common method variance and construct validity (convergent and discriminant validity) were carried out. Normality and common method variance tests were obtained using SPSS while reliability and construct validity (convergent and discriminant validity) results were obtained using SMART PLS. Skewness values for the variables were less than 2 while kurtosis values were less than 7 (see Appendix 1) as suggested by Xiong and King (2015). There were no collinearity issues as the Variance Inflation Factors (VIF) were below 10.0. Common method variance values were below 0.50 (see Appendix 1) and such common method variance results do not affect research findings. Reliability values were above 0.80 way beyond the recommended threshold (Nunnally & Bernstein, 1978) (see Appendix 1), while composite reliability values were above 0.40 implying the existence of convergent validity (Taks, Chalip, & Green, 2015) (see Appendix 1). Similarly, average variance extracted values (AVE) were 0.50 and above supporting the presence of convergent validity. Discriminant validity values obtained using the heterotrait-monotrait method were below the set threshold of 0.9 (Friman *et al.*, 2019; Henseler, Ringle, & Sarstedt, 2015) thus indicating the presence of discriminant validity (see Appendix 2).

3.5 Factor analysis

A factor analysis examines the relationship between the measurement items and their constructs. The constructs in this study included the usage of digital cash-based assistance, financial service providers' technology readiness and humanitarian organizational culture. The factor analysis was run using SMART PLS. All items for the constructs had loading higher than 0.30 (see Tables 2–4).

Dimension	Criteria of measurement	Measurements items	Unit of measurement
Coverage	Reach and accessibility of the financial service provider	Number of financial service provider branches/agents, mobile network coverage, internet access, regional coverage consistent with the Number of areas served by the HO per region, lists of the areas	Areas/Regions Number, Percentage
Reliability	Consistency and dependability of the service provider	Uptime, availability or System downtime, number of failed transactions or transaction failure rate, float availability (absence of liquidity challenges)	Percentage number
Security and compliance	The degree of security and Compliance with legal and regulatory requirements, and data security	Number of audits passed, security certifications, regulatory adherence or Number of security breaches/ incidents, compliance records	Certificates/ Checks Number records
Cost effectiveness	Costs involved in implementing digital cash-based transfers Affordability and efficiency of the service	Cost per transaction, setup costs, ongoing fees or Service fees, transaction costs, overall cost per beneficiary	Currency Currency (UGX, USD)
User experience and accessibility	Ease of use, literacy requirements and accessibility to all, including disabled persons	Number of languages supported, ease of use ranking, accessibility features	Ranking/Number
Speed and timeliness	Speed of transactions and responsiveness to emerging needs	Transaction time, delay statistics, responsiveness to urgent requests	Time (minutes/ hours)
Partnership and local integration	Alignment with local systems and ability to partner with other stakeholders	Number of local partners, integration with existing local systems Number of compatible systems, ease of integration	Number/Extent ease indicators
Innovation and scalability	Ability to innovate and scale up as per the requirements Ability to adapt the service to varying levels of demand	Number of innovations introduced, ability to handle increased load, scalability assessment Maximum transaction volume, ease of expansion to new regions/populations	Number/ Assessment, capacity indicators
User friendliness	The ease of use of the service for beneficiaries	User training required, ease of transaction, user complaint rate	Number, percentage
Transparency and accountability	Ability to track and report transactions accurately	Record keeping capability, availability of transaction reports	Records, reports
Programme requirements and implementation context	<ul style="list-style-type: none"> • Programme objectives National financial landscape Assessment	Cash-centric theory of change. Density and strength of financial infrastructure. Financial behaviors matching programme design	Records, reports

Table 1.
Financial service providers' technology readiness dimensions and measures

Source(s): Table by authors

	Loading
<i>Bank money transfers</i>	
Bank money transfers made by the financial service provider contracted by our humanitarian organization have been effective for all beneficiaries	0.796
Our humanitarian organization uses financial service providers that offer bank money transfers that are fast and reliable	0.853
Our humanitarian organization always uses financial service providers that offer bank money transfers for beneficiaries in urban and rural areas	0.878
The financial service providers' bank money transfers contracted by our humanitarian organization are not affected by network problems	0.845
Our humanitarian organization works with different banks to effect money transfers to the different beneficiaries	0.743
<i>Mobile money transfers</i>	
Most of the beneficiaries our humanitarian organization serves prefer mobile money transfers to other payment modalities	0.783
Our humanitarian organization views mobile money transfers as unsafe compared to other money transfer modalities	0.804
Our humanitarian organization thinks that the mobile money payment modality is easy to use	0.684
Our humanitarian organization contracts financial service providers that employ mobile money transfers alongside other money transfer methods	0.796
Our humanitarian organization contracts financial service providers whose mobile money transfer network is reliable	0.760
<i>Cheques</i>	
Our humanitarian organization contracts financial service providers using cheques to transfer money to selected beneficiaries	0.849
Our humanitarian organization thinks that cheques give better references and accountability	0.851
Most of the beneficiaries our humanitarian organization serves are well conversant with cheques	0.853
Our humanitarian organization allows cheques as a mode of payment to beneficiaries who are both in urban and rural areas	0.862
Our humanitarian organizations finds cheques as a friendlier and familiar payment modality to all people	0.863
Source(s): Table by authors	

Table 2.
Usage of digital cash based assistance factor analysis results

4. Findings

This sub-section provides and discusses findings obtained as a result of testing the four established hypotheses including the influence of humanitarian organizational culture on the usage of digital cash-based assistance by humanitarian organizations in humanitarian crises, the influence of financial service providers (FSPs) technology readiness on the usage of digital-based Assistance by humanitarian organizations in humanitarian crises; the influence of humanitarian organizational culture on Financial providers' technology readiness and the mediating role of financial service providers' technology readiness on the relationship between organizational culture and the usage of digital cash-based assistance by humanitarian organizations in humanitarian crises. Below is the presentation and discussion of the findings.

4.1 Humanitarian organizational culture and usage of digital cash-based assistance by humanitarian organizations in humanitarian crises

Findings indicate that the humanitarian organization's culture positively influences the usage of digital cash-based assistance by humanitarian organizations in humanitarian crises ($\beta = 0.711$; $p \leq 0.001$). The results imply that organizations that have values, visions and

Table 3.
Organization culture
factor analysis results

	Loading
<i>Vision</i>	
Our humanitarian organization's vision clearly clarifies our business's meaning and purpose for stakeholders	0.866
Our humanitarian organization's vision is intended to state the current and future objectives of our organization	0.737
All our humanitarian organization's goals align with our vision statements	0.763
Our humanitarian organization's goals are challenging and motivating	0.774
All our humanitarian organization's goals are specific, measurable, attainable, realistic and time bound	0.721
<i>Beliefs</i>	
This humanitarian organization respects the beliefs of its employees and beneficiaries	0.767
This humanitarian firm believes in time management	0.684
This humanitarian firm believes that every opinion counts	0.843
This humanitarian organization respects its workers and beneficiaries	0.774
This humanitarian organization believes that criticism is important	0.774
<i>Values and norms</i>	
We have shared values in this humanitarian organization	0.786
This humanitarian organization believes in honesty and professionalism	0.793
Maximizing and maintaining customers satisfaction is key to our humanitarian organization's work	0.758
Our humanitarian organization always uses teams to accomplish different tasks	0.744

Source(s): Table by authors**Table 4.**
Financial service
providers technology
readiness factor
analysis results

	Loading
<i>Items</i>	
Financial service providers for our firm charge lower transactional costs for digital cash transfers	0.801
Financial service providers for our firm provide easy to use digital cash transfer technologies	0.798
Financial service providers for our firm have a reliable digital cash transfer network	0.866
Financial service providers for our firm take limited time when providing digital cash transfer services to beneficiaries	0.752
Financial service providers for our firm have accessible technologies	0.865
Financial service providers for our firm have all the necessary infrastructure in place relevant for the provision of digital cash transfer services to beneficiaries	0.821
Financial service providers for our firm have effective risk management strategies in case a problem occurs during digital cash transfer operations	0.778
Financial service providers for our firm have feedback mechanisms in place to provide accountability for digital cash transfer disbursements to refugees	0.860
Financial service providers for our firm have enough liquidity on them necessary for the smooth running of the digital transfer operations	0.808
Financial service providers for our firm ensure privacy of the information for the beneficiaries	0.714
Financial service providers for our firm ensure safety and security of the digital cash transfer transactions with beneficiaries	0.608
Financial service providers for our firm provide digital cash transfer mechanisms that are convenient to use by beneficiaries	0.741
Financial service providers for our firm innovate relevant digital cash transfer technologies to solve existing cash transfer problems in refugee contexts	0.722

Source(s): Table by authors

norms that favor digital cash assistance are more likely to successfully implement digital cash-based assistance. Further, cultural values serve as the foundation for decision-making and guide human action (Leal-Rodríguez, Sanchís-Pedregosa, Moreno-Moreno, & Leal-Millán, 2023). Besides, digital financial services (DFS) are much more common in the humanitarian field in Uganda and other refugee-hosting nations such as Kenya and Ethiopia because of the shift from physical cash transfers to digital cash transfers (GSMA, 2023). Also, research conducted by the World Food Programme in Kenya shows that organizational culture influences cash-based transfers although the focus is placed on physical cash transfers (Odera, 2017). Further, previous research emphasizes that an institutional culture affects decision-making. Thus, such cultures may enhance the adoption of digital approaches during cash transfers or may hinder it (Hemerling, Kilmann, Danoesastro, Stutts, & Ahern, 2018; Roelen, Longhurst, & Sabates-Wheeler, 2018; Leal-Rodríguez *et al.*, 2023; Loonam, Eaves, Kumar, & Parry, 2018; Brunetti *et al.*, 2020).

4.2 Financial service providers (FSPs') technology readiness and usage of digital-based assistance by humanitarian organizations in humanitarian crises

The research findings indicate the presence of a positive influence of financial service providers' technology readiness on the usage of digital cash-based assistance by humanitarian organizations ($\beta = 0.639$; $p \leq 0.001$). Financial providers' technology readiness is seen in the form of reliable networks, accessibility of the technology, liquidity, ease of use of the technology, convenience, transactional costs that may be incurred when using the technology, safety and security, compliance with regulations, risk management during the digital cash transfer process, privacy, speed of delivery of the digital cash and coverage among others. These factors are enablers but their absence may inhibit (such as prohibitive withdrawal fees, and limited or no liquidity) the use of the digital cash transfer mechanism by humanitarian organizations. For example, World Food Programme (WFP) is expanding the use of digital delivery mechanisms through the use agency banking of the contracted Financial service provider (Kwetonda & Kentenyingi, 2023). Further, financial service providers' (FSP's) technology readiness varies in the various refugee settlement areas in Uganda thus resulting in the use of a particular financial product by humanitarian organizations in digital cash transfers (either mobile money usage or use of banks). Besides, financial service providers develop partnerships and engage in knowledge-sharing to come up with digital financial systems that meet the needs of humanitarian organizations (Gurung & Perlman, 2018; Kwetonda & Kentenyingi, 2023).

Despite the above, previous research on technology readiness shows that technology readiness enhances technology adoption, for instance, the adoption of airline self-service kiosks (Lee, Castellanos, & Chris Choi, 2012); and airline self-service mobile application adoption (Smit, Roberts-Lombard, & Mpinganjira, 2018). Elliott, Meng, and Hall (2012) find technology readiness fosters or hinders the adoption of new technology while Roy and Moorthi (2017) find technology readiness to result in M-commerce adoption.

4.3 Humanitarian organizational culture and financial service providers' technology readiness in humanitarian crises

The findings indicate the presence of a positive influence of humanitarian organizational culture on financial providers' technology readiness (See Figure 2). From the findings, the movement of humanitarian organizations to digitized cash-based assistance has led to the prevalence of digital financial services in the humanitarian field. For instance, the move towards the use of digital payment platforms has resulted in new technological innovations that can be used in enhancing digital cash transfers in refugee contexts. Similarly, humanitarian agencies in other nations have focused on the growth of digital financial

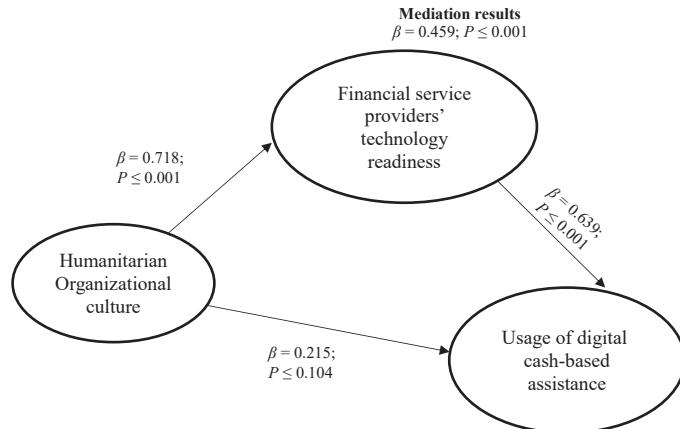


Figure 2.
Research findings

Source(s): Figure by authors

systems to deliver cash transfers using bank cards and mobile money in crisis-stricken areas (Mebur, 2021). Whereas financial service providers' technology readiness may be important, and despite the shift in humanitarian organization culture, humanitarian organizations can only use digital cash transfer platforms when appropriate (Bailey *et al.*, 2016). The findings are supported by Holm-Nielsen, Raju, and Furu (2022) who argue that changes in humanitarian organizations affect or alter the humanitarian context although the changes may be in the form of strong emotional reactions. Further, culture is seen to influence the speed at which any changes would take place.

4.4 The mediating role of financial service providers' technology readiness on the relationship between humanitarian organizational culture and the usage of digital cash based assistance by humanitarian organizations in humanitarian crises

A simultaneous mediation analysis was undertaken to examine the mediating role of the financial service providers' technology readiness. From the analysis, the findings indicate the existence of a full mediation effect of humanitarian organizational culture in the relationship between financial service providers' technology readiness and usage of digital cash-based assistance by humanitarian organizations in humanitarian crises. (See Figure 2). A full mediation effect exists because the influence of the humanitarian organizational culture on the usage of Digital Cash Based Assistance in by humanitarian organizations ceases once the Financial Service Providers' Technology Readiness variable is introduced in the model. Prior to the mediation analysis, humanitarian organizational culture had a direct influence on the usage of Digital Cash Based Assistance in by humanitarian organizations (see Appendix 3).

The findings are supported by grey literature that shows that humanitarian organizations are changing from the use of the physical cash delivery method to the use of digital financial aid to deliver assistance (Ankunda, 2022). For example, the *United Nations Capital Development Fund (UNCDF)* has continued to work with UN agencies and non-governmental organizations (NGOs) to ensure the adoption of a conducive environment for digital payments within refugee settlements. Also, the move by NGOs including the Norwegian Refugee Council (NRC), International Rescue Committee (IRC), World Vision and World Food Programme (WFP) in distributing cash digitally has influenced financial service providers' technology readiness (UNCDF, 2018) through developing convenient, easy-to-use, reliable technologies and the necessary infrastructure that have enhanced the use of digital cash

transfer mechanisms for aid delivery (Ankunda, 2022). Further Shiong, Qhotsokoane, and Phillips (2020) advance that mobile money operators can waive transaction charges like Safaricom, and Palmpay to make mobile an appropriate substitute for physical cash.

The results are supported by previous research that shows that organizational culture impacts technology readiness when it influences participants' technology readiness (both the financial service-providing firms and refugees) (Lu *et al.*, 2012). Other scholars like Dubey *et al.* (2019) argue that organizational culture is critical for information technology (IT) adoption and affects a firm's propensity to embrace and use technology (Govender & Pretorius, 2015). Besides culture and technology readiness, technology readiness affects user's technology adoption behavior (Rahardja, Hapsari, Putra, & Hidayanto, 2023) and enhances technology acceptance (Kim, Lee, & Preis, 2020). In addition, technology readiness influences the predisposition of a firm or individuals to use technology through motivators and inhibitors (Ritz, Wolf, & McQuitty, 2019).

5. Conclusion

The study aimed to examine the impact of the culture in humanitarian organizations on the usage of digital cash-based assistance by humanitarian organizations in humanitarian crises and Financial providers' technology readiness; the impact of financial service providers' technology readiness on the usage of digital cash-based assistance by humanitarian organizations in humanitarian crises and the mediating role of financial service providers' technology readiness on the relationship between the culture of humanitarian organizations and the usage of digital cash-based assistance by humanitarian organizations in humanitarian crises. Findings from the analysis indicate that the culture in humanitarian organizations positively influences the use of digital cash-based assistance by humanitarian organizations in humanitarian crises. Financial providers' technology readiness. Financial service providers' technology readiness positively influences the use of digital cash-based assistance by humanitarian organizations in humanitarian crises and fully mediates the relationship between the culture of humanitarian organizations and the usage of digital cash-based assistance by humanitarian organizations in humanitarian crises.

The change from physical cash disbursement to digital cash transfers in humanitarian organizations has influenced a change in the way financial service providers need to do business in humanitarian supply chains. Humanitarian organizations are ready to work with and support those financial service providers' firms that have developed digital financial products that are fit for use in digital cash disbursements in refugee contexts. The humanitarian organizations further give a hand in terms of monetary support to the financial service providers that would like to establish themselves in refugee settlements thus resulting in improved technology readiness in the financial service-providing firms. Besides, previous research also shows that the presence of technologically ready financial service providers and a digitally orientated culture in humanitarian organizations enhances digital cash-based transfers.

Besides the findings, the research has theory, policy and practical implications. The study contributes to the humanitarian supply chain theory by examining determinants for digital cash-based assistance adoption in the humanitarian supply chain context. Further, examines the influence of the humanitarian organizations' culture and financial service providers' technology readiness on the usage of digital cash-based assistance by humanitarian organizations in humanitarian crises and the mediating role of financial service providers' technology readiness on the relationship between the culture of humanitarian organizations and the usage of digital cash-based assistance by humanitarian organizations in humanitarian crises. Research examining the influence of the two variables is non-existent in a humanitarian supply chain context. The majority of research and grey literature focuses on how digital cash-based transfers can be used to enhance financial inclusion in refugee contexts.

To practice, the study contributes by examining technology readiness using a humanitarian organization perspective. The research helps in providing an understanding to financial service providers on what is expected from them in terms of technology readiness required to serve the refugee contexts. Financial service providers will be able to develop digital technologies that can be used in digital cash transfers to beneficiaries in the humanitarian supply context. However, variances in terrain, climate and cultural norms across different regions also exert influence on technical preparedness. The cultural practices of indigenous populations can shape their receptivity towards digital aid, while climatic and geographical factors affect the cost-benefit dynamics of aid deployment. These factors collectively influence the stance of financial service providers towards extending financial support.

To policy, governments will come up with policies that govern the transactional costs that are charged during digital transactions in refugee settlements. Also, policies that lead to the achievement of financial service providers' technology readiness components from a humanitarian organization perspective will be developed. For example, policies focusing on reducing taxes on digital cash transfer transactions in refugee contexts.

Like any other study, this study had limitations that included methodological and theoretical limitations. The study used a cross-sectional quantitative approach when examining the influence of humanitarian organizations' culture and financial service providers' technology readiness on the usage of digital cash transfers by humanitarian organizations in humanitarian crises. However, given that the usage of digital cash-based assistance is a behavior, then a longitudinal approach needs to be employed. Further, a qualitative approach may be used in future research to get more insights into the role of the humanitarian organization culture and financial service providers' technology readiness.

Further granularity can be applied to the analysis of corporate culture and technological readiness. For instance, exploring the types of organizational cultures that facilitate digital technology usage and the technological preparedness levels of financial service providers. Moreover, identifying specific aspects of technological readiness among financial service providers that promote technology usage by organizational culture can enhance the robustness of the findings, supported by rigorous data analysis.

Also, Government policies and perspectives warrant examination. Varying governmental stances across different regions regarding humanitarian assistance creates inconsistencies in the operational challenges faced by humanitarian organizations and the technical preparedness required by financial service providers. When local policies do not support such endeavors, the deployment of cash-based digital assistance becomes arduous, thereby significantly impacting the execution of humanitarian aid efforts.

Besides the methodological limitations, the study's theoretical limitations involve examining financial service providers' technology readiness using a government perspective. Further, future researchers may also examine the technology readiness of financial service providers using for example the technology readiness index. Also, more research is required on the effect of other factors such as the attitude of humanitarian organizations employees and tax regimes on the use of digital cash-based assistance.

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(The Appendix follows overleaf)

Table A1.
Reliability, composite reliability, collinearity, AVE values and common method variance

Variables	Reliability values	Composite reliability	Collinearity statistics (VIF)	Skewness	Kurtosis	Common method variance (%)	CVI	Average variance extracted (AVE)
Usage of digital cash-based assistance	0.896	0.902		-1.443	2.102	30.40	0.744	0.589
Financial service providers' technology readiness	0.867	0.870	1.985	-1.223	1.441	28.67	0.789	0.549
Organizational culture	0.845	0.830	2.961	-1.409	2.563	35.53	0.812	0.533

Appendix 2

Variables	1	2
Organizational culture (1)		
Financial service providers' technology readiness (2)	0.782	
Usage of digital cash-based assistance (3)	0.600	0.788
Source(s): Authors' own creation		

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Table A2.

Heterotrait-mono-trait
discriminant validity
values

Appendix 3

Variables	Standardized estimate	p-value
Organizational culture → Usage of digital cash-based assistance	0.711	$p \leq 0.001$

Table A3.

Organizational culture
on usage of digital
cash-based assistance

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Drivers of non-fungible token (NFT) investment intention: the roles of innovativeness, knowledge, subjective norms and perceived value

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Abstract

Purpose – This study explores key factors influencing individuals' intentions to invest in NFTs, focusing on personal innovativeness, reward sensitivity, knowledge, subjective norms, perceived value and perceived risk. The aim is to provide insights into what motivates investors within this emerging market, addressing a gap in the understanding of NFT adoption from an investor perspective.

Design/methodology/approach – An online survey collected data from 272 participants in China and Hong Kong. The research employs partial least squares-structural equation modeling (PLS-SEM) to assess the relationships between various individual, social and market factors and NFT investment intentions.

Findings – The results suggest that personal innovativeness, reward sensitivity, NFT knowledge, subjective norms and perceived value positively impact NFT investment intentions. Additionally, age and income moderate the effects of subjective norms and perceived value on investment intentions, highlighting demographic influences.

Practical implications – For practitioners, insights into investor motivators can inform strategies to promote NFT investments, such as promoting the high reward potential, enhancing investor knowledge, leveraging social proof and emphasizing NFTs' perceived value. For academics, the findings open pathways for further research into investor psychology and the evolving dynamics of NFT and traditional investment markets.

Originality/value – This study advances NFT literature by identifying determinants of NFT investment behavior, a relatively uncharted area. By incorporating theories from investment behavior and technology adoption, it provides a new framework to understand the psychological and social drivers specific to NFT investments.

Keywords Knowledge, Subjective norm, Non-fungible token, Perceived value, Personal innovativeness, Reward sensitivity

Paper type Research paper

Introduction

Non-Fungible Token (NFT) represents a cutting-edge application of blockchain technology, offering a means to certify ownership and authenticity of digital content (Wang, Li, Wang, & Chen, 2021). Unlike crypto-assets such as Bitcoin or Ethereum, which are fungible and interchangeable, NFTs embody unique digital entities (Dowling, 2022). These entities encompass various forms, including text, images, sound files or videos (Wilson, Karg, & Ghaderi, 2022). Consequently, NFTs are not merely subsets of digital assets but signify a broader ecosystem that combines creativity with ownership authenticity.



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A key distinction between NFTs and crypto currencies lies in their market dynamics and utility. While cryptocurrencies are primarily used for transactions, as store of value or for decentralized financial operations, NFTs have established their position within creative industries, gaming and digital arts (Jain, Bruckmann, & McDougall, 2022). This development has contributed to the rise of an emerging market with a high degree of independence from the cryptocurrency ecosystem (Bao & Roubaud, 2022). According to Gherghelas (2023), the trading volume of NFT is reaching US\$946 million in January 2023. The investment volume in NFTs is expected to increase to around US \$2.38 billion in 2024, compared to US \$656 million in 2021 (Statista, 2023, April).

Another key characteristic of NFTs is their unique positioning in the investment landscape. Traditional investment tools, such as stocks and bonds, are evaluated based on their financial returns and intrinsic value tied to physical and corporate fundamentals. In contrast, NFTs derive value from digital provenance and the psychological appeal of creativity and ownership (Sestino, Guido, & Peluso, 2022). Thus, NFTs combine financial considerations with aesthetic and social drivers. Similar to certain alternative investment tools, NFTs offer both high market volatility and portfolio diversification opportunities due to their low correlation with those of conventional financial assets (Dowling, 2022).

The growing popularity of NFTs can be attributed to several factors, including the gradual acceptance of cryptocurrencies, emerging trends in popular culture and a surge in digital investments (Nadini *et al.*, 2021; Philippas, Rjiba, Guesmi, & Goutte, 2019). Moreover, their increasing transaction numbers and prices have been driven by high market volatility, low barriers to entry and investors' pursuit of speculative assets (Baker, Pizzo, & Su, 2022; Lee, Yan, & Wang, 2021). However, despite this enthusiasm, NFTs face significant challenges, such as environmental concerns arising from blockchain's energy consumption, regulatory ambiguities and fluctuating valuations (Ali *et al.*, 2023). These challenges highlight the need for a deeper understanding of the psychological and social factors influencing NFT investment behavior, which remains underexplored in the literature.

Previous studies of NFTs have primarily focused on pricing dynamics (Dowling, 2022) and economic value (Ko, Son, Lee, Jang, & Lee, 2022). Some researchers have also explored the relationship between NFTs and other financial products (Aharon & Demir, 2022). There has been a lack of research on the key factors that investors consider when purchasing NFTs, such as investor personality, perceived values and situational circumstances (Fortagne & Lis, 2023). This study addresses this gap by examining the determinants of NFT investment intentions. By integrating constructs such as personal innovativeness, reward sensitivity, knowledge, subjective norms, perceived values and perceived risk, it provides a robust framework for understanding what drives investors to adopt NFTs. These findings not only offer empirical insights into an emerging area of research but also provide practical implications for NFT platforms, marketers, financial institutions and other stakeholders aiming to promote investments in this domain.

Theoretical framework and development of hypotheses

This study builds upon previous research on cryptocurrencies and individual investment behavior to investigate the factors influencing individuals' intention to invest in NFTs. NFT purchases can be motivated by different perspectives, including those of investors, collectors and general consumers. Investors primarily view NFTs as financial assets, assessing their potential for monetary returns, portfolio diversification and market speculation (Ko *et al.*, 2022). Conversely, collectors are drawn to NFTs for their aesthetic appeal, cultural significance and uniqueness of NFTs, often prioritizing personal satisfaction and social signaling over financial gains (Sestino *et al.*, 2022). General consumers view NFTs as digital goods that enhance experiences in areas such as gaming, virtual environments or digital identity (Wilson *et al.*, 2022). This study focuses on the investor perspective, as the determinants of financial decision-making differ fundamentally from those influencing collecting or consumption behavior.

According to Che Hassan, Abdul-Rahman, Mohd Amin, and Ab Hamid (2023), several key theoretical perspectives are utilized to investigate investment intentions. The Theory of Planned Behavior (TPB) is prominently applied to examine individuals' intentions to invest, highlighting the relationship between individuals' attitudes, subjective norms and their investment intentions. Many studies have extended the traditional TPB model by incorporating variables from different perspectives. For instance, personality traits such as risk tolerance and uncertainty avoidance (Lim, Soutar, & Lee, 2013) are identified as antecedents predicting investment decisions. Cognitive factors, including financial literacy and investment experience, are recognized as strong predictors of investment intention (Raut, 2020). Moreover, social influences play a significant role in shaping investment behavior (Raut, 2020; Lai, 2019; Khawaja & Alharbi, 2021). These theories collectively highlight the importance of psychological, social and cognitive factors in understanding why individuals choose to invest in specific assets, including NFTs.

While six broad areas of determinants have been identified for investment intentions - (1) personal factors, (2) social factors, (3) market information, (4) firm-specific factors, (5) product-related factors and (6) demographical factors (Che Hassan *et al.*, 2023) – not all are directly applicable to NFTs. Firm-specific and product-related factors are less relevant to NFTs due to their lack of organizational backing. Instead, this study emphasized perceived value as a key determinant, reflecting the combination of aesthetic and financial evaluations that characterized NFTs (Ko *et al.*, 2022).

This study aims to investigate the influence of individuals' personal innovativeness, reward sensitivity and NFT knowledge – key personal factors – on their intention to invest in NFTs. Personal innovativeness captures an individual's willingness to adopt new technologies, while reward sensitivity highlights the anticipation of financial returns, both of them are particularly relevant to NFTs' speculative nature. NFT knowledge represents the cognitive aspect of investment, emphasizing the availability of market information in this emerging market.

In addition to personal factors, social influences, particularly subjective norms, are examined to understand how perceived social pressure affects individual's propensity to invest in NFTs (Perez *et al.*, 2023; Shanmugham & Ramya, 2012). The decision of an investor to invest in a specific product is influenced by various market, product and firm variables, including price fluctuations, relevant news, information from other sources and so on (Almansour, Elkrgigli, & Almansour, 2023). This study will investigate the effects of the perceived risk of the traditional investing market and the perceived value of NFTs on investors.

Finally, this study examines the role of demographic and socioeconomic factors as moderating variables to capture their impact on investment behavior. Demographic characteristics play an influential role in shaping investment intentions. In this study, demographics are treated as moderating variables to examine their influence on the relationships between the key determinants and investment intentions. For example, younger investors may be more responsive to personal innovativeness, while older investors may place more emphasis on personal experience (Lai, 2019). Treating demographics as moderating variables would allow exploration of these interactions, providing deeper insights into the heterogeneous nature of NFT investment behaviors (Saivasan & Lokhande, 2022).

Personal innovativeness

Personal innovativeness refers to an individual's tendency to be the early adopter of novel products and experiences, which significantly influence their willingness to adopt new technological products (Hong, Lin, & Hsieh, 2017). For example, personal innovativeness is positively associated with the adoption of health and fitness applications (Acikgoz, Filieri, & Yan, 2023) and augmented reality as a shopping tool (Romano, Sands, & Pallant, 2022). Akhtar and Das (2019) also suggested that individuals with an intense disposition towards innovation are more likely to invest in the financial markets. NFTs, being digital assets, represent a novel concept in the domains of art, collectibles and digital ownership (Wilson

et al., 2022). Individuals with high personal innovativeness, who are willing to explore and embrace new concepts, are thus more willing to invest in NFTs (Sestino *et al.*, 2022). Therefore, we formulated the hypothesis that:

H1. Personal innovativeness is positively related to an individual's investment intention of NFTs.

Reward sensitivity

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Reward sensitivity is defined as the extent to which behavior, emotion and cognitive processes are influenced by rewarding stimuli, such as food, social recognition or access to resources (Kim, Yoon, Kim, & Hamann, 2015). Individuals with high reward sensitivity often engage in goal-directed behavior to achieve positive outcomes (Carver, Sutton, & Scheier, 2000). Reward sensitivity is used to explain various human behaviors related to motivation, learning and emotion (Ávila, Parcet, & BarroS-Loscertales, 2008; Corr, 2004). It is also closely related to positive affectivity, approach motivation, extraversion, impulsivity, risk-taking and sensation seeking (Carver *et al.*, 2000; Elliot & Thrash, 2002; Satchell, Bacon, Firth, & Corr, 2018). Sun, Dedahanov, Shin, and Kim (2020) applied reward sensitivity to predict investors' intentions to switch their investments to the cryptocurrency market. In the context of NFTs, investors who exhibit greater sensitivity to the returns and benefits of investing in NFTs are more likely to invest in them. Therefore, we hypothesize that:

H2. Reward sensitivity is positively related to an individual's investment intention of NFTs.

NFT knowledge

NFT knowledge refers to an individual's understanding of NFTs and their underlying blockchain technology. Several research studies have shown that possessing relevant financial knowledge is a reliable indicator of one's intention to utilize financial products and services (Akhtar & Das, 2019; Arora & Chakraborty, 2023; Lusardi & Mitchell, 2013). Hastings, Madrian, and Skimmyhorn (2013) found that financial knowledge positively influences decisions about credit card usage and investing tools. Similarly, research has shown that having information about products has a substantial impact on online purchasing behaviors (Karimi, Papamichail, & Holland, 2015). In the context of NFTs, knowledge plays a key role in empowering investors to invest these innovative financial products (Arora & Chakraborty, 2023). Consequently, the following hypothesis is proposed:

H3. NFT knowledge is positively related to an individual's investment intention of NFTs.

Subjective norms

Subjective norm refers to "the perceived social pressure to perform or not to perform the behavior" (Ajzen, 1991, p. 188). Subjective norms, which are a form of social influence, are widely used to predict behavioral intentions, including consumers' mobile banking acceptance (Elhajjar & Ouaida, 2020), employees' investment of remote working (Odat, Alshurafat, Al Shbail, Ananze, & Al Amosh, 2023) and consumers' purchase of green products (Kumar & Pandey, 2023). Some studies also highlight the fact that subjective norms are significant determinants of investors' intention to invest in particular investment products (Alleyne & Broome, 2011; Pilatin & Dilek, 2023). For NFTs, subjective norms reflect the potential influence of social circles on an individual's decision to invest. As such, the following hypothesis is proposed:

H4. Subjective norms have a positive relationship with an individuals' intention to invest NFTs.

Perceived value of NFTs

Perceived value plays a key role in investment decisions by weighing monetary costs (transaction costs, relational costs, etc.) against nonmonetary considerations (time, effort, risk). Mattsson (1992) categorized value into three dimensions: emotional (consumer feelings), practical (functional and physical consumption) and logical (rational purchase). While originally a consumer decision-making construct, perceived value also applies to investment decisions, particularly in emerging technologies (Pham & Ho, 2015). For example, people's intention to adopt blockchain technology are influenced by their perceived usefulness and enjoyment (Grover, Kar, Janssen, & Ilavarasan, 2019). If individuals believe that blockchain can provide greater perceived value, it could potentially enhance their desire to utilize it (Yilmaz, Sagfossen, & Velasco, 2023). While cryptocurrencies lack inherent value, the perspective of investors regarding potential high returns plays a significant role in identifying instances of increased predictability in returns (Cheah & Fry, 2015).

In the context of blockchain and NFTs, perceived value often includes an assessment of potential returns and utility. Many customers acquire cryptocurrencies only for speculative purposes, aiming to capitalize on the substantial price fluctuations and retain them until the exchange rates appreciate (Böhme, Christin, Edelman, & Moore, 2015). However, some studies suggested that perceived usefulness and ease of use is a significant factor driving its investment (Mendoza-Tello, Mora, Pujol-López, & Lytras, 2018; Shahzad, Bouri, Roubaud, Kristoufek, & Lucey, 2019). Similarly, Yilmaz *et al.* (2023) and Sukumaran, Bee, and Wasiuzzaman (2022) also highlighted that perceived value is an important driver in NFT purchasing decisions. Thus, we hypothesize that:

- H5. Perceived value of NFTs is positively related to a person's investment intention of NFTs.*

Perceived risks of traditional investments

Some researchers have analyzed the correlation between cryptocurrencies and traditional investments, such as stocks, but the results of these studies have been inconclusive. Baur, Dimpfl, and Kuck (2018) argue that Bitcoin exhibits unique time series characteristics when compared to other assets, such as gold and the US dollar. Similarly, Umar, Jareño, and González (2021) and Charfeddine, Benlagha, and Maouchi (2020) found minimal correlation between cryptocurrency and traditional investments. However, some research indicates the presence of spillover effects, where risks in traditional markets may impact cryptocurrency investments (Aharon & Demir, 2022; Wang, 2022; Zhang, Sun, & Ma, 2022). In the case of NFTs, Dowling (2022) and Ko *et al.* (2022) found that NFTs exhibit low correlation with other assets, making them as effective tools for investment diversification and risk hedging. Investors who perceive traditional financial market as overly volatile or lacking attractive opportunities may be drawn to NFTs as an alternative investment. Therefore, we propose the following hypothesis:

- H6. Perceived risk of traditional investment is positively related to a person's investment intention of NFTs.*

Demographical factors

Demographic and socioeconomic factors, such as age, gender, income and investment experience, plays a key role in shaping investment behavior. These factors influence an individual's access to resources, risk tolerance and openness to technological innovations. For instance, Lai (2019) found that gender moderates the relationship between subjective norms and attitude towards investing in stocks. Kaur and Kaushik (2016) argued that demographic variables, including age, gender, occupation, income and education, influenced the level of awareness among Indian investors regarding mutual funds.

Research in the technology adoption domain further highlights the role of demographics. For example, users with higher income and more experience exhibit a greater intention to adopt and use mobile banking and payment services (Chawla & Joshi, 2023). However, limited research has examined the impact of user characteristics on their willingness to invest in NFTs. Examining user demographics is essential for comprehending the distinct effects of different factors on the intention to invest in NFTs, which allows investment platforms to customize their marketing strategies, design different communication strategies and formulate different marketing campaigns (Chawla & Joshi, 2023; Lai, 2019). Thus, we propose that to examine the effects of these factors on users' intention to invest in NFTs:

- H7a.* Personal innovativeness affects users' intention to invest NFTs differently based on (a) age, (b) gender, (c) income and (d) investment experience.
- H7b.* Reward sensitivity affects users' intention to invest NFTs differently based on (a) age, (b) gender, (c) income and (d) investment experience.
- H7c.* Subjective norms affects users' intention to invest NFTs differently based on (a) age, (b) gender, (c) income and (d) investment experience.
- H7d.* NFT Knowledge affects users' intention to invest NFTs differently based on (a) age, (b) gender, (c) income and (d) investment experience.
- H7e.* Perceived value affects users' intention to invest NFTs differently based on (a) age, (b) gender, (c) income and (d) investment experience.
- H7f.* Perceived risk of conventional investment affects users' intention to invest NFTs differently based on (a) age, (b) gender, (c) income and (d) investment experience.

Research methodology

This study examines the determinants of NFT investment intentions of participants from Hong Kong and China. These regions represent significant markets for digital assets, characterized by a tech-savvy population with evolving interest in blockchain technologies. While the findings are based on participants in Hong Kong and China, the framework has broader applicability to other regions with similar technological ecosystems and market characteristics. Future research could extend this to compare findings across diverse cultural and regulatory environments, enhancing the generalizability of the model.

Participant and data collection

The data for this study was collected using online survey platforms, specifically Google Form and Wenjuanxing, through snowball sampling. In order to ascertain the participants' foundational understanding of NFTs, screening questions were implemented to verify that the respondents possess rudimentary knowledge regarding NFTs. The data was collected from May to June 2023. A total of 272 responses were obtained in this survey, all of which were complete and suitable for analysis (response rate 76.1%). Table 1 displays the demographic characteristics of the respondents. The largest demographic proportion consisted of males (51.1%) aged 31 to 40, holding an undergraduate degree and possessing 1–5 years of investment experience.

Measurement items

The measurement items utilized in this study were derived from previously validated instruments and were slightly adjusted to suit the specific context of this research (Table 1).

Table 1. Respondent profile

Respondent characteristics (N=272)	Frequency	Percentages (%)
<i>Gender</i>		
Male	139	51.10
Female	133	48.90
<i>Age</i>		
18–30 years old	108	39.70
31–40 years old	134	49.30
41–50 years old	28	10.30
50 years old or over	2	0.70
<i>Education</i>		
Primary education	2	0.74
Secondary education	34	12.50
Post-secondary/university education	190	69.90
Postgraduate education or above	46	16.90
<i>Monthly income (in HKD)</i>		
<15,000 HKD	65	23.90
15,001–30,000 HKD	134	49.30
30,001–45,000 HKD	56	20.60
45,001–60,000 HKD	13	4.80
>60,000 HKD	4	1.50
<i>Investing experience</i>		
<1 year	77	28.30
1–5 years	104	38.20
6–10 years	67	24.60
>10 years	24	8.80
Source(s): Authors' own work		

The measurement of all constructs was conducted using multi-item scales. The participants were presented with a series of statements and were asked to rate their level of agreement on a seven-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree).

Data analysis

The relationships in our model were examined using partial least square structural equation modeling (PLS-SEM) through the utilization of SmartPLS 4.08 software. PLS-SEM has garnered support from various disciplines within the social sciences, such as information systems research (Chin *et al.*, 2020), organizational studies (Ringle, Sarstedt, Mitchell, & Gudergan, 2020) and marketing (Sarstedt *et al.*, 2022). We employed PLS-SEM due to its capability to assess the impact of the construct on investment intention, as well as its support for estimating measurement models and intricate structural models (Hair, Hult, Ringle, & Sarstedt, 2016).

Result and findings

Exploratory factor analysis

An initial exploratory factor analysis (EFA) was performed to assess the 25 items on measuring different constructs. EFA helps identify latent constructs and their underlying factor structure (Fabrigar, Wegener, MacCallum, & Strahan, 1999). The analysis was conducted using VARIMAX rotation in SPSS 26. The resulting solution consisted of seven factors, which accounted for 72.4% of the variance. The Kaiser-Meyer-Olkin (KMO) test yielded a value of

0.896, which suggests that the sampling is sufficient. The Bartlett's test for sphericity yielded a result of 2917.22 ($p < 0.001$), indicating that the data is suitable for factor analysis.

Assessment of measurement models

According to Gefen, Rigdon, and Straub (2011) validation guidelines, it is necessary to test the reflective measurement model for its unidimensionality. According to Table 2, all items demonstrated acceptable levels as defined by Henseler, Hubona, and Ray (2016). Reliability was confirmed using Cronbach's alpha, with values ranging from 0.754 to 0.904, exceeding the acceptable threshold. Convergent validity was established through standardized factor loadings (all >0.7) and average variance extracted (AVE) values (range: 0.619–0.771), satisfying criteria proposed by Hair, Risher, Sarstedt, and Ringle (2019) and Fornell and Larcker (1981). Composite reliability (CR) for all constructs ranged from 0.754 to 0.905, further supporting convergent reliability (Hair *et al.*, 2019).

Next, discriminant validity was evaluated using the square roots of AVE values and heterotrait-monotrait (HTMT) ratios (Table 3). The square roots of the AVE values consistently exceeded the off-diagonal correlations, while HTMT values remained below 0.9, confirming adequate discriminant validity Henseler, Ringle, and Sarstedt (2015). Therefore, the overall reliability and validity of constructs were significant enough to perform the structural analysis using SEM for testing the proposed hypotheses.

Assessment of structural model

The structural model and hypotheses were assessed according to the processes proposed by Hair *et al.* (2016). Variance inflation factor (VIF) of NK, PR, PV, PI, RS and SN as predictors of IN ranged from 1.295 to 1.924, indicating no multicollinearity issues (Hair *et al.*, 2016). The coefficient of determination (R^2) of investment intention of NFTs was 0.566, demonstrating strong-to-moderate predictive power (Hair *et al.*, 2016; Henseler, Ringle, & Sinkovics, 2009).

After the bootstrapping procedure (5,000 samples, no sign changes option), 5 out of 6 structural relationships were significant ($p < 0.01$). The supported paths for investment intention (IN) were those with PI (H1), RS (H2), NK (H3), SN (H4) and PV (H5). In addition, the effect size (f^2) ranged from 0.036 to 0.097, indicating small-to-moderate predictive relevance (Hair, Sarstedt, Ringle, & Mena, 2012). The results are shown in Table 4 and Figure 1.

Personal innovativeness (H1), reward sensitivity (H2), NFT knowledge (H3), subjective norms (H4) and perceived value (H5) were all positively and significantly related to investment intention in NFTs. Specifically, the standardized path coefficients were as follows: personal innovativeness ($\beta = 0.321, p < 0.01$), reward sensitivity ($\beta = 0.284, p < 0.01$), NFT knowledge ($\beta = 0.301, p < 0.01$), subjective norms ($\beta = 0.256, p < 0.01$) and perceived value ($\beta = 0.347, p < 0.01$). These results provide strong support for the hypothesized relationships, indicating that these factors play critical roles in shaping NFT investment intentions. However, perceived risk of traditional investments (H6) demonstrated a weaker, albeit statistically significant, positive relationship with NFT investment intentions ($\beta = 0.182, p < 0.05$). While this supports H6, the smaller effect size suggests that perceived risk operates more subtly compared to the other predictors.

Multigroup comparison

To test hypotheses 7(a) to (f), four multi-group analyses were respectively conducted for age, gender, income and investment experience using the PLS-MGA approach proposed by Keil *et al.* (2000). Results indicated no significant differences for gender or investment experiences. However, significant group differences were observed for income and age: (1) a significant path was identified between subjective norm and investment intention across age groups and (2) a significant path was found between perceived value and investment intention across income groups (see Table 5).

Table 2. Quality criteria of the constructs

Constructs and items	Mean	SD	Standardized loading
<i>Perceived risk (Sun et al., 2020) (CA = 0.852, CR = 0.863, AVE = 0.771)</i>			
PR1 It is inconvenient to find good investment targets in the traditional financial market	3.628	0.802	0.880
PR2 It is not wise to spend a lot of time investing in traditional financial market	3.671	0.897	0.909
PR3 It costs too much to get satisfying expected returns on the traditional financial market	3.749	0.797	0.844
<i>Reward sensitivity (Sun et al., 2020) (CA = 0.804, CR = 0.825, AVE = 0.718)</i>			
RS1 A good opportunity to get profits from NFTs can motivate me to purchase or invest in it	3.541	0.708	0.810
RS2 In most cases, I prefer to do something that pays off soon	3.826	0.689	0.839
RS3 I want to be the best of the people around me	3.763	0.793	0.891
<i>NFT knowledge (Chang & Chen, 2022) (CA = 0.845, CR = 0.849, AVE = 0.619)</i>			
NF1 I know the function and purpose of the NFTs	3.696	0.730	0.788
NF2 I will learn voluntarily about the product knowledge of the NFTs	3.556	0.792	0.742
NF3 I can provide knowledge about the NFTs to other people	3.333	0.881	0.863
NF4 I have had the experience of learning the NFTs	3.691	0.751	0.813
NF5 I have had the experience of experimenting with the NFTs	3.164	0.991	0.719
<i>Perceived value (Sukumaran et al., 2022) (CA = 0.863, CR = 0.865, AVE = 0.647)</i>			
PV1 Using NFTs in investment could help me improve the effectiveness, profitability and investment of my wealth	3.609	0.715	0.798
PV2 I find that investing in NFTs can earn money as it allows me to invest it quickly and inexpensively with lower transaction costs	3.386	0.741	0.783
PV3 Using NFTs could help me improve my financial performance because I could have total control over my money	3.401	0.736	0.842
PV4 I feel satisfied with my NFTs investment decisions	3.691	0.738	0.785
PV5 Investing in NFTs will increase opportunities to achieve important goals for me	3.643	0.768	0.811
<i>Personal innovativeness (San Martín & Herrero, 2012) (CA = 0.839, CR = 0.854, AVE = 0.755)</i>			
PI1 I like to try new things	4.000	0.646	0.855
PI2 I like to try out the new things	4.072	0.703	0.874
PI3 If there is any new products for investment, I would look for ways to experiment with it	3.826	0.762	0.878
<i>Subjective Norm (Armitage & Conner, 1999) (CA = 0.743, CR = 0.754, AVE = 0.660)</i>			
SN1 People who are important to me thinks that I should invest in NFTs	3.188	0.749	0.843
SN2 My interaction with people influences me to purchase or invest in NFTs	3.357	0.709	0.753
SN3 My acquaintances would approve of my decisions to purchase or invest in NFTs	3.261	0.696	0.838
<i>Investment intention (Sun et al., 2020) (CA = 0.904, CR = 0.905, AVE = 0.839)</i>			
IN1 I am likely to purchase or invest in NFTs	3.652	0.714	0.914
IN2 I desire to purchase or invest in NFTs	3.430	0.815	0.908
IN3 I plan to purchase or invest in NFTs	3.633	0.813	0.927

Source(s): Authors' own work

Common method bias

As self-reported cross-sectional survey were used, common method bias (CMB) was tested by two statistical tests. The Harmon one-factor test revealed that a single factor accounted for only 37.91% of the variance, below the 50% threshold (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003). A full collinearity test further indicated VIF values below the threshold of 5.0, confirming that CMB was not a serious concern in this study (Kock & Lynn, 2012).

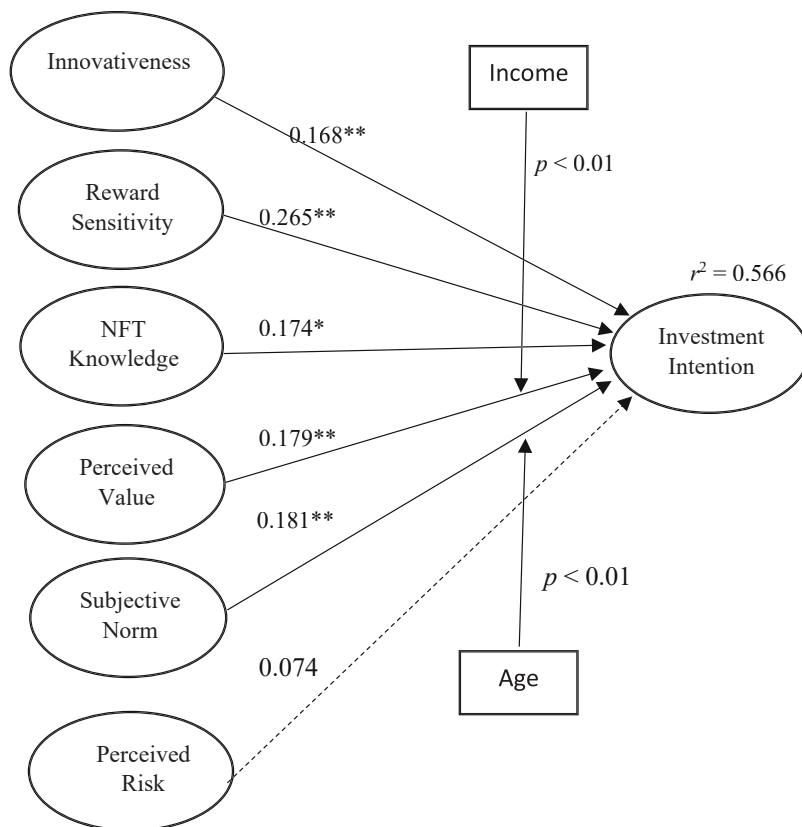
Table 3. Discriminatory validity

Fornell-Larcker criterion correlation matrix						Heterotrait-Monotrait ratio matrix					
NK	PI	PR	PV	RS	IN	NK	PI	PR	PV	RS	IN
0.787	0.869					NK	0.595				
0.504	0.233	0.878				PI	0.397	0.275			
0.338	0.467	0.355	0.804			PR	0.712	0.537	0.414		
0.609	0.500	0.364	0.501	0.475	0.847	PV	0.595	0.433	0.603	0.561	
0.500	0.595	0.524	0.399	0.588	0.584	RS	0.680	0.593	0.452	0.661	0.677
0.595	0.388	0.393	0.172	0.399	0.271	IN	0.489	0.475	0.221	0.496	0.357
0.388	Source(s): Authors' own work						NK	0.570			

Table 4. Significance testing results of the structural model path coefficients

	Path	Std. Beta	SE	t-value	p-value	f-square	Result
H1	PI → IN	0.168	0.058	2.892	0.004	0.043	Supported
H2	RS → IN	0.265	0.074	3.591	0.000	0.097	Supported
H3	NK → IN	0.174	0.073	2.399	0.016	0.036	Supported
H4	SN → IN	0.181	0.060	3.008	0.003	0.058	Supported
H5	PV → IN	0.179	0.064	2.788	0.005	0.040	Supported
H6	PR → IN	0.074	0.056	1.308	0.191	0.009	Unsupported

Source(s): Authors' own work



Note(s): * $p^2 < 0.05$, ** $p^2 < 0.01$

Source(s): Authors' own work

Figure 1. Result of structural model analysis

Discussion and implications

Results discussion

This study contributes to the existing literature by providing insights into the factors that influence users' intention to invest in NFTs. Our findings highlights the importance of personal factors, social influences and demographic characteristics in shaping investment intention.

Table 5. Comparison of age groups and income groups using PLS-MGA (H7a-H7f)

Path	Age group		Income group			Gp1 vs 2 <i>p</i> -value
	Gp 1: 108 respondents, ≤30 years old	Gp 2: 164 respondents, >30 years old	Gp 1: 199 respondents, ≤HK\$30,000	Gp 2: 73 respondents, >HK\$30,000	Gp 1: 199 respondents, ≤HK\$30,000	
PI → IN	0.265**	0.137*	0.266	0.201**	0.183	0.887
RS → IN	0.204*	0.287**	0.561	0.199*	0.464**	0.139
NK → IN	0.219*	0.218*	0.999	0.114	0.238	0.468
SN → IN	0.011	0.287**	0.009	0.123	0.325**	0.115
PV → IN	0.258*	0.086	0.248	0.313**	-0.099	0.006
PR → IN	0.024	0.073	0.654	0.091	-0.093	0.170

Note(s): Italic indicates a significant difference between Group 1 and Group 2 at a significance level

p* < 0.05, *p* < 0.01

Source(s): Authors' own work

First, the significant role of personal innovativeness aligns with innovation diffusion theory, which asserts that early adopters are more open to novel technologies. Previous research on cryptocurrencies (Sun *et al.*, 2020) similarly emphasizes the importance of personal innovativeness. Our results suggest that individuals with high personal innovativeness are drawn to NFT for their unique features (Yilmaz *et al.*, 2023).

Second, the positive influence of reward sensitivity aligns with findings in behavioral finance, which associate reward-driven individuals with higher levels of risk-taking and speculative behavior (Satchell *et al.*, 2018). The anticipation of significant financial returns serves as a powerful motivator for NFT investments. This result aligns with theories of approach motivation (Carver *et al.*, 2000), which posits that the expectation of rewards drives decision-making, particularly in high-reward contexts like NFTs.

Third, consistent with cognitive models such as financial literacy frameworks (Lusardi & Mitchell, 2013), we find that knowledge about NFTs is a key driver of investment intentions. Knowledge enables investors to navigate the complexities of NFT trading with greater confidence (Sun *et al.*, 2020). Providing accurate and accessible information about NFTs may therefore enhance investment confidence and adoption rates.

The significant influence of subjective norms is supported by the Theory of Planned Behavior (Ajzen, 1991), which highlights the role of perceived social pressure in shaping behavioral intentions. Similar to findings in investment research (Lai, 2019; Sun *et al.*, 2020), our results suggest that opinions and behaviors within social networks influence individuals' decision regarding NFT investments.

The results also show how market and product factors relate to the investment intentions of NFTs. This finding is consistent with the study of purchase intention of NFTs conducted by Fortagne and Lis (2023), which indicate that the perceived value and utilitarian attitude toward NFT has strong influence on the purchase intention of NFTs. However, our finding that perceived traditional investment risk is not significantly related to NFT investment intention. This finding deviates from conventional investment market theories and raises intriguing questions about the unique nature of NFTs as an investment asset (Dowling, 2022). This deviation highlights the need for further research into the relationship between NFTs and conventional asset classes.

Finally, demographic factors, such as age and income, moderate the relationships between the identified determinants and investment intention. The results show that subjective norm is less influential for the younger group of investors to consider purchasing NFTs and the perceived value of NFTs is more emphasis by lower income group when they make their investment decision. These findings align with prior studies on demographic influences (Lai, 2019) and suggest that the impact of personal factors and social influences on investment intention may vary depending on individuals' demographic characteristics.

Theoretical implications

This study offers important theoretical contributions to the understanding of NFT investment behavior. By examining personal factors, social influences and the moderating effects of demographic factors, our research extends existing theories in behavioral finance and technology adoption. These findings contribute to both academic research and practical applications in the field of NFT investments and enrich the literature on emerging financial markets.

First, our study confirms that constructs traditionally applied to technology adoption and financial investments – such as personal innovativeness, knowledge and reward sensitivity – are also relevant in the contexts of NFTs. This supports the generalizability of these constructs across different asset types, including novel digital assets. Importantly, integrating perceived value into the model, our research highlights the dual finance and emotional appeals of NFTs, advancing theories on utilitarian and hedonic motivations in investment decisions.

Second, the non-significance of perceived risks challenges established assumptions in cryptocurrency literature that perceived risk perception as a key consideration of investment behavior (Wang, 2022; Zhang *et al.*, 2022). Our findings suggest that investors may perceive NFTs as distinct from cryptocurrencies, focusing more on their innovative and speculative nature rather than traditional risk evaluations. This contributes to the growing literature distinguishing NFTs from broader blockchain-based financial products.

Finally, the study enhances theoretical models such as the Theory of Planned Behavior (Ajzen, 1991) by incorporating demographic moderators. Findings that younger investors are less influenced by subjective norms and that lower-income investors place greater emphasis on perceived value highlight the heterogeneous nature of NFT investment behavior. These insights extend existing theories by illustrating how individual differences shape decision-making in the context of emerging financial markets.

Managerial implications

Overall, this timely study delivers valuable theoretical and practical insights into an emerging investment domain. By identifying key drivers of NFT investment intentions, the study informs strategies to attract investors, such as emphasizing financial rewards, improving knowledge, leveraging social influences and enhancing perceived value of NFTs as digital assets.

To use the connection between personal factors and investment intention of NFTs, it is beneficial to target on persons who possess a high level of personal innovativeness and reward sensitivity. People with high level of personal innovativeness are more likely to explore the unique and groundbreaking characteristics of NFTs. Engaging with tech enthusiasts, early adopters and influencers can foster a favorable view of NFTs and promote their acceptance across a broader demographic. As individuals who are sensitive to high returns and rewards are more likely to express an interest in investing in NFTs, it is important to emphasize the potential financial gains associated with NFT investments. Marketing campaigns and investment guides can highlight success stories and showcase the profitability of NFT investments. This can attract more investors who are motivated by the allure of significant financial gains.

Given the significant role of NFT knowledge in driving investment intention, it is crucial to provide individuals with sufficient information, skills and knowledge about NFTs and other cryptocurrencies. Workshops, seminars and training programs can be organized by universities, financial institutions and industry professionals to provide education to potential investors regarding the distinctive characteristics and advantages of NFTs. This can enhance self-assurance and motivate investors to incorporate NFTs into their financial portfolios.

Due to the impact of subjective norms on investment decisions, it is essential to cultivate favorable perceptions and opinions regarding investments in NFTs. One effective approach to achieve this is by utilizing social proof, which involves showcasing successful NFT investors and their experiences to influence the investment decisions of others. By establishing a

network of NFT investors and encouraging discussions, a supportive environment can be created that promotes investment in NFTs.

Recognizing the influence of perceived value of NFTs on investment intentions, it is crucial to focus on enhancing the perceived value and utility of NFTs as investment assets (Vishnu Prasad, Murthy, Joseph, & Adhikari, 2023). This can be achieved by promoting the uniqueness, scarcity and authenticity of NFTs (Fortagne & Lis, 2023). Additionally, conducting further research to understand the relationship between NFTs and traditional investment markets can provide valuable insights for investors and guide their decision-making process.

Limitation and future studies

The present study serves as a valuable starting point for understanding the relationship between various factors and the investment intention of NFTs. While this study provides insightful findings, there are certain limitations that hinder drawing conclusive results. Firstly, the study was conducted with investors in Hong Kong and China using a non-probabilistic sampling method. Therefore, caution is advised when generalizing and applying the results to other populations. Future research should aim to include investors from diverse cultures and demographic backgrounds.

Secondly, it is important to acknowledge that there are different types of NFTs, and investors in each type may have distinct expectations, values, motivations and behaviors. This study did not explore the key characteristics among various types of NFT investors. Given the rapid development of cryptocurrencies and NFTs, it is anticipated that more types of NFTs will emerge. Future studies can delve into the psychological processes and behavioral outcomes of investors across different types of NFTs and cryptocurrencies.

Lastly, in recent years, the platforms and processes involved in investing in NFTs and cryptocurrencies have become more comprehensive. There are multiple touchpoints throughout the investment process. For instance, key opinion leaders may promote new cryptocurrencies through various social media platforms during the pre-consumption stage. Following the promotion, they may encourage viewers to join social network groups to foster ongoing communication and relationships during the post-consumption stage. Future studies can expand their scope to include more communication and promotional elements across different stages of NFT investment. This will enable a better understanding of the unique characteristics of this rapidly evolving domain of cryptocurrencies and NFTs.

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The synergistic effects of remittances, savings, education and digital financial technology on economic growth in Sub-Saharan Africa

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Abstract

Purpose – This paper aims to investigate the impact of remittances, savings and education on economic growth in Sub-Saharan Africa. The study focuses on understanding how these factors independently and interactively contribute to growth, with a specific emphasis on their potential to drive sustainable economic development in the region.

Design/methodology/approach – The study employs a panel dataset comprising 23 Sub-Saharan African countries over the period from 1974 to 2020. The system generalized method of moments (GMM) estimation technique is utilized to address potential endogeneity issues and also explore the interactions between these variables to assess their combined influence on growth.

Findings – The findings reveal that remittances, savings and education have a significantly positive effect on economic growth in Sub-Saharan Africa. Additionally, the study finds that the interactions between remittances and both savings and education are positively and significantly associated with economic growth.

Practical implications – The results indicate that Sub-Saharan African countries could harness the full potential of remittances to drive economic growth by implementing policies that encourage a savings culture and improve educational outcomes.

Originality/value – This paper contributes to the literature by providing a comprehensive analysis of the independent and interactive effects of remittances, savings and education on economic growth in Sub-Saharan Africa. The study's use of the System GMM approach allows for robust estimation, accounting for potential endogeneity, and offers new insights into how these factors work together to influence economic development in the region.

Keywords Remittances, Savings, Education, Economic growth, SSA

Paper type Research paper

1. Introduction

International migration from Africa has seen a significant rise in recent years. In 2020, an estimated 19.5 million Africans were living outside the continent, marking an increase of 2.5 million since 2017 (McAuliffe & Triandafyllidou, 2022). Additionally, around 21 million African migrants were living within another African country during the same period. This trend of both internal and external migration is expected to continue growing, driving further increases in remittances sent back to home countries—a phenomenon that has garnered



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attention in both research and policy-making circles. Sub-Saharan Africa (SSA) has long been one of the largest recipients of remittances among developing regions. In 2021, official development aid to Africa was \$35bn, while remittance inflows reached approximately \$49bn (World Bank, 2022). For many SSA countries, remittances are not just a crucial driver of economic growth but also a vital source of livelihood for the majority of households. Remittances complement domestic savings and contribute to human capital development, particularly through education financing.

However, savings rates in SSA remain low compared to other developing regions such as South Asia, East Asia, and Latin America. Despite the region's rich natural resources, domestic capital mobilization has been hampered by challenges such as widespread poverty, high public debts, rapid population growth, inefficiencies in the financial sector, and persistent balance of payment issues. These challenges have led to insufficient domestic investment, resulting in sluggish economic growth. For instance, while East Asia's average savings rate was 34% between 1990 and 2019, SSA's average was just 22% during the same period (Tagem & Sen, 2022). Moreover, savings rates in SSA have been highly volatile, with a peak of 29% in the early 2000s, dropping to 24% in 2005, and rising again to 27% in 2016. As of the most recent World Bank estimates, the region's average savings rate stands at approximately 19%. Notably, there are significant variations within the region; for example, Kenya has a relatively high average savings rate of 28.60%, while Niger's rate is consistently low, averaging 13.06%.

Given these dynamics, the role of remittances in boosting savings and providing the necessary capital for sustainable economic growth in SSA cannot be overstated. Furthermore, digital financial technologies, such as mobile money and online banking, have revolutionized the way remittances are sent, received, and utilized, thereby enhancing their impact on savings and investment (Guermond, 2022). These technologies have made it easier and more cost-effective for migrants to send money back home, increasing the flow of remittances and enabling more households to access these funds for savings and education.

Education is another critical channel through which remittances can drive economic growth and poverty reduction. Education empowers individuals socially and economically, enhancing the quality and productivity of the labor force—key ingredients for economic transformation. Several studies (e.g. Arif, Raza, Freiman, & Suleman, 2019; Azizi, 2018; Barajas, Chami, Fullenkamp, Gopen, & Peter, 2009) have shown that remittances support education, particularly in rural areas of developing countries, by reducing school dropouts and absenteeism. This is particularly true for low-income households, where remittances help finance children's education, especially at higher levels. However, public financing of education in SSA is often insufficient due to limited resources, leading to high dropout rates (UNESCO, 2022a, b). Digital financial technology plays a crucial role here as well, enabling more efficient distribution of remittances to cover educational expenses, thereby increasing enrollment and completion rates among children.

While a large inflow of remittances is desirable, it is crucial to understand how this inflow enhances the productivity of savings and education. Remittances help lower the cost of accessing education for low-income households, particularly at higher levels. This allows students to focus on their studies without the need to work to support their education, leading to better academic performance and higher productivity in the labor market upon graduation. On the savings side, remittances augment domestic savings, providing capital for economic activities. Digital financial platforms further facilitate the accumulation of these savings, reducing the cost of borrowing and making it easier to invest in productive ventures. When channeled into such activities, remittances can expand economic opportunities, thereby driving economic growth.

Given this background, it is imperative to investigate how migrant remittances, bolstered by digital financial technology, reinforce savings and education to affect economic growth in Sub-Saharan Africa. This paper seeks to answer the following research questions: (1) What are the individual effects of migrant remittances, savings, and education on economic growth in

Sub-Saharan Africa? (2) What is the interactive effect between migrant remittances and savings on economic growth in Sub-Saharan Africa? (3) What is the interactive effect of migrant remittances and education on economic growth in Sub-Saharan Africa? To address these research questions, this study analyzes data from 23 Sub-Saharan African countries over the period 1974–2020, where complete datasets for the variables of interest are available. The study employs the system GMM estimator, a robust estimation technique capable of addressing key econometric challenges such as unobserved individual country characteristics, endogeneity, and omitted variable bias.

Although previous research has explored the impact of remittances on economic growth, this paper offers a unique contribution by focusing on how remittances complement domestic savings and education to drive sustained economic growth, particularly in a region with generally low savings rates. Additionally, this study argues that the impact of remittances, savings, and education on economic growth may not be instantaneous, necessitating an analysis that includes both current and past levels of these variables. This approach distinguishes this paper from existing literature, highlighting its contribution to the ongoing discourse on remittances and economic growth in Sub-Saharan Africa.

2. Literature review

The theoretical foundations of modern economic growth are predominantly rooted in two key frameworks: the neoclassical growth theory and the endogenous growth theory, both of which now intersect significantly with the role of digital financial technology. The neoclassical growth model, pioneered by Solow (1956), remains a cornerstone in understanding economic growth. This model posits that technological progress is the primary driver of long-term economic growth. Traditionally, economic growth was largely fueled by capital accumulation, measured by the amount of capital per labor unit, which enhanced productivity within a country. However, with the advent of digital financial technologies, the nature of capital accumulation has evolved. Digital platforms have facilitated greater access to financial resources, enabling more efficient capital allocation and mobilization. This, in turn, accelerates productivity growth and economic expansion. A central tenet of the Solow model is the concept of the “steady-state,” where economies grow consistently over time. In today’s context, digital financial technologies can help poorer countries accelerate their growth rates by enhancing financial inclusion and providing access to capital, thus promoting convergence with wealthier nations.

The second influential framework in economic growth literature is the endogenous growth theory, also known as the new growth theory, developed by economists such as Paul Romer and Robert Lucas in the 1980s and 1990s. The central premise of endogenous growth theory is that knowledge, rather than just physical capital, drives economic growth. In the digital age, financial technologies play a crucial role in the dissemination and accumulation of knowledge. Digital platforms facilitate the spread of ideas, innovations, and technological advancements, which are essential for economic growth. Unlike physical capital, knowledge can be infinitely shared and expanded, leading to sustained growth without the limitations of diminishing returns. Digital financial technologies also support research and development (R&D) by providing new avenues for funding and collaboration, further driving technological innovation and economic expansion. As these technologies are integrated into the economy, they enhance the productivity of knowledge and technological advancements, leading to increasing returns to scale and fostering long-term economic development.

Both the neoclassical and endogenous growth theories now incorporate the transformative impact of digital financial technology. These technologies enhance capital accumulation, knowledge dissemination, and innovation, providing a modern understanding of the dynamics of economic growth. By facilitating financial inclusion, improving access to capital, and supporting innovation, digital financial technologies are central to driving sustainable economic growth in the digital age.

Following from the above theoretical discussions, there has been a plethora of researches and studies aimed at identifying the factors that explain differences in output growth and income among countries and regions across the world. One of those factors that have received considerable attention happens to be migrant remittances aid strongly by digital financial technology.

Several channels through which remittances can affect economic growth have been hypothesized, and the integration of digital financial technology has amplified these effects. First, remittances are expected to boost economic growth by providing an alternative source of funding that helps overcome liquidity constraints and sustain economic activities in the receiving country. Digital financial platforms enhance this effect by making the transfer and access to remittances faster, more secure, and more widely accessible. This increased efficiency in remittance flows aids in capital formation and investment by complementing domestic savings (UNCTAD, 2010; Woodruff & Zenteno, 2007).

Moreover, remittances create supplementary income for receiving households, adding to their disposable income, and boosting consumption and aggregate demand, which directly contributes to economic growth (Mondal & Khanam, 2018; Acosta, Fajnzylber, & Lopez, 2007; Yang & Martinez, 2006). Digital financial technologies further facilitate this by enabling households to manage and utilize remittances more effectively through digital wallets and mobile banking, enhancing their purchasing power and economic participation.

Additionally, remittances provide the means for households to finance educational needs, contributing to the development of a productive labor force that can accelerate economic growth (Barajas *et al.*, 2009; Azizi, 2018). Digital platforms support this by making educational payments more accessible and affordable, allowing for greater investment in human capital. However, remittances can have adverse consequences on the receiving country's economic growth, particularly through a decline in labor supply, as recipients may reduce their work efforts (Azizi, 2018). The role of digital financial technology in this context is distinct, as while it enhances the positive impacts of remittances, it may also contribute to these adverse effects by making remittances more reliable and reducing the need for recipients to seek additional income.

The relationship between remittances and economic growth has produced mixed results in the literature. Some studies have found a positive and significant impact, while others have noted a negative or negligible effect.

For instance, the World Bank (2006) conducted a study on 67 countries using the system GMM estimation, finding that remittances positively impact economic growth. Faini (2007) also found a significantly positive relationship between remittances and growth for a panel of 68 countries from 1980 to 2004, although the effect was more pronounced with better infrastructure and lower uncertainty. Digital financial technology, by improving infrastructure and reducing transaction costs, could amplify this positive effect.

Anyanwu and Erhijakpor (2010) estimated the impact of international remittances on poverty reduction in 33 African countries from 1990 to 2005, finding that a 10% increase in remittances led to a 2.9% reduction in poverty headcount. Digital platforms can enhance this poverty-reduction effect by making remittance transfers more affordable and accessible Ozili (2018).

Adams and Klobodu (2016) examined the impact of remittances on economic growth in 33 Sub-Saharan African countries between 1970 and 2012, finding no robust impact. However, they found that when remittances were combined with stable and democratic governance, the effect on growth was positive and significant, suggesting that the broader economic environment plays a crucial role. Abduvaliev and Bustillo (2020) assessed remittances' impact on economic growth and poverty reduction compared to other capital flows in 10 Commonwealth Independent Countries. They found that a 1% increase in remittance flows triggered a 0.25% rise in per capita GDP and a 2% decline in poverty severity. The authors attributed this to the smoothing of consumption levels, a process made more efficient by digital financial technologies. A more recent study by Dutta and Saikia (2022) on 17 Asian countries

from 1993 to 2017 found that remittances positively and significantly boosted economic growth. The incorporation of digital financial technology in these countries likely contributed to this positive outcome by enhancing the efficiency and impact of remittance flows on the economy.

Notwithstanding the positive impact of remittances on economic growth highlighted above, there are some studies that found evidence of a negative relationship between economic growth and remittances. Chami, Fullenkamp, and Jahjah (2005) developed a model to determine whether remittances were a source of capital flow for economic growth among 113 countries over the period 1970–1998. After controlling for other variables, their paper finds that remittances have significantly negative effect on economic growth. The authors however, argued that with better development of social institutions, remittances rather tend to enhance economic growth. A more recent study by Ayenew (2022) provides further evidence on the adverse effect of remittances on economic growth. The author investigates the impact of foreign financial inflows on economic growth among 31 sub-Saharan African countries using a two-step system GMM and finds that economic growth is negatively affected by remittances, though not statistically significant. Lim and Simmons (2015) employed panel cointegration analysis to investigate the effect of remittances on economic growth among countries in the Caribbean Community and Common Market and find no evidence of a long-run relationship between remittances and real GDP per capita or investment. The authors however, find evidence of a long-run relationship between remittances and consumption.

Another area of importance is the relationship between remittances and human capital. Several studies have suggested that remittances support education leading to accumulation of human capital in the recipient countries. The argument has been that remittances help to reduce school dropouts and absenteeism significantly especially in the rural areas of the developing world since children will not have to work to supplement household income. This way, remittances help to enhance enrollment and completion rates among children. For instance, Azizi (2018), using a panel data consisting of 122 developing countries covering 1990–2015 finds that on average, a 10% increase in remittances respectively raises primary and secondary school enrollments by 3.5 and 0.6% while it raises primary completion rate by 0.6% and secondary completion rate by 0.9%.

As noted earlier, remittances augment domestic capital formation in the receiving country and several studies have provided evidence in this regard. A UN Conference on Trade and Development study conducted in 2010 showed that nearly 30% of the remittances received in countries like Guatemala and Ghana provide the initial capital for many small-scale businesses. In a related study by Woodruff and Zenteno (2010) in Mexico, the authors find positive relationship between remittances and domestic capital formation. They discovered that remittances account for approximately 20% of the capital base of many small businesses and microenterprises operating across many urban areas in Mexico. A further analysis in their study shows that more than one-third of the capital invested in small scale enterprises within the 10 Mexican states which tend to have the highest number of migrants in the United States comes from remittances.

The above review shows that there are varied findings regarding the relationship between remittances and economic growth, a situation that could be explained in part by datasets, choice of control variables and estimation strategies. It is also clear that large volume of the existing literature estimates the direct aggregate impact of remittances on growth with just a few delving deeper to examine the indirect impact or the mechanisms through which remittances affect growth. This paper thus contributes to the literature by investigating how remittances enhance the productivities and impacts of education and savings on economic growth. It is significant to note that most of the existing studies focus on only remittance-education and remittance-savings nexuses without linking their impact to economic growth (See Amega, 2018; Gyimah-Brempong & Asiedu, 2015; Mansour, Chaaban, & Litchfield, 2011; UNCTAD, 2010; Woodruff & Zenteno, 2007).

Education provides the essential training and skills which make the labor force more productive for economic growth. Again, education provides the foundation for research and development activities which constitute an important source of growth. Nonetheless, public funding of education in many developing countries is greatly inadequate due to limited resources, a situation which often leads to school dropout (UNESCO, 2022a, b). To finance their education therefore, households tend to rely on remittances received from family members abroad. In this sense, remittances help to keep children in school which is expected to improve their educational outcomes. Thus, if remittances contribute significantly to household investment in education in developing countries, then it could improve the productivity of education leading to economic growth. Similarly, savings rates in many developing countries are generally low and as a result dependence on remittances to build domestic capital for economic transformation cannot be overemphasized. In sub-Saharan Africa where the rates of savings are generally low, remittances could supplement domestic savings to raise the much-needed capital for economic transformation. Again, it has been observed that many households depend on remittances sent by family members abroad to finance their children's education particularly at the higher level. Consequently, this present study attempts to investigate the indirect effects of remittances or how remittances complement domestic savings and education to affect economic growth in sub-Saharan Africa.

3. Data

This paper utilizes panel data encompassing annual observations from 23 countries in Sub-Saharan Africa over the period 1974–2020. The selection of these countries was influenced by the availability of comprehensive data for all variables of interest during this period. The dataset features a time dimension of 47 years and a cross-sectional dimension of 23 countries, resulting in a total sample size of 1,081 observations. This sample size is relatively substantial compared to similar empirical studies. For example, Anyanwu and Erhijakpor (2010) analyzed 528 observations to examine the impact of remittances on growth and poverty reduction in Sub-Saharan Africa, while Adams and Klobodu (2016) used a sample of 1,319 to explore the effects of remittances and regime durability on economic growth. Similarly, Dutta and Saikia (2022) investigated the long-run effects of remittances in Asia with a sample size of 442, and Lim and Simmons (2015) utilized 481 observations to study the impact of remittances on economic growth in the Caribbean Community and Common Market.

The primary variables of interest in this paper include gross domestic product per capita, remittances, education, savings, and digital financial technology. GDP per capita is measured in constant 2015 US dollars. Remittances are assessed through three metrics: the volume of remittances received by households, remittances as a percentage of GDP, and remittances per capita. Education is evaluated using gross tertiary and gross secondary school enrollment rates. Savings are measured as a percentage of GDP. Additionally, the paper considers the role of digital financial technology, measured by indicators such as digital payment adoption rates, access to digital financial services, and the volume of digital transactions.

Control variables include political regime, external debt, commodity prices, foreign aid, financial development, and inflation. Data on political regimes, education, and commodity prices were sourced from the PolityIV Project (2021), UNESCO (2022a, b), and IMF Financial Statistics (2023), respectively. Data on all other variables, including digital financial technology, were obtained from the World Development Indicators (2023).

4. Methodology

The core objective of this paper is to estimate the impact of remittances, savings and education on economic growth. We start with an endogenous growth model framework. Endogenous growth theory emphasizes that economic growth is driven by internal factors such as technology, human capital, and investment. The introduction of digital financial technology

(DFT) can enhance these factors by improving financial access, efficiency, and investment. In this framework, the production function can be expressed as:

$$Y_{it} = A_{it} K_{it}^\alpha L_{it}^{1-\alpha} \quad (1)$$

Where Y_{it} = output in country i at time t , A_{it} = total factor productivity, K_{it} = capital stock, L_{it} = labour force, α = output elasticity of capital. Capital accumulation is given by $\dot{K}_{it} = I_{it} - \delta K_{it}$, where I_{it} = investment, δ = depreciation rate. Investment can be influenced by remittances, savings, education, and digital financial technology:

$$I_{it} = \varnothing_1 REMITT_{it} + \varnothing_2 SAV_{it} + \varnothing_3 EDU_{it} + \varnothing_4 DFT_{it} \quad (2)$$

Where REMITT is the net inflow of migrant remittances, SAV is savings rate, EDU represents education and DFT is digital financial technology. $\varnothing_1, \varnothing_2, \varnothing_3, \varnothing_4$ are Coefficients to be estimated. Human capital H_{it} evolves based on education and technology:

$$\dot{H}_{it} = \beta_1 EDU_{it} - \beta_2 H_{it} \quad (3)$$

Where β_1 = Rate at which education translates into human capital and β_2 = Depreciation of human capital. Technological progress can be enhanced by digital financial technology, which facilitates innovation and research:

$$A_{it} = \varphi_1 REMITT_{it} + \varphi_2 SAV_{it} + \varphi_3 EDU_{it} + \varphi_4 DFT_{it} \quad (4)$$

We Incorporate the effects of remittances, savings, education, and digital financial technology on economic growth:

$$\frac{dY_{it}}{dt} = \gamma_1 REMITT_{it} + \gamma_2 SAV_{it} + \gamma_3 EDU_{it} + \gamma_4 DFT_{it} \quad (5)$$

Note: As the role of digital financial technology becomes increasingly integrated into the economy, its marginal effect may diminish over time due to saturation or improved financial systems becoming standard.

The dynamic panel data regression model that incorporates the interaction effects of remittances, savings, and education, and the diminishing role of digital financial technology where $\lim_{\varphi DFT_{it}} \rightarrow 0$, can be specified as:

$$y_{it} = \varphi + \tau y_{it-1} + \gamma_1 REMITT_{it} + \gamma_2 SAV_{it} + \gamma_3 EDU_{it} + \gamma_4 (REMITT * SAV)_{it} \\ + \gamma_5 (REMITT * EDU)_{it} + \delta' X_{it} + \lambda_i + \varepsilon_{it} \quad (6)$$

where $i = 1, 2, 3, \dots, N$ is the cross-sectional dimension of countries, $t = 1, 2, 3, \dots, T$ represents time, y_{it} is the logarithm of real GDP per capita, y_{it-1} is the lag of logarithm of real GDP per capita, $(REMITT * SAV)_{it}$ is the interaction between remittances and savings, $(REMITT * EDU)_{it}$ is the interaction between remittances and education, X_{it} is a set of control variables, τ , γ and δ are the coefficients to be estimated, λ_i represents the unobserved country specific fixed effect while, ε_{it} represents the error term. All the variables have been sufficiently defined in the previous section. If $\gamma_4 > 0$, it means remittances and savings are complements. $\gamma_4 < 0$ implies that remittances and savings are substitutes. In much the same way, if $\gamma_5 > 0$, it means remittances and education are complements while $\gamma_5 < 0$ implies that remittances and education are substitutes. A statistically insignificant γ_4 and γ_5 would imply that the effects of remittances, savings and education on economic growth are independent. Given this background, γ_4 and γ_5 are expected to be positive since we expect the interactions between

remittances and savings and remittances and education to produce positive growth effects. Also, remittances, savings and education are theoretically and intuitively expected to promote economic growth, hence γ_1 , γ_2 and γ_3 are expected to be positive.

We further argue that the impact of remittances, savings, education and their interactions on economic growth may not be contemporaneous. Thus, it may take some time for the impact of these variables on economic growth to show. This implies that economic growth in this case may be influenced by both current and past levels of these explanatory variables. To account for this, we respecify Equation (6) to include both current levels and lags of these variables as shown in Equation (2) below:

$$\begin{aligned}
 y_{it} = & \varphi + \tau y_{it-1} + \gamma_1 REMITT_{it} + \gamma_2 SAV_{it} + \gamma_3 EDU_{it} + \gamma_4 (REMITT * SAV)_{it} \\
 & + \gamma_5 (REMITT * EDU)_{it} + \gamma_{6h} \sum_{h=0}^5 REMIT_{it-h} + \gamma_{7h} \sum_{h=0}^5 SAV_{it-h} + \gamma_{8h} \sum_{h=0}^5 EDU_{it-h} \\
 & + \gamma_{9h} \sum_{h=0}^5 (REMIT * SAV)_{it-h} + \gamma_{10h} \sum_{h=0}^5 (REMIT * EDU)_{it-h} + \delta' X_{it} + \lambda_i + \varepsilon_{it}
 \end{aligned} \tag{7}$$

where h is the maximum number of lags, $\gamma_6 - \gamma_{10}$ are coefficients of the lagged variables and are all expected to be positive. The preceding model clearly shows that dynamic data methodology is utilized in this paper. More precisely, the paper makes use of the system Generalized Method of Moment (simply called system GMM) estimator proposed by Blundell and Bond (1998). This estimator is an improvement on the first-difference GMM earlier developed by Arellano and Bond (1991) whose significant reliance on lagged variables resulted in poor instruments. By modifying the first-difference GMM estimator through the introduction of lagged levels and lagged differences, Blundell and Bond's (1998) system GMM is capable of removing potential fixed effects as well as unobserved country-specific features which are likely to correlate with the independent variables. Consequently, the problems of omitted variable bias and endogeneity which often plague studies related to economic growth such as this are efficiently dealt with. Hence, the choice of the system GMM estimator is appropriate for this study given that it provides consistent estimates. The system GMM estimation was done by implementing the Stata user-written command *xtabond2* developed by Roodman (2012). The flexibility of this command makes it more user-friendly than the traditional Stata command.

5. Results

In this section, we delve into the presentation and detailed analysis of the empirical results obtained through the System Generalized Method of Moments (GMM) estimation technique. The primary focus is to evaluate the impact of lagged and current levels of remittances, savings, and education, as well as their interactions on economic growth. This comprehensive analysis is grounded in a panel of 23 Sub-Saharan African countries over the period from 1974 to 2020. Table A5 in the Appendix presents the descriptive statistics which describe the characteristics of the dataset.

Tables 1 and 2 provide the detailed results from five distinct models, with the change in the log of GDP per capita serving as the dependent variable. Table 1 presents the findings related to the lagged variables, whereas Table 2 reports the effects of these variables at their current levels. The results are organized as follows:

Column 1 of both tables reports the relationship between remittances and economic growth. The results in Table 1 indicate that remittances have a positive and statistically significant impact on economic growth after a five-year period. Specifically, the coefficient on remittances is positive, suggesting that a 1% increase in remittances leads to a 0.02% increase

Table 1. Remittances, savings, education and growth: system GMM estimation with lagged explanatory variables

Variables	(1)	(2)	(3)	(4)	(5)
$\Delta \ln \text{GDPC}_{it-1}$	-0.0157** (0.0103)	-0.0163** (0.0104)	-0.0177** (0.0106)	-0.0169** (0.0106)	-0.0181** (0.0102)
[REMIT/GDP] _{it-5}	0.0208*** (0.0022)	0.0446*** (0.0029)	0.0128*** (0.0025)	0.0183*** (0.0032)	0.0504*** (0.0045)
[SAV/GDP] _{it-5}		0.0032* (0.0017)		0.0049** (0.0021)	
LNCOMMOPX _{it}	0.0400** (0.0190)	0.0408** (0.0190)	0.0395** (0.0186)	0.0396** (0.0189)	0.0404** (0.0184)
POLREGIME _{it}	0.0227*** (0.0060)	0.0225*** (0.0057)	0.0214*** (0.0062)	0.0212*** (0.0055)	0.0197*** (0.0069)
[AID/GDP] _{it}	0.0034 (0.0030)	0.0033* (0.0021)	0.0034 (0.0030)	0.0034* (0.0021)	0.0037 (0.0031)
[EXTDEBT/GDP] _{it}	-0.0392*** (0.0095)	-0.0353*** (0.0094)	-0.0416*** (0.0083)	-0.0352*** (0.0097)	-0.0392*** (0.0082)
[FINDEVT/GDP] _{it}	-0.0030 (0.0028)	-0.0025* (0.0016)	-0.0044 (0.0032)	-0.0026* (0.0017)	-0.0046* (0.0028)
INFL _{it}	-0.0077** (0.0036)	-0.0051 (0.0055)	-0.0092*** (0.0031)	-0.0040 (0.0054)	-0.0095*** (0.0031)
EDU _{it-5}			0.0090** (0.0039)		0.0079* (0.0040)
[REMIT*SAV/GDP] _{it-5}				0.0012** (0.0005)	
[REMIT*EDU] _{it-5}					0.0026** (0.0010)
Constant	-0.144** (0.0655)	-0.143** (0.0627)	-0.140** (0.0648)	-0.136** (0.0624)	-0.147** (0.0654)
Observations	966	966	966	966	966
No. of countries	23	23	23	23	23
AR(1) <i>p</i> -value	0.000	0.000	0.000	0.000	0.000
AR(2) <i>p</i> -value	0.432	0.452	0.475	0.497	0.468

Note(s): ***, ** and * denote significance at 1, 5 and 10% levels, respectively; values in () are robust standard errors

Source(s): Authors, 2024

in economic growth after five years. This finding aligns with existing literature, such as the studies by Dutta and Saikia (2022), Abduvaliev and Bustillo (2020), Azizi (2018), Mondal and Khanam (2018), and Woodruff and Zenteno (2007), which highlight that remittances significantly contribute to economic growth by aiding in capital formation and boosting household consumption. However, Table 2 shows that current levels of remittances do not have a significant impact on economic growth, echoing the results of Lim and Simmons (2015), who found no evidence of a direct positive effect of remittances on GDP per capita among countries in the Caribbean Community and Common Market. These seemingly contradictory results suggest that the positive effects of remittances on economic growth may take time to become evident in the economy.

Columns 2 and 3 focus on the effects of savings and education on economic growth. The results for savings, as shown in Table 1, reveal a positive but marginally significant coefficient. A 1% increase in gross domestic savings results in a 0.003% increase in economic growth after five years. Although the statistical significance is relatively low (10%), this finding supports the traditional growth theory that higher savings rates lead to greater capital accumulation and investment, consistent with the conclusions of UNCTAD (2010). Similarly, Table 2 confirms

Table 2. Remittances, savings, education and growth: system GMM estimation with current levels of explanatory variables

Variables	(1) Chlndgpc	(2) Chlndgpc	(3) Chlndgpc	(4) Chlndgpc	(5) Chlndgpc
$\Delta \ln GDPC_{it-1}$	-0.0136 (0.0104)	-0.0148 (0.0108)	-0.0154* (0.0105)	-0.0137 (0.0104)	-0.0167* (0.0109)
[REMIT/GDP] _{it}	0.0172 (0.0228)	0.0214 (0.0353)	0.0855*** (0.0252)	0.0541 (0.0405)	0.0713*** (0.0264)
[SAV/GDP] _{it}		0.0051 (0.0354)		0.013 (0.0419)	
LNCOMMODPX _{it}	0.0443** (0.0177)	0.0441** (0.0195)	0.0438** (0.0173)	0.0428** (0.0201)	0.0465*** (0.0178)
POLREGIME _{it}	0.0223*** (0.0055)	0.0220*** (0.0056)	0.0210*** (0.0056)	0.0216*** (0.0055)	0.0168*** (0.0057)
[AID/GDP] _{it}	0.0033 (0.00289)	0.0033 (0.00288)	0.0033 (0.00288)	0.0034 (0.000286)	0.0034 (0.00287)
[EXTDEBT/GDP] _{it}	-0.0320*** (0.0097)	-0.0334*** (0.0100)	-0.0327*** (0.0090)	-0.0332*** (0.0010)	-0.0363*** (0.0089)
[FINDEVT/GDP] _{it}	-0.0260 (0.0439)	-0.0263 (0.0445)	-0.0405 (0.0459)	-0.0233 (0.0450)	-0.0452 (0.0395)
INFL _{it}	0.0083** (0.0037)	0.0079 (0.0049)	0.0090*** (0.0034)	0.0066 (0.0055)	0.00047 (0.0039)
EDU _{it}			0.0814* (0.0392)		0.0658** (0.0264)
[REMIT*SAV/GDP] _{it}				0.0066** (0.0026)	
[REMIT*EDU] _{it}					0.0034*** (0.0011)
Constant	-0.164** (0.0813)	-0.165** (0.0838)	-0.164** (0.0801)	-0.159* (0.0863)	-0.179** (0.0842)
Observations	1,035	1,035	1,035	1,035	1,035
No. of countries	23	23	23	23	23

AR(1) *p*-valueAR(2) *p*-value**Note(s):** ***, ** and * denote significance at 1, 5 and 10% levels, respectively; values in () are robust standard errors**Source(s):** Authors, 2024

that current levels of savings do not significantly affect economic growth, reinforcing the notion that past savings levels have a more substantial impact on growth.

Column 3 presents the effects of education on economic growth. The analysis shows a positive and significant effect, with a 1% increase in tertiary school enrollment leading to a 0.009% increase in economic growth five years later. This result is consistent with earlier research by Bloom, Canning, and Chan (2006), Barro and Lee (1994), and Mankiw, Romer, and Weil (1994), which emphasizes the role of tertiary education in enhancing labor force productivity and fostering economic growth. Although current education levels are positively related to economic growth, the effect is less significant compared to the impact of lagged education.

Columns 4 and 5 examine the interactions between remittances and savings (*REMITSAV*) and *remittances and education (REMITEDU)*. Both interactions show positive and significant relationships with economic growth, both with and without lags. These findings highlight the complementary role of remittances in enhancing domestic savings and supporting higher educational attainment, thereby contributing to economic growth. When households are net savers, remittances can facilitate capital mobilization, leading to increased investment and growth in GDP per capita.

Among the controlled variables, the paper finds political regime and commodity prices to be positively and significantly related to economic growth in all the estimations while external debt and inflation have significantly negative impact on economic growth, yet foreign aid and financial development are not statistically significant except in equations with savings (see columns (1) and (2) in Table 2). The coefficients on political regime remain positive and statistically significant in all the estimations. This implies that paradigm shift towards democratic governance in many African countries is yielding growth dividends. Indeed, democratic development not only promotes political stability and fundamental civil liberties but also promotes property protection, business freedom, as well as contract enforcement. All these contribute to increasing the level of business and economic activities resulting in economic growth. This finding is in line with earlier findings obtained by Asiedu and Ofori (2022) Adams and Klobodu (2016) and Jalles (2010). Also found to be positive and significantly related to economic growth is commodity prices. As a major exporter of primary products, higher prices for exports are crucial to raise foreign exchange to supplement domestic resources to boost economic activities. External debt consistently has a negative relationship with economic growth in all regression results. Higher external debt represents future transfer of resources from the domestic economy to foreign creditors which have the potential to derail efforts aimed at economic growth.

Inflation's effect on economic growth as shown in the results is negative and significant though not in all the estimations. This is consistent with Uddin and Ullah (2024). A rise in inflation increases the cost of doing business which reduces the rate of investment. Inflation also reduces consumption as it increases household expenditure on goods and services. Overall, a rise in inflation decreases aggregate demand and the level of economic activities which tend to slow down the rate of economic growth. Finally, the results show that autocorrelation is not a problem since the Arellano-Bond tests for first and second order serial correlations in both levels and differences fail to reject the null hypothesis of absence of autocorrelation. The selected instruments for all the estimations are also valid as the Sargan tests do not reject the validity of the overidentifying restrictions.

5.1 Sensitivity analysis

To further assess the robustness of our methodology, we conducted several robustness checks under plausible scenarios.

First, we investigated the sensitivity of our results by excluding Nigeria from the dataset and re-estimating the growth model. Nigeria, being the largest recipient of remittances in Sub-Saharan Africa and accounting for over one-third of total remittance inflows into the region, could disproportionately influence the results. If the coefficients of remittances significantly decreased upon removing Nigeria, it would suggest that the observed positive effect of remittances on economic growth was largely driven by Nigeria's substantial remittance inflows. However, as shown in Table A1 in the Appendix, the impact of remittances on economic growth remains robust, positive, and statistically significant even without Nigeria in the dataset. The coefficients for both lagged and current levels of remittances, as well as their interactions with savings and education, exhibit only minimal differences between the models with and without Nigeria. This indicates that the positive growth effect of remittances is not solely attributable to Nigeria, affirming the robustness of our growth model.

Next, we explored the interaction effects of savings and education with foreign aid to assess their impact on economic growth. This analysis was conducted under the premise that both remittances and foreign aid are external inflows aimed at supporting recipient countries, albeit through different channels. The results, presented in Table A2, show that the interaction between foreign aid and savings is not statistically significant, suggesting that foreign aid does not significantly impact the relationship between savings and growth. Conversely, the interaction between foreign aid and education is statistically significant, indicating that foreign aid, being directed to central governments, has a macroeconomic impact that complements

education rather than directly influencing savings. Despite these findings, remittances, when used as a control variable, continue to have a positive and significant effect on economic growth. Education remains positively and significantly correlated with economic growth, while savings does not exhibit a significant effect. These results reinforce the stability and reliability of our methodology.

In the next phase of our sensitivity analysis, we examined the impact of different measures of remittances on economic growth, specifically focusing on the volume of remittances and remittances per capita. The results, detailed in Table A3 in the Appendix, indicate that both measures—regardless of whether lags are included—show that remittances remain robust and statistically significant when the growth equation is estimated using the volume of remittances in US dollars. The statistical significance of savings, education, and interaction terms further supports the robustness of our findings.

Finally, we extended our analysis to include multiple lag periods, as detailed in Table A4 in the Appendix. This extended lag analysis reveals that the positive impact of remittances on economic growth becomes apparent from the third lag period. Savings shows marginal significance only in the fifth period, while education exhibits positive significance in the fourth and fifth periods, though marginally significant in the fourth. Regarding interaction terms, the impact of savings with remittances is not statistically significant across lag periods, whereas the interaction between education and remittances remains positively significant. These results underscore that the effects of remittances, savings, and education on economic growth are not immediate but evolve over time.

Overall, these robustness checks validate the stability of our results, confirming that the positive impacts of remittances, savings, and education on economic growth are consistent across various specifications and time lags.

6. Conclusion and policy implication

Sub-Saharan Africa stands out as one of the leading regions in the developing world for remittance inflows, a trend significantly bolstered by the recent increase in migration across the continent. The substantial rise in remittances now exceeds both official development aid and foreign direct investment in terms of monetary value. This paper delves into the ways in which these large remittance inflows can enhance the effectiveness of savings and education, thereby fostering sustained economic growth. By examining the interplay between remittances and these critical factors, the study contributes valuable insights into how their interactions impact economic outcomes.

The analysis reveals that remittances and education independently have a positive and statistically significant effect on economic growth, while the effect of savings is marginally significant. Furthermore, the interactions between remittances and both savings and education are significantly and positively associated with economic growth. These findings suggest several important policy implications:

Firstly, the substantial inflow of remittances offers a unique opportunity to drive economic growth, particularly when coupled with effective savings and educational policies. Governments should design strategies that facilitate the productive use of remittances. This could involve creating financial products that encourage the investment of remittance funds into productive sectors, as well as promoting policies that ensure remittances support long-term economic development rather than just short-term consumption. Secondly, given the positive interaction between remittances and savings, fostering a strong savings culture is crucial. Policymakers should implement initiatives that incentivize savings among households receiving remittances. This might include offering attractive savings account options, providing financial education, and creating incentives for saving remittance funds. Enhancing savings can lead to increased capital formation, which, in turn, can spur economic growth.

Thirdly, the significant impact of education on economic growth highlights the need for continued investment in educational infrastructure. Fourthly, remittances have the potential to

make education more productive by increasing accessibility and affordability, particularly for higher education. Policies should encourage the use of remittances to cover educational expenses, thus allowing students to concentrate on their studies without the burden of earning additional income. This can lead to improved academic performance and better job market outcomes. Governments could facilitate this process by developing programs that link remittance flows with educational grants or scholarships. Lastly, the evidence that the effects of remittances, savings, and education on economic growth unfold over time implies the need for long-term strategic planning. Policymakers should adopt policies that account for the delayed impacts of these variables. This includes designing sustainable development strategies that integrate remittances, savings, and education into a coherent growth framework, and ensuring that policies are adaptable to evolving economic conditions.

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Appendix

Table A1. Remittances, savings, education and growth: system GMM estimation with no outlier

Variables	(1)	(2)	(3)	(4)	(5)
$\Delta \ln GDPC_{it-1}$	-0.0163* (0.0108)	-0.0168* (0.0106)	-0.0181** (0.0103)	-0.0173* (0.0109)	-0.0181** (0.0107)
[REMIT/GDP] _{it-5}	0.0184*** (0.0016)	0.0341*** (0.0027)	0.0281*** (0.0021)	0.0177*** (0.0021)	0.0458*** (0.0043)
[SAV/GDP] _{it-5}	0.0036 (0.0043)		0.0059 (0.0042)		
LNCOMMOPX _{it}	0.0352* (0.0200)	0.0364* (0.0202)	0.0355* (0.0196)	0.0359* (0.0202)	0.0363* (0.0196)
POLREGIME _{it}	0.0232*** (0.0063)	0.0226*** (0.0060)	0.0219*** (0.0064)	0.0223*** (0.0057)	0.0214*** (0.0068)
[AID/GDP] _{it}	0.0351*** (0.0113)	0.0356 (0.0302)	0.0351*** (0.0112)	0.0364 (0.0305)	0.0357* (0.0204)
[EXTDEBT/GDP] _{it}	-0.0332*** (0.0091)	-0.0338*** (0.0092)	-0.0395*** (0.0081)	-0.0334*** (0.0094)	-0.0393*** (0.0080)
[FINDEVT/GDP] _{it}	-0.0021 (0.0051)	-0.0013 (0.0052)	-0.0035 (0.0055)	-0.0012 (0.0050)	-0.0038 (0.0053)
INFL _{it}	0.0077** (0.0036)	0.0050 (0.0057)	0.0091*** (0.0032)	0.0037 (0.0056)	0.0093*** (0.0033)
EDU _{it-5}			0.0083** (0.0036)		0.0080** (0.0035)
[REMIT*SAV/GDP] _{it-5}				0.0011** (0.0005)	
[REMIT*EDU] _{it-5}					0.0086*** (0.0027)
Constant	-0.125* (0.0807)	-0.127* (0.0805)	-0.125* (0.0804)	-0.123* (0.0803)	-0.128* (0.0808)
Observations	924	924	924	924	924
No. of countries	22	22	22	22	22

Note(s): ***, **, * denote significance at 1, 5 and 10% levels respectively, Values in () are robust standard errors

Source(s): Authors, 2024

Table A2. Aid, savings, education and growth

Variables	(1)	(2)
$\Delta \ln GDPC_{it-1}$	-0.0148* (0.0085)	-0.0161* (0.0092)
[REMIT/GDP] _{it-5}	0.0394*** (0.0032)	0.0822*** (0.0017)
SAV/GDP] _{it-5}	0.0023 (0.0039)	
[AID/GDP] _{it-5}	0.0353*** (0.0017)	0.0436*** (0.0015)
[AID*SAV] _{it-5}	0.0018 (0.0051)	
LNCOMMOPX _{it}	0.0377** (0.0189)	0.0365** (0.0181)

(continued)

Table A2. Continued

Variables	(1)	(2)
POLREGIME _{it}	0.0193*** (0.0054)	0.0174*** (0.0061)
[EXTDEBT/GDP] _{it}	-0.0351*** (0.0096)	-0.0406*** (0.0089)
[FINDEV/T/GDP] _{it}	-0.0032 (0.0038)	-0.0049 (0.0039)
INFL _{it}	0.0059 (0.0047)	0.0099*** (0.0026)
EDU _{it-5}		0.0013*** (0.0004)
[AID*EDU] _{it-5}		0.0097** (0.0038)
Constant	-0.128** (0.0633)	-0.129** (0.0627)
Observations	966	966
No. of countries	23	23

Note(s): ***, **, * denote significance at 1, 5 and 10% levels respectively. Values in () are robust standard errors
Source(s): Authors, 2024

Table A3. Remittances and economics growth: system GMM estimation with value of remittances

Variables	(1)	(2)	(3)	(4)	(5)
ΔlnGDPC _{it-1}	-0.0169** (0.0122)	-0.0171* (0.0124)	-0.0187** (0.0122)	-0.0174** (0.0118)	-0.0188*** (0.0120)
LNREMIT _{it-5}	0.00503*** (0.00148)	0.00492*** (0.00159)	0.00478*** (0.00157)	0.00369** (0.00147)	0.00501*** (0.00173)
LNCOMMOPX _{it}	0.0347* (0.0189)	0.0346*** (0.0191)	0.0351** (0.0189)	0.0338*** (0.0193)	0.0354*** (0.0188)
POLREGIME _{it}	0.00154** (0.000643)	0.00155*** (0.000645)	0.00143*** (0.000667)	0.00140** (0.000651)	0.00143** (0.000669)
LNAID _{it}	0.000358 (0.000291)	0.000349 (0.000302)	0.000359 (0.000289)	0.000370 (0.000316)	0.000356 (0.000286)
[EXTDEBT/GDP] _{it}	-0.000289*** (0.0000843)	-0.000292*** (0.0000829)	-0.000353*** (0.0000815)	-0.000291*** (0.0000892)	-0.000357*** (0.0000819)
[FINDEV/T/GDP] _{it}	-0.000577* (0.000316)	-0.000577* (0.000318)	-0.000673* (0.000358)	-0.000522 (0.000333)	-0.000671* (0.000359)
INFL _{it}	-0.000468 (0.000326)	-0.000393 (0.000506)	-0.000613*** (0.000304)	-0.000407 (0.000482)	-0.000608** (0.000302)
[SAV/GDP] _{it-5}		0.00108* (0.000373)		-0.00209* (0.00166)	
EDU _{it-5}			0.000815** (0.000379)		0.00153* (0.00122)
[REMIT*SAV/GDP] _{it-5}				0.000112* (0.000101)	
[REMIT*EDU] _{it-5}					0.000449** (0.000109)
Constant	-0.203** (0.0894)	-0.198** (0.0874)	-0.199** (0.0870)	-0.174* (0.0904)	-0.204** (0.0909)
Observations	966	966	966	966	966
No. of countries	23	23	23	23	23

Note(s): ***, **, * denote significance at 1, 5 and 10% levels respectively. Values in () are robust standard errors
Source(s): Authors, 2024

Table A4. Remittances, savings, education and economic growth: system GMM estimation with multiple lags

Variables	Coefficients
$\Delta \ln GDPC_{it-1}$	-0.0151 (0.0124)
$[REMIT/GDP]_{it-1}$	0.0201 (0.0324)
$[REMIT/GDP]_{it-2}$	0.0193 (0.0369)
$[REMIT/GDP]_{it-3}$	0.0268** (0.0125)
$[REMIT/GDP]_{it-4}$	0.0506** (0.0218)
$[REMIT/GDP]_{it-5}$	0.0419** (0.0210)
$[SAV/GDP]_{it-1}$	0.0185 (0.0171)
$[SAV/GDP]_{it-2}$	0.0159 (0.0140)
$[SAV/GDP]_{it-3}$	0.0142 (0.0151)
$[SAV/GDP]_{it-4}$	0.0169 (0.0842)
$[SAV/GDP]_{it-5}$	0.0795* (0.0476)
EDU_{it-1}	0.0702 (0.0509)
EDU_{it-2}	0.0185 (0.0165)
EDU_{it-3}	0.0878 (0.0603)
EDU_{it-4}	0.0210* (0.0106)
EDU_{it-5}	0.0845** (0.0364)
$[REMIT*SAV/GDP]_{it-1}$	0.01630 (0.0297)
$[REMIT*SAV/GDP]_{it-2}$	0.0261 (0.0301)
$[REMIT*SAV/GDP]_{it-3}$	0.0472 (0.4220)
$[REMIT*SAV/GDP]_{it-4}$	0.0158 (0.0245)
$[REMIT*SAV/GDP]_{it-5}$	0.0208 (0.0169)
$[REMIT*EDU]_{it-1}$	0.0633 (0.0621)
$[REMIT*EDU]_{it-2}$	0.0109 (0.0135)
$[REMIT*EDU]_{it-3}$	0.0324 (0.0240)
$[REMIT*EDU]_{it-4}$	0.0858** (0.0418)
$[REMIT*EDU]_{it-5}$	0.0476** (0.0219)
$LNCOMMODPX_{it}$	0.0481*** (0.0178)

(continued)

Table A4. Continued

Variables	Coefficients
POLREGIME _{it}	0.0178*** (0.0059)
[AID/GDP] _{it}	0.00278 (0.00351)
[EXTDEBT/GDP] _{it}	-0.00347*** (0.00115)
[FINDEVT/GDP] _{it}	-0.00564 (0.00592)
INFL _{it}	-0.0041 (0.0095)
Constant	-0.170** (0.0817)
Observations	966
Number of ctry_dum	23

Note(s): ***, **, * denote significance at 1, 5 and 10% levels respectively, Values in () are robust standard errors
Source(s): Authors, 2024

Table A5. Descriptive statistics

Variable	Mean	Std. Dev.	Min	Max	Kurtosis
lnGDPC	6.42	1.03	4.67	9.17	2.55
REMIT/GDP	17.31	2.84	2.39	24.97	5.25
SAV/GDP	14.68	18.58	-103.42	87.10	11.20
EDU	11.21	7.04	0.07	71.05	16.11
lnCOMMODPX	112.52	41.43	29.45	413.32	10.16
POLREGIME	-0.80	6.24	-10.00	9.00	1.43
AID/GDP	17.93	35.88	-8.02	18.45	6.34
EXTDEBT/GDP	59.53	49.02	3.39	489.30	13.23
FINDEVT/GDP	24.79	12.01	2.83	151.55	16.53
INFL	125.73	1646.02	-11.69	26,419.62	218.16

Note(s): Number of observations = 1,081**Source(s):** Authors, 2024**Corresponding author**

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Spillover effects among cryptocurrencies in a pandemic: a time frequency approach

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Abstract

Purpose – This study investigates the time-varying volatility spillover connectedness among seven major cryptocurrencies before and during the COVID-19 pandemic. It aims to understand contagion risk and its implications for diversification and financial stability, especially during periods of extreme price volatility.

Design/methodology/approach – Using the frequency-domain spillover index, the study analyzes the interconnectedness of cryptocurrency markets with daily data from 10 August 2015 to 10 December 2021. This method allows for examining volatility spillovers across different time frequencies.

Findings – The study finds that cryptocurrencies are highly interconnected at higher frequencies, indicating significant contagion risk and limited short-term diversification opportunities. The spillover effects are frequency-dependent, varying across different time horizons.

Practical implications – The findings suggest the need for targeted regulatory policies focused on short-term cryptocurrency behavior to maintain financial stability. Investors should exercise caution when using cryptocurrencies for portfolio diversification, given the high interconnectedness and contagion risk.

Originality/value – This study uniquely contributes to the literature by applying a frequency-domain approach to analyze volatility spillovers across multiple cryptocurrencies, particularly in the context of the COVID-19 pandemic. It provides novel insights into the frequency-dependent nature of spillover effects, offering a deeper understanding of the contagion risk in cryptocurrency markets.

Keywords Cryptocurrencies, Volatility, Spillover index, Time-varying

Paper type Research paper

1. Introduction

The international financial market has increasingly embraced cryptocurrencies as novel financial instruments (Corbet, Meegan, Larkin, Lucey, & Yarovaya, 2018), evidenced by their rapid growth in both number and market value (Ji, Bouri, Lau, & Roubaud, 2019). Although Bitcoin continues to dominate the cryptocurrency market, alternative coins, commonly

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referred to as altcoins – such as Ethereum, Litecoin, Ripple, Dash, Monero and Stellar – are progressively gaining market share. This trend indicates that economic actors are diversifying their investments beyond Bitcoin, seeking higher returns through altcoins. Altcoins share the foundational technological concept of cryptography with Bitcoin, and several have achieved substantial market capitalizations, reaching billions and millions of dollars (Liu, 2019; <http://www.coinmarketcap.com>). The rise of altcoins offers significant diversification benefits to investors, as some altcoins are relatively isolated from others (Corbet *et al.*, 2018), provide lower transaction costs (Kim, 2017), and enable swift transactions (Fantazzini, Nigmatullin, Sukhanovskaya, & Ivliev, 2016) compared to traditional forex markets, contributing to increased liquidity within the cryptocurrency market.

Despite the notable growth and active participation of investors in the cryptocurrency market, there remains limited empirical evidence on the interaction among cryptocurrencies, particularly during periods of market stress such as pandemics (Apergis, 2022). The cryptocurrency market is relatively shallow and exhibits excessive price volatility compared to traditional financial markets, raising concerns about potential market collapses should fluctuations or shocks impact the leading cryptocurrencies (Kumar & Ajaz, 2019). Furthermore, the integration of cryptocurrencies with traditional assets (Henriques & Sadorsky, 2018; Guesmi, Saadi, Abid, & Ftiti, 2019; Klein, Thu, & Walther, 2018) could heighten investor attention and contribute to excessive liquidity in the cryptocurrency market. Such a phenomenon necessitates an in-depth understanding of the interconnections among leading cryptocurrencies over time, enabling economic agents interested in cryptocurrencies to develop informed trading and investment strategies for portfolio optimization and risk management. Additionally, understanding volatility transmissions across cryptocurrencies during pandemics is crucial for comprehending the market's microstructure and overall functioning.

This study aims to investigate the time-varying volatility spillovers among seven leading cryptocurrencies, namely Bitcoin, Ethereum, Litecoin, Ripple, Dash, Monero and Stellar, using the Baruník and Křehlík (2018) frequency domain spillover index. Specifically, the study seeks to decompose the contribution of each cryptocurrency to total market volatility across different frequencies and identify the main transmitters and receivers of spillover effects over time. By focusing on the frequency-dependent behavior of these spillovers, the study aims to provide a nuanced understanding of the interconnectedness within the cryptocurrency market, particularly during periods of heightened market stress.

This study makes several important contributions to the existing body of knowledge. First, it extends the literature on cryptocurrency market dynamics by applying a frequency domain approach to analyze volatility spillovers, which allows for a more detailed examination of short-term, medium-term and long-term interconnectedness among leading cryptocurrencies. Second, the study contributes to the ongoing debate on the role of cryptocurrencies as potential diversifiers in investment portfolios by providing empirical evidence on the frequency-dependent contagion risks within the market. Third, by identifying the cryptocurrencies that serve as the primary transmitters and receivers of volatility spillovers, the study offers valuable insights for investors and policymakers interested in optimizing portfolio strategies and managing risks associated with cryptocurrency investments.

While this study offers significant insights into the dynamics of cryptocurrency markets, it is not without limitations. One limitation is the reliance on data from a specific period, which may not capture the full range of market conditions, especially given the rapidly evolving nature of the cryptocurrency market. Additionally, the study focuses on a select group of seven cryptocurrencies, which, while representative of the market's leading assets, excludes a large number of other digital currencies that may also play significant roles in

market dynamics. Moreover, the frequency domain spillover index used in this study, while robust, is subject to the limitations of the models it is based on, including potential sensitivity to extreme market events and structural breaks. Future research could address these limitations by incorporating a broader range of cryptocurrencies, extending the analysis over a longer time horizon, and exploring alternative methodologies to capture the complex interactions within the cryptocurrency market.

The remainder of this study is structured as follows: Section 2 discusses the methodology. Section 3 provides a description of the data and its statistical properties. Section 4 presents the results and discusses spillover frequency connectedness. Section 5 concludes the study and outlines policy implications.

2. Literature review

2.1 The evolution of cryptocurrencies and their market dynamics

Cryptocurrencies have emerged as a significant innovation in the global financial market, representing a departure from traditional fiat currencies through their decentralized, cryptographic underpinnings. Bitcoin, introduced by Nakamoto (2008), was the first cryptocurrency, and it has since remained the dominant player in the market. However, the emergence of alternative cryptocurrencies, commonly known as altcoins, such as Ethereum, Litecoin, Ripple, Dash, Monero and Stellar, has transformed the market landscape (Corbet *et al.*, 2018). These altcoins have introduced diversity into the market, offering distinct technological features and use cases, which has attracted a broad spectrum of investors and users.

The literature on cryptocurrency market dynamics has predominantly focused on Bitcoin due to its pioneering status and substantial market capitalization. Studies like Bouri, Molnár, Azzi, Roubaud, and Hagfors (2017) have analyzed Bitcoin's role as a potential hedge or safe haven against traditional financial assets. Similarly, Dyhrberg (2016) explored Bitcoin's volatility and its comparisons to gold and the US dollar, positioning Bitcoin as a unique asset class with features of both commodities and currencies.

As the cryptocurrency market has evolved, so too has the academic focus on the interconnectedness among various cryptocurrencies. Ji *et al.* (2019) documented the increasing market value and number of cryptocurrencies, highlighting the diversification benefits they offer. However, they also pointed out the market's inherent risks, particularly the extreme volatility that characterizes cryptocurrencies, which differentiates them from traditional assets. The integration of cryptocurrencies into mainstream finance, such as through the introduction of cryptocurrency derivatives, has further fueled academic interest in understanding the market dynamics and volatility spillovers between cryptocurrencies and other financial assets (Guesmi *et al.*, 2019).

Volatility is a critical characteristic of cryptocurrency markets, distinguishing them from more established financial markets. Several studies have explored the nature of this volatility, often finding that it is not only higher but also more persistent and erratic compared to traditional assets (Katsiampa, 2018). Volatility in cryptocurrency markets is influenced by various factors, including market sentiment, regulatory news, technological developments and macroeconomic events (Liu & Tsvybinski, 2018). The extreme price fluctuations observed in cryptocurrencies are often linked to their limited market depth, speculative trading and the absence of central regulatory oversight (Kumar & Ajaz, 2019).

The interconnectedness of cryptocurrencies has been a subject of extensive research, with many studies focusing on the spillover effects between different coins. Katsiampa (2018) applied an asymmetric diagonal BEKK multivariate GARCH model to examine volatility spillovers among Bitcoin, Litecoin, Ripple, Ethereum and Stellar, finding significant positive associations among these cryptocurrencies. The study highlighted that shocks in one

cryptocurrency could propagate to others, creating a network of volatility spillovers that complicates risk management strategies.

Similarly, Ji *et al.* (2019) used the Diebold and Yilmaz (2012) and Diebold and Yilmaz (2016) approach to investigate return and volatility spillover connectedness across six major cryptocurrencies. Their findings suggested that Bitcoin and Litecoin have substantial spillover effects on other cryptocurrencies, emphasizing the role of these coins as central nodes in the cryptocurrency network. This interconnectedness implies that movements in Bitcoin, for example, can have widespread implications for the entire market, thereby influencing investor behavior and market stability.

Another study by Koutmos (2018) employed a VAR model to analyze the volatility spillovers among cryptocurrencies, identifying strong interdependence among the coins. The study pointed out that the volatility spillover patterns are not static but vary over time, particularly during periods of market stress. This time-varying nature of spillovers is further supported by research using wavelet-based methods, which show that cryptocurrency interconnectedness is frequency-dependent (Omane-Adjepong & Alagidede, 2019).

The COVID-19 pandemic provided a unique opportunity to study the resilience and behavior of cryptocurrency markets during an extreme global event. Apergis (2022) investigated how cryptocurrencies interacted during the pandemic, finding that the market experienced heightened volatility and increased interconnectedness. The study highlighted that during crises, investors often treat cryptocurrencies as a homogenous asset class, leading to synchronized movements across the market. This behavior contrasts with the pre-pandemic period, where diversification benefits were more pronounced.

Huynh (2019) extended the analysis of extreme events by applying Granger causality, VAR-SVAR, and Student's-t Copulas to study spillover risks in cryptocurrency markets. The research found that Bitcoin was a primary recipient of spillover effects, while Ethereum often acted independently. This finding underscores the complexity of the cryptocurrency market, where different coins can exhibit varying degrees of sensitivity to external shocks.

Moreover, Trabelsi (2018) employed a VAR model to explore volatility spillovers during the pandemic, finding that spillover effects intensified as the crisis deepened. The study emphasized the importance of understanding these dynamics for investors seeking to manage risks in their cryptocurrency portfolios. The findings also suggest that during pandemics or similar extreme events, traditional diversification strategies may become less effective due to the increased correlation among cryptocurrencies.

Despite the growing body of research on cryptocurrency markets, several gaps remain. One significant gap is the limited understanding of the frequency-dependent nature of volatility spillovers among cryptocurrencies, particularly during periods of extreme market stress such as pandemics. While studies like Omane-Adjepong and Alagidede (2019) have explored frequency-based interconnectedness, there is still a lack of comprehensive analysis that decomposes spillover effects across different frequencies over time.

Additionally, most existing studies focus on a static analysis of spillovers without adequately considering how these dynamics evolve over different time horizons. The reliance on models that do not capture the time-varying nature of spillovers limits the ability to fully understand how cryptocurrencies interact in the short term, medium term and long term. Moreover, while Bitcoin and a few other major cryptocurrencies have been extensively studied, there is a need for more research on how lesser-known altcoins contribute to or are affected by volatility spillovers.

This study addresses these gaps by employing the Barunik and Křehlík (2018) frequency domain spillover index to analyze the time-varying volatility spillovers among seven leading cryptocurrencies. With the focus on frequency-based analysis, this research provides a more complex understanding of the interconnectedness within the cryptocurrency market, particularly during periods of high volatility, such as the COVID-19 pandemic. The study's

findings will contribute to the ongoing discourse on cryptocurrency market dynamics, by giving information that could improve portfolio diversification strategies and risk management practices in this rapidly evolving market.

3. Methodology

The study investigates the volatility spillover connectedness among seven cryptocurrencies applying Baruník and Křehlík (2018) frequency domain spillover index, which is based on Dew-Becker and Giglio (2016) spectral representations of variance decomposition. This methodology has theoretical root to Diebold and Yilmaz (2012), but its time-frequency connectedness was first introduced by Baruník and Krehlik (2016) and extended by Baruník and Křehlík (2018).

As noted by Baruník and Krehlik (2016), the generalized impulse response function is decomposed considering the spectral behavior of series X_t as follows:

$$S_x(w) = \sum_{h=0}^{\infty} E(X_t X_{t-h}) e^{-ihw} = \psi(e^{ihw}), \quad (1)$$

where w is frequency, ∞ is infinite horizon connectedness, and $\psi(e^{-ihw}) = \sum_{h=0}^{\infty} \psi(e^{-ihw})$. The unconditional generalized forecast error variance decomposition (GFVED) is calculated on a particular frequency w as follows:

$$(\Theta(w))_{ij} = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{\infty} (\psi(e^{-ihw}) \sum)_{ij}^2}{\sum_{h=1}^{\infty} (\psi(e^{-ihw}) \sum \psi(e^{ihw}))_{ij}}, \quad (2)$$

which is standardized to the following equation:

$$(\Theta(w))_{ij} = \frac{(\Theta(w))_{ij}}{\sum_{j=1}^k (\Theta(w))_{ij}}. \quad (3)$$

We follow Baruník and Krehlik (2016) and express accumulative connectedness table over an arbitrary frequency band $d = (a; b)$ as follows:

$$(\Theta_d)_{ij} = \int_a^b (\Theta(w))_{ij} dw. \quad (4)$$

We then specify the overall connectedness within a frequency band d as follows:

$$C^d = \frac{\sum_{\substack{i=1, i \neq j \\ ij}}^k (\Theta_d)_{ij}}{\sum_{ij} (\Theta_d)_{ij}} = 1 - \frac{\sum_{i=1}^k (\Theta_d)_{ii}}{\sum_{ij} (\Theta_d)_{ij}}. \quad (5)$$

Within the spectral band $d = (a; b)$, strong connectedness is indicated when C^d is close to unity. The contribution of a market ($i \neq j$) to another i on the spectral band d is measured using the *within from* connectedness specified as follows:

$$C_{i \leftarrow}^d = \sum_{j=1, i \neq j}^k (\Theta_d)_{ij}. \quad (6)$$

whereas the contribution to a market ($i \neq j$) from another i on the spectral band d is measured using the *within to* connectedness specified as follows:

$$C_{i \rightarrow}^d = \sum_{j=1, i \neq j}^k (\Theta_d)_{ij}. \quad (7)$$

Following Diebold and Yilmaz (2012), we measure total connectedness as $Sg(H) = \sum_d C^d$ and pairwise connectedness as $\theta_{ij} \neq \theta_{ji}$.

4. Data description and preliminary analysis

In this study, we focus on seven cryptocurrencies (Bitcoin, Ethereum, Litecoin, Das, Ripple, Monero and Stellar) which have existed for the past seven years with market capitalization above 1 billion USD. These cryptocurrencies are among the top fifteen currencies by market capitalization and can proxy for the cryptocurrency market. We use daily data sourced from CoinMarketCap (2019) and spans 10th August 2015 to 10th December 2021. We calculate returns as change in log price, Monday-to-Friday and there were 1,097 observations.

Table 1 presents summary statistics on the seven daily cryptocurrency return series studied. Average daily return range from 0.2% for Bitcoin and Ethereum to 0.55% for Stellar and daily variance range from 0.18% for Bitcoin and Ethereum to 0.88% for Stellar. Litecoin, Ripple, Das, Monero, and Stellar are positively skewed except Bitcoin and Ethereum. Kurtosis and skewness values show leptokurtic and non-normality in cryptocurrency returns which is confirmed by the Shapiro–Wilk test by rejecting the normality assumption at all conventional levels of significance. These go on to support the need for using asymmetric distributions in modeling the volatility spillover connectedness among cryptocurrencies.

5. Results and discussion

Following Baruník and Křehlík (2018) approach as used by Tiwari, Cunado, Gupta, and Wohar (2018), and Qarni, Gulzar, Fatima, Khan, and Shafi (2019), we first of all estimate a seven variable VAR with two lag lengths. We then construct the directional spillover

	Bitcoin	Ethereum	Litecoin	Ripple	Das	Monero	Stellar
Observ	1,097	1,097	1,097	1,097	1,097	1,097	1,097
Mean	0.002	0.002	0.0007	0.0026	0.0021	0.0026	0.0055
Variance	0.0018	0.0018	0.0038	0.0044	0.0035	0.0044	0.0088
Skewness	-0.2356	-0.2356	1.2575	4.5132	0.2983	4.5132	2.1108
Kurtosis	4.7234	4.7234	12.1915	76.4051	3.383	76.4051	17.9168
Normtest.W	0.914	0.914	0.8425	0.5981	0.9463	0.5981	0.8568
Normtest.p	0	0	0	0	0	0	0

Table 1.
Summary statistics of
cryptocurrencies

Note(s): Observ. – Observations, Shapiro–Wilk test reject the normality assumption at all conventional levels of significance

Source(s): Authors' own work

connectedness index, the pairwise net directional spillover connectedness, and the rolling window spillover and results discussed in Sections 4.1, 4.2, and 4.3 respectively. As noted by Barunik and Krehlik (2016, 2018) the spillover table has four frequency bands, and we choose the first and second bands [1] (freq. 1 and 2) as short-term connectedness, third band [2] (freq. 3) as medium-term connectedness and fourth band [3] (freq. 4) as long-term connectedness of the cryptocurrencies.

5.1 Directional spillover connectedness

We construct the directional spillover connectedness table using a variance decomposition forecasting horizon (H) of 100 period ahead since Barunik and Krehlik (2018) approach does not support a forecasting horizon less than 100 ($H < 100$) and results shown in Table 2. From the decomposed spillover exhibited in Table 2, we observe that the shortest horizon (freq. 1) contributes most (30.46%) of total connectedness followed by freq. 2 which is also a short-time horizon (7.88%). The medium-term horizon (freq. 3) contributes (2.57%) to total connectedness whiles the long-term movement of the currencies (freq. 4) contributes only (0.43%) to total connectedness. We can conclude from this result that, the total spillover connectedness index among the seven cryptocurrencies is high in the short-time horizon than in the medium and long-time horizons suggesting contagion and that portfolio diversification benefits are low in the short-term. The result for total spillover connectedness supports the findings of Trabelsi (2018) which incorporate time-decomposition to VAR to investigate the volatility spillover effects among cryptocurrencies and reports connectedness within the cryptocurrency market.

The across frequencies FROM_ABS (TO_ABS) expose the cryptocurrency that highly contributes to (receives from) the total spillover effects across frequencies. From panels 1 and 2 of Table 2, it is evident that Bitcoin is the major contributor and receiver of total spillover effects in the short-term connectedness (freq. 1 and 2), followed by Litecoin, Das, Monero, Ethereum, Stellar and Ripple. However, panels 3 and 4 which shows the medium-term (freq. 3) and long-term (freq. 4) connectedness, respectively, depicts Litecoin, Bitcoin, and Das as the major contributors and receivers of total spillover effects whiles Ripple neither contributes to nor receives spillover effects from any of the cryptocurrencies. This suggests Ripple as the independent coin among the cryptocurrencies. This finding is in line with Ji *et al.* (2019) who document Bitcoin and Litecoin as the two largest transmitters and receivers of spillover effects from other cryptocurrencies. From this result, we suggest that Bitcoin, Litecoin and Das markets should be given regulatory initiatives since these cryptocurrencies contributes and receives most of the total volatility spillovers in the cryptocurrency market.

The difference between TO_ABS and FROM_ABS (TO_ABS – FROM_ABS) measures the net directional spillover connectedness (Net_ABS) of cryptocurrencies across time. This shows the cryptocurrencies that are net transmitters (positive values) and recipients (negative values) of spillover effects to (from) other cryptocurrencies across frequencies. We observe from Table 2 that, the shortest horizon (freq. 1) show Bitcoin, Litecoin and Das as the net transmitters of spillover effects, whiles Ethereum, Ripple, Monero and Stellar are the net recipients of spillover effects. Nevertheless, frequencies 2, 3 and 4 depict Bitcoin, Ethereum and Stellar as the net transmitters of spillover effects whiles Litecoin, Ripple, Das and Monero are the net recipients of spillover effects. We once again confirm the findings of Ji *et al.* (2019) which shows Bitcoin and Litecoin as the largest net transmitters of spillovers and Ethereum and Das as the largest net spillover effect receivers.

5.2 Pairwise directional spillover connectedness

Furthermore, we investigate the results in more detail by constructing a net-pairwise directional spillover connectedness of the currencies and results shown in Table 3. The net-

	BTC	ETH	LTC	XRP	DASH	XMR	XLM	FROM_ABS	FROM_WTH
<i>Freq. 1</i>									
BTC	32.50	4.76	13.20	0.02	9.39	9.44	4.55	5.91	7.95
ETH	7.10	42.73	7.34	0.01	7.51	6.21	2.39	4.36	5.87
LTC	13.49	4.97	32.86	0.00	8.08	7.31	5.48	5.62	7.56
XRP	0.09	0.02	0.08	71.41	0.20	0.05	0.16	0.09	0.11
DASH	9.91	5.52	8.40	0.02	38.30	8.95	3.91	5.24	7.06
XMR	11.07	4.47	8.37	0.01	9.32	40.77	2.94	5.17	6.96
XLM	6.87	2.61	8.66	0.01	6.16	4.16	48.42	4.07	5.47
TO_ABS	6.93	3.19	6.58	0.01	5.81	5.16	2.77	30.46	
TO_WTH	9.33	4.30	8.85	0.01	7.82	6.94	3.73		40.99
Net_ABS	1.0226	-1.1708	0.9610	-0.0747	0.5647	-0.0089	-1.2938		
<i>Freq. 2</i>									
BTC	8.29	1.16	3.56	0.00	1.82	2.34	1.72	1.51	8.19
ETH	1.24	12.99	1.45	0.00	1.72	1.14	0.82	0.91	4.92
LTC	3.55	1.40	8.66	0.00	1.94	2.04	2.54	1.64	8.86
XRP	0.04	0.00	0.01	19.19	0.01	0.00	0.06	0.02	0.09
DASH	2.32	1.69	2.24	0.00	7.87	2.16	1.80	1.46	7.89
XMR	2.46	1.69	2.07	0.01	2.20	7.28	1.06	1.36	7.33
XLM	1.86	0.95	2.09	0.00	1.08	0.88	10.02	0.98	5.30
TO_ABS	1.64	0.98	1.63	0.00	1.25	1.22	1.14	7.88	
TO_WTH	8.86	5.33	8.83	0.02	6.77	6.61	6.18		42.59
Net_ABS	0.1246	0.0741	-0.0050	-0.0144	-0.2071	-0.1334	0.1613		
<i>Freq. 3</i>									
BTC	2.74	0.38	1.17	0.00	0.56	0.77	0.59	0.50	8.03
ETH	0.39	4.37	0.45	0.00	0.51	0.32	0.27	0.28	4.49
LTC	1.18	0.48	2.83	0.00	0.59	0.66	0.86	0.54	8.73
XRP	0.01	0.00	0.00	7.39	0.00	0.00	0.02	0.01	0.09
DASH	0.81	0.57	0.76	0.00	2.44	0.71	0.63	0.50	8.06
XMR	0.81	0.56	0.69	0.00	0.69	2.26	0.36	0.45	7.23
XLM	0.62	0.31	0.66	0.00	0.31	0.27	3.15	0.31	5.05
TO_ABS	0.55	0.33	0.53	0.00	0.38	0.39	0.39	2.57	
TO_WTH	8.86	5.32	8.67	0.02	6.16	6.32	6.35		41.68
Net_ABS	0.0509	0.0514	-0.0039	-0.0043	-0.1177	-0.0564	0.0799		
<i>Freq. 4</i>									
BTC	0.46	0.06	0.19	0.00	0.09	0.13	0.10	0.08	8.01
ETH	0.06	0.73	0.07	0.00	0.08	0.05	0.04	0.05	4.45
LTC	0.20	0.08	0.47	0.00	0.10	0.11	0.14	0.09	8.71
XRP	0.00	0.00	0.00	1.25	0.00	0.00	0.00	0.00	0.08
DASH	0.14	0.10	0.13	0.00	0.40	0.12	0.11	0.08	8.07
XMR	0.14	0.09	0.12	0.00	0.11	0.37	0.06	0.07	7.22
XLM	0.10	0.05	0.11	0.00	0.05	0.05	0.52	0.05	5.03

Table 2.
Directional Spillover
index results

(continued)

	BTC	ETH	LTC	XRP	DASH	XMR	XLM	FROM_ABS	FROM_WTH
TO_ABS	0.09	0.05	0.09	0.00	0.06	0.06	0.07	0.43	
TO_WTH	8.85	5.32	8.65	0.02	6.11	6.29	6.35		41.58
Net_ABS	0.0086	0.0089	-0.0007	-0.0007	-0.0202	-0.0095	0.0136		

Note(s): Freq. 1& 2 = short-term (1 to 16 days), freq. 3 = medium-term (16 to 64 days) and freq. 4 = long-term (>64 days) connectedness of the currencies. WTH and ABS = within and absolute in the estimated system, respectively. BTC, ETH, LTC, XRP, DASH, XMR and XLM denote Bitcoin, Ethereum, Litecoin, Ripple, Das, Monero and Stellar, respectively

Source(s): Authors' own work

Table 2.

Currencies	Freq. 1	Freq. 2	Freq. 3	Freq. 4
BTC-ETH	-0.3334	-0.0123	-0.0014	-0.0002
BTC-LTC	-0.0402	0.0024	-0.0012	-0.0002
BTC-XRP	-0.0105	-0.0047	-0.0014	-0.0002
BTC-DASH	-0.0736	-0.0724	-0.0355	-0.0061
BTC-XMR	-0.2334	-0.0171	-0.0058	-0.0010
BTC-XLM	-0.3316	-0.0206	-0.0055	-0.0009
ETH-LTC	0.3382	0.0075	-0.0038	-0.0007
ETH-XRP	-0.0011	0.0001	0.0000	0.0000
ETH-DASH	0.2838	0.0039	-0.0094	-0.0017
ETH-XMR	0.2488	-0.0795	-0.0346	-0.0059
ETH-XLM	-0.0323	-0.0183	-0.0050	-0.0008
LTC-XRP	-0.0116	-0.0016	-0.0006	-0.0001
LTC-DASH	-0.0456	-0.0426	-0.0244	-0.0042
LTC-XMR	-0.1510	-0.0040	-0.0047	-0.0008
LTC-XLM	-0.4547	0.0631	0.0286	0.0048
XRP-DASH	0.0257	0.0007	-0.0001	0.0000
XRP-XMR	0.0053	-0.0011	-0.0006	-0.0001
XRP-XLM	0.0205	0.0086	0.0029	0.0005
DASH-XMR	-0.0525	-0.0057	0.0023	0.0004
DASH-XLM	-0.3219	0.1024	0.0460	0.0078
XMR-XLM	-0.1738	0.0261	0.0130	0.0022

Note(s): Freq. 1& 2 = short-term (1 to 16 days), freq. 3 = medium-term (16 to 64 days), and freq. 4 = long-term (>64 days) connectedness of the currencies

Source(s): Authors' own work

Table 3.
Net-pairwise Spillover

pairwise directional spillover effect from one currency to another is measured by subtracting the second variable from the first. A negative (positive) value depicts that the first cryptocurrency is a net receiver (transmitter) of spillover effects from (to) the corresponding cryptocurrency. It is evident from Table 3 that the net-pairwise directional spillover effects switches between positive and negative connectedness indicating that at any given point of time, each cryptocurrency can act as a net transmitter or receiver of spillover effects. Specifically, all Bitcoin pairs (BTC-ETH, BTC-LTC, BTC-XRP, BTC-DASH, BTC-XMR,

BTC-XLM) exhibit negative connectedness across frequencies suggesting Bitcoin as net spillover effect recipient from corresponding currencies. The Ethereum pairs ETH-LTC and ETH-DASH (except freq. 3 and 4), ETH-XRP (except freq. 1), show positive connectedness depicting Ethereum as net spillover effect transmitter to corresponding currencies across the frequencies, however, except for freq. 1 of ETH-XMR pairs, Ethereum receives spillover effects from Monero and Stellar. The Litecoin pairs LTC-XRP, LTC-DASH, LTC-XMR and LTC-XLM (only freq.1) indicate Litecoin as net receiver of spillover effects from corresponding cryptocurrencies across time. The Stellar pairs XRP-DASH (except freq. 3), XRP-XMR (only freq. 1) and XRP-XLM show Stellar as a net transmitter of spillover effects to corresponding currencies. DASH-XMR (freq. 2 and 3), DASH-XLM (freq. 2 to 4) and XMR-XLM (freq. 2 to 4) depicts Dash and Monero as the net transmitters of spillover effects to corresponding currencies. From this result we can conclude that, the net connectedness between pairs of cryptocurrencies is mostly negative and Bitcoin is the largest spillover effect receiver from other cryptocurrencies. This finding provides evidence in support of Huynh (2019) study which indicates Bitcoin as the spillover effect recipient in the cryptocurrency market.

5.3 Rolling window analysis

To better appreciate and visualize the direction, strength and structure of spillovers, we capture the time-varying net-pairwise directional and overall spillover connectedness among the cryptocurrencies using the rolling window approach. Figure 1 exhibit the overall spillover connectedness of cryptocurrencies at frequency bands. The horizontal axis of the graphs depict the period of analysis where 200, 400, 600 and 800 represent connectedness in 2015–2016, 2017–2018, 2019–2020 and 2021, respectively, which corresponds with our period of analysis. The vertical axis indicates the level of connectedness of the system. We observe that the overall spillover connectedness at the various frequency bands (Figure 2) confirm the results of the directional spillover connectedness (Table 2) which indicates that cryptocurrencies are highly connected in the short-term than medium- and long-terms. This result is in line with previous studies (Baruník & Křehlík, 2018; Tiwari *et al.*, 2018; Qarni *et al.*, 2019; Belke & Gokus, 2014) that document a time-varying volatility spillover effects.

The net-pairwise directional connectedness between cryptocurrencies in Figure 2 shows high volatility with mostly negative connections especially for Bitcoin pairs which is in line with the results in Table 3.

6. Conclusion and policy implication

The study explores the time-varying volatility spillovers connectedness among cryptocurrencies in the pandemic adopting Baruník and Křehlík (2018) approach. The result from time-varying directional spillover index suggests that the total spillover connectedness among the seven cryptocurrencies is high in the short-time horizon than in the medium and long-time horizons indicating low portfolio diversification benefits in the short-term. However, the net transmitters and receivers of volatility spillovers across cryptocurrencies are contingent on the frequency under consideration.

Our study provides evidence in support of the findings of Corbet *et al.* (2018), and Ji *et al.* (2019) that leading cryptocurrencies are interconnected but differs in showing that the interconnectedness is time-varying and that stronger interconnectedness occurs at higher frequencies. The evidence of all cryptocurrencies alternating between being receivers and transmitters of spillover effects across time suggest that Bitcoin is losing its dominant role in the cryptocurrency market.

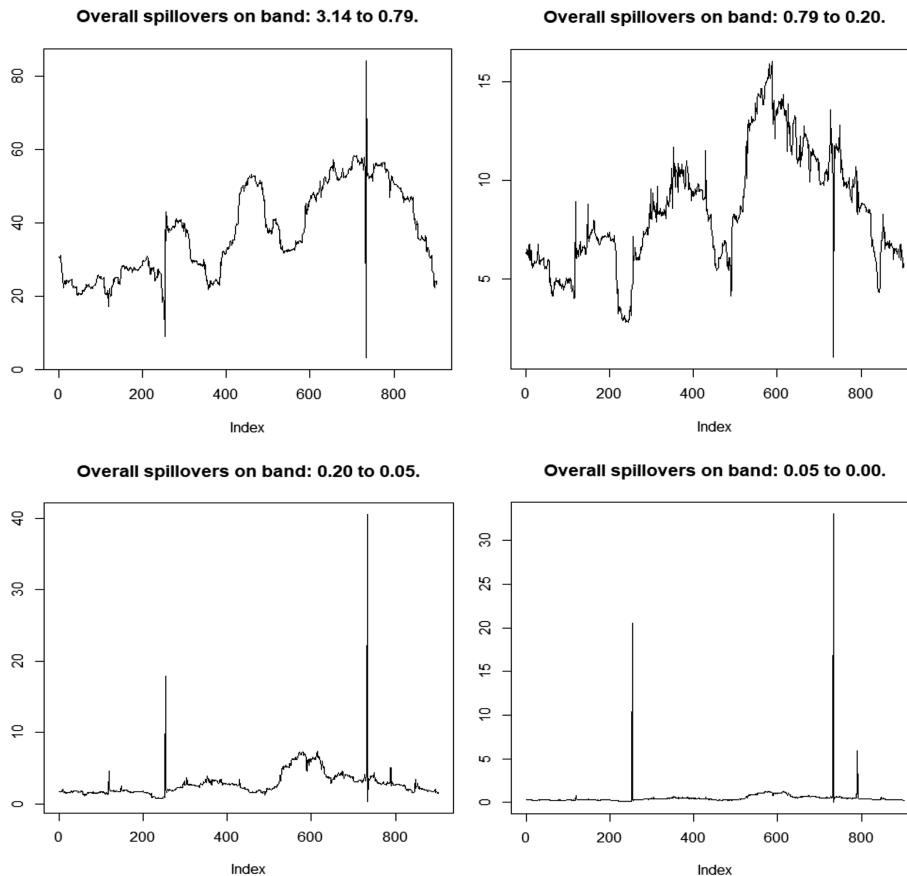


Figure 1.
Overall across-
frequencies spillovers

Source(s): Authors' construct (2024)

We also find from the pairwise spillover that the net connectedness between pairs of cryptocurrencies is mostly negative and Bitcoin is the largest spillover effect receiver from other cryptocurrencies. Nevertheless, the rolling window analysis confirms the results depicted by the directional and pairwise spillover tables. The evidence of weak and negative connections in the medium and lower frequencies may benefit economic agents interested in investing in cryptocurrencies to enhance hedging and portfolio diversifications in the medium and long-term horizons. As policy decisions are frequency-dependent, the horizon-based result of volatility spillovers among cryptocurrencies is clearly important since it highlights the need of regulatory policies to be directed to Bitcoin, Litecoin and Das markets across all horizons but especially in the short-term to reduce global risk.

This study investigates the volatility spillover frequency connectedness across seven leading cryptocurrencies. Future studies can replicate this study by extending the enquiry into several cryptocurrencies and other financial instruments to broaden our understanding of the volatility of financial instruments.

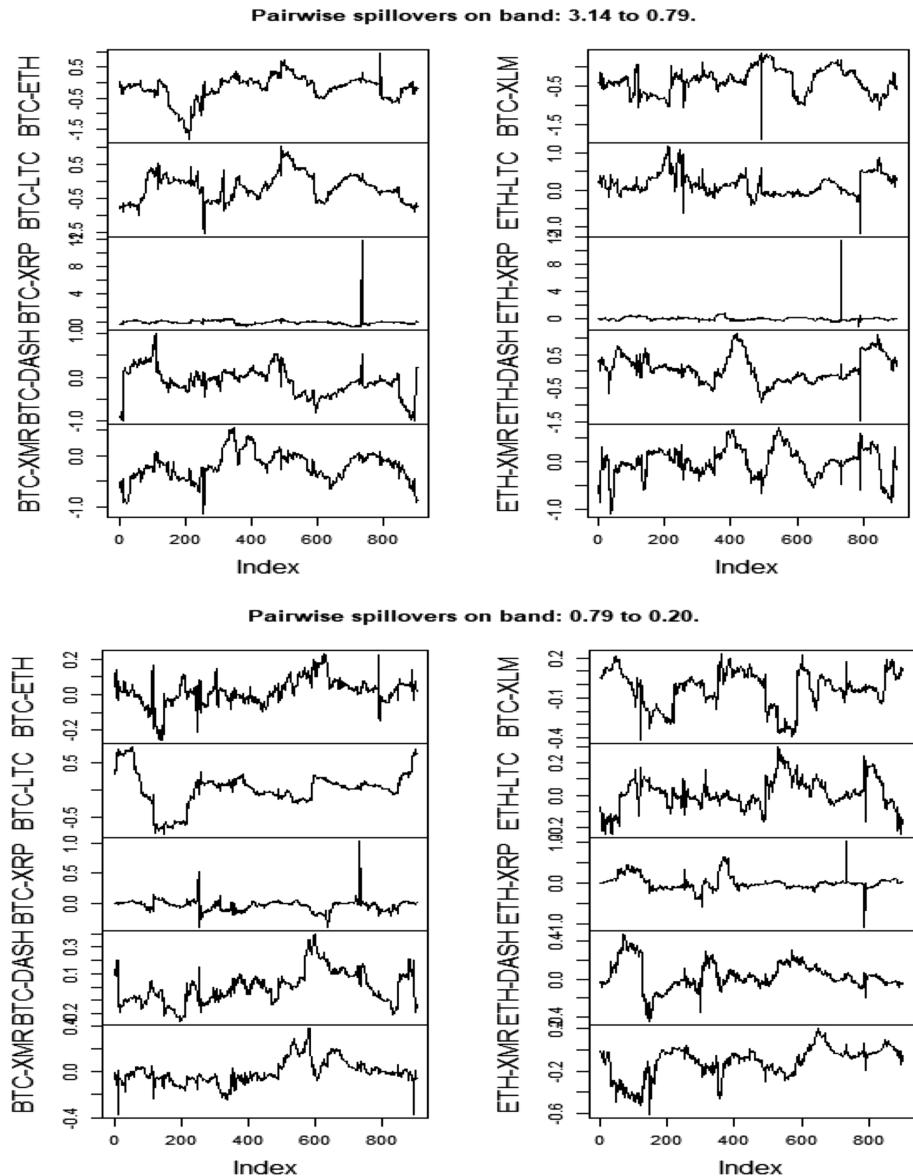
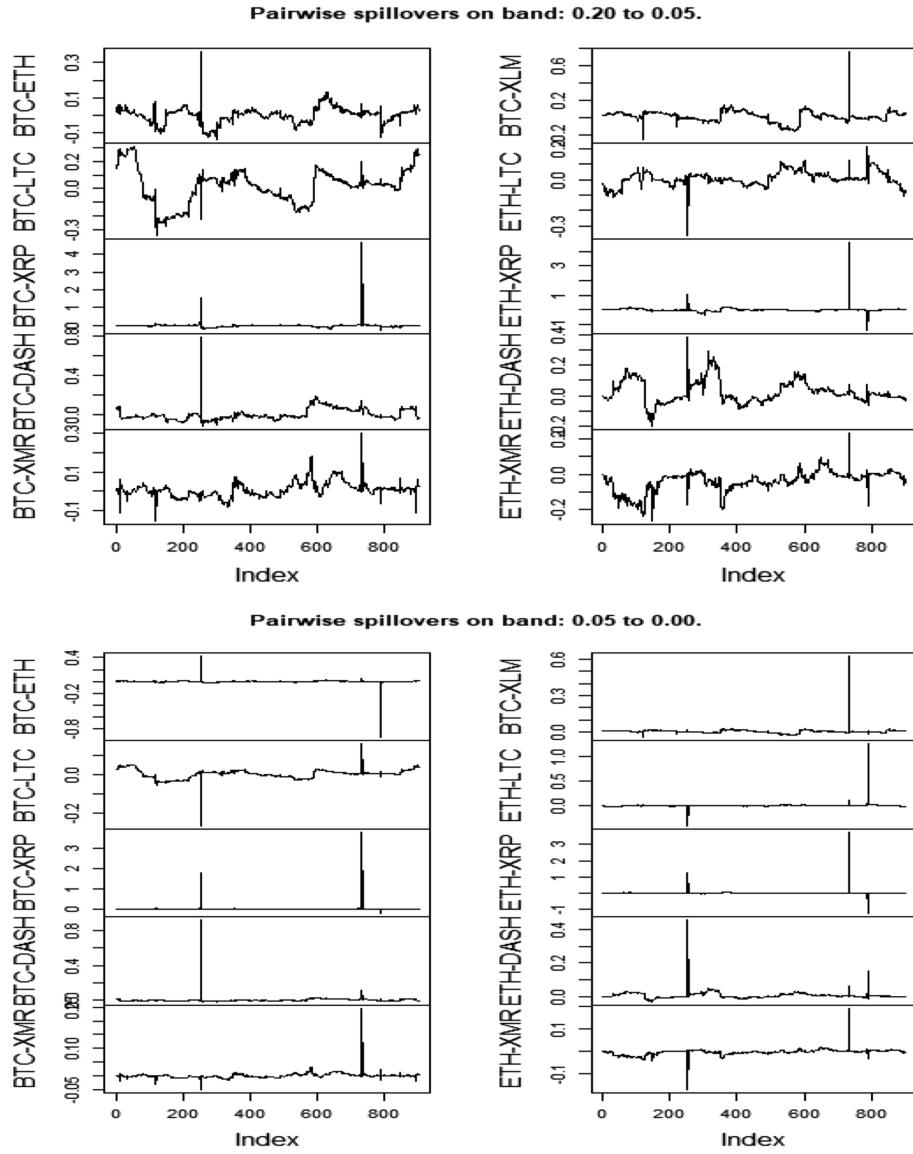


Figure 2.
Pairwise net
directional
connectedness across-
frequencies

(continued)



Note(s): The vertical axis represents the cryptocurrencies examined in the study, while the horizontal axis shows the time periods covered

Source(s): Authors' construct (2024)

Figure 2.

Notes

1. The spillover table for first band (freq. 1) 3.14 to 0.79 roughly corresponds to 1 to 4 days, and second band (freq. 2) 0.79 to 0.20 roughly corresponds to 4 to 16 days.
2. The spillover table for third band (freq. 3) 0.20 to 0.05 roughly corresponds to 16 to 64 days.
3. The spillover table for fourth band (freq. 4) 0.05 to 0.00 roughly corresponds to more than 64 days.

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Appendix

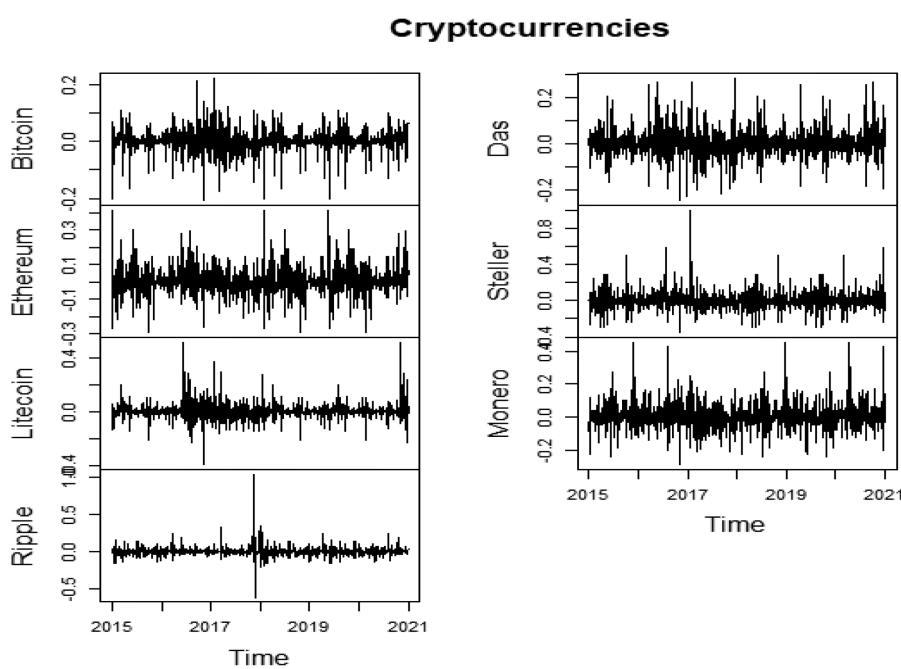


Figure A1.
Time series plot of
selected
cryptocurrencies

Note(s): The vertical axis represents the cryptocurrencies studied, while the horizontal axis indicates the analysis period

Source(s): Authors' own work

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Digital dynamics: exploring ICT's role in revolutionising Nigeria's trade sectors

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Abstract

Purpose – This study examined the influence of information and communication technology (ICT) on Nigeria's trade in sectors. Specifically, the research evaluated the effects of internet penetration, mobile phone subscriptions and fixed telephone subscriptions on exports and imports.

Design/methodology/approach – The study considered data from 1995 to 2022, highlighting ten trade sectors per standard international trade classification (SITC) single digit. It utilised the panel auto-regressive distributed lag (ARDL) with a preference for a pooled mean group (PMG) estimator.

Findings – The study finds that, in the short run, increases in internet penetration, mobile phone subscriptions and fixed telephone subscriptions significantly decrease export levels in Nigeria. Nonetheless, ICT advancements, particularly in mobile and fixed telephone subscriptions, significantly boost import activities by 17.9 and 41.5% in the long run, highlighting their positive impact on trade dynamics. In the long run, mobile telephone subscriptions substantially negatively affect exports. In contrast, internet penetration and fixed telephone subscriptions show no significant impact, indicating differing influences of ICT components on trade over time.

Practical implications – The study underscored the need to prioritise enhancing ICT infrastructure to boost export growth, especially in sectors identified under the SITC framework. Strategies should be developed to mitigate the negative impacts associated with ICT advancements.

Originality/value – The study used the SITC framework, which presents different export and import sectors. It offers a distinctive examination of the short- and long-term effects of ICT on Nigeria's trade sectors. It also provided valuable insights into the impact of mobile and internet technologies on exports and imports, highlighting sector-specific effects and the need for strategic resource allocation.

Keywords ICT, Internet, Mobile phone, Trade, Nigeria, Export, Import

Paper type Research paper

1. Introduction

Information and Communication Technology (ICT) is a critical factor in promoting inclusive development at both the micro and macroeconomic levels, as it stimulates various economic activities. It improves Total Factor Productivity (TFP) through industrial research, development, and innovation (Efobi, Tanankem, & Asongu, 2018; Franck & Galor, 2017). ICT has enhanced production capacity, which is crucial for overall economic growth and has improved economic welfare, as noted by Heshmati and Rashidghalam (2016) Adeleye and Eboagu (2019), Asongu and Le Roux (2017), Ejemeyovwi and Osabuohien (2018), Makun and Jayaraman (2020). In addition, it increased household income (Comin & Mestieri, 2013) and enhanced employment opportunities (Azu *et al.*, 2021; Sovbetov, 2018). ICT has been shown to contribute to educational development (Uibu & Kikas, 2008), stimulate entrepreneurs' engagement (Shamaki *et al.*, 2022), reduce female discrimination, and revitalise health delivery

JEL Classification — F10, F14, C13

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(Asongu & Odhiambo, 2018, 2020; Makun, Singh, Lal, & Chand, 2022; Kliner, Knight, Mamvura, Wright, & Walley, 2013).

As a driving force behind globalisation, ICT is increasingly transforming the global economy into a digital one (Azu *et al.*, 2021). The ability of nations and businesses to efficiently process information is becoming more critical for maintaining competitiveness in international trade. This research seeks to contribute to the literature by examining the impact of ICT on Nigeria's trade sectors. Specifically, it will analyse how ICT influences exports and imports across various sectors, as classified under the Standard International Trade Classification (SITC). The study will also explore the consistency of ICT's impact across different sectors in Nigeria while assessing the short-term and long-term effects of ICT on trade. Rauch (1996), Belderbos & Sleuwaegen (1998), and Rauch & Casella (2003) identified information costs as barriers to international trade, leading to higher transaction costs. Lin (2014) and Wang and Choi (2018) further noted that Internet adoption enhances suppliers' access to customer and market data. ICT refers to the use of digital tools and systems like the Internet, mobile phones, and telecommunications infrastructure to facilitate communication, information sharing, and connectivity. It provides an avenue to enhance market access and reduce trade costs.

The literature offers diverse perspectives on the impact of ICT on bilateral and international trade, with many studies employing gravity models to explore this relationship. Freunda and Weinhold (2004) discovered that a 10% increase in web hosts led to a 1% rise in trade, particularly benefiting developing nations. Bojnec and Fertö (2009) highlighted that internet usage positively affected the export of manufactured goods in OECD nations, while Yadav (2014) found that internet use positively influenced the extensive margin of trade, though not the intensive margin. Lin (2014) noted that even small increases in internet use could boost bilateral trade, and Wang and Choi (2018) observed that ICT had a more significant positive impact on exports than imports in BRICS nations, particularly benefiting labour-intensive countries. Tay (2018) identified internet connectivity as having a significant effect on service trade and exports, with broadband and telephone subscriptions being especially impactful across various forms of trade.

Recent studies continue to support the positive role of ICT in international commerce. Dumor *et al.* (2023) found that ICT improves bilateral exports and economic growth in Eastern African BRI countries. Islam, Haque, Islam, Hassan, and Alam (2024) emphasised the importance of education human capital in enhancing ICT-driven trade flows. Azu and Nwauko (2021) and Rodriguez-Crespo, Marco, and Billon (2021) further confirmed the favourable impact of ICT on service exports and bilateral trade, with mobile phone usage playing a pivotal role. Özsoy, Ergüzel, Ersoy, and Saygılı (2022) demonstrated that ICT development promotes high-tech manufacturing exports in developing countries. Abendin, Duan, and Nkukporu (2022) identified a positive impact of ICT on West African trade, and Kere and Zongo (2023) revealed that ICT usage boosts intra-African trade, though it may reduce imports of primary and total commodities. Overall, the literature underscores ICT's significant and wide-ranging effects on trade, particularly for exports.

Despite the extensive body of research, there remains a significant gap in understanding the specific impact of ICT on Nigeria's various trade sectors. Many studies have focused on broader regional contexts or comparative analyses across multiple countries, often neglecting Nigeria's unique trade dynamics. Moreover, the distinct effects of ICT across different sectors and the potential variations in ICT's influence on each have yet to be fully explored. This study aims to fill these gaps by focussing on Nigeria and employing a dynamic panel ARDL approach emphasising Pooled Mean Group (PMG) estimators. This method is chosen for its ability to distinguish between short-term and long-term effects, allowing for a more nuanced understanding of ICT's lasting impact on trade. According to the SITC classification, Nigeria's trade data is categorised into ten sectors: 0-Food and Animals; 1-Beverage and Tobacco; 2-Crude Materials, Inedible, Except Fuel; 3-Mineral Fuel; 4-Animal and Vegetable Oils, Fats, and Waxes; 5-Chemicals and Related Products; 6-Manufactured Goods; 7-Transport and

Machinery; 8-Miscellaneous Manufactured Articles; and 9-Transactions and Commodities Not Classified Elsewhere.

A detailed and focused examination of Nigeria's trade sectors is essential to uncover the specific patterns and nuances that broader regional studies may overlook, using data from 1995 to 2022. Unlike the widely used gravity model in previous studies (Abendin *et al.*, 2022; Rodriguez-Crespo *et al.*, 2021; Azu & Muhammad, 2020; Azu, 2022; Muhammad, Diyoke, & Azu, 2020; Azu, 2019; Julius, Azu, & Muhammad, 2019), the dynamic panel ARDL approach with Pooled Mean Group (PMG) estimators provides a deeper analysis of both short- and long-term effects, adding a fresh perspective to the literature. This study focuses on Nigeria's trade data from 1995 to 2022 and categorised according to the Standard International Trade Classification (SITC). By incorporating ICT indicators such as internet penetration rate, mobile telephone subscriptions, and fixed telephone subscriptions, this research offers a comprehensive view of ICT's impact on trade, contributing to the ongoing discourse on global commerce and digital transformation. Choosing Nigeria as the focus of this study is justified by the country's unique position as one of Africa's largest economies and a key player in regional and global trade. Nigeria's diverse and complex trade sectors and significant ICT infrastructure growth provide a compelling case for examining the interplay between ICT and trade.

The significance of this study is its capacity to enlighten strategic decisions and policies that can improve Nigeria's trade performance by leveraging ICT advancements. Identifying the differential impacts of ICT across various sectors enables policymakers to customise interventions to optimise benefits in the most critical areas. Furthermore, comprehending the long-term and short-term impacts of ICT on trade can assist in developing sustainable trade policies that capitalise on digital technologies. This study addresses a critical lacuna in the literature and offers actionable insights to improve Nigeria's competitiveness in the global market, thereby contributing to economic growth and development.

2. Brief literature review

The assimilation of new technology in any sector is crucially influenced by the Technology Acceptance Model (TAM) proposed by Davis (1989). TAM posits that the acceptance of a given technology is determined by the user's voluntary and willing intention to adopt and utilise the technology. This model, along with the Theory of Reasoned Action (TRA), as discussed by Asongu (2018) and Efobi *et al.* (2018), forms the theoretical foundation for understanding technology adoption in this research. The TRA, popularised by Fishbein and Ajzen (1975) and Ajzen and Fishbein (1980) and further reinforced by Bagozzi (1982), assumes that consumers make rational decisions by carefully considering the potential outcomes of their actions before forming an attitude. This model is intuitive and effective in clarifying attitudes and identifying factors that motivate intentionally adopted behaviours.

Davis (1989) extended the TRA framework with the TAM, which suggests that an individual's acceptance of technology can be explained by their enthusiastic intention to adopt and use it. Asongu (2018) elaborates that in this context, "intention" implies an individual's perception of the technology's usefulness or attitude towards its use. By leveraging these theoretical models, this research explores how Information and Communication Technology (ICT) revolutionises Nigeria's trade sectors, focussing on technology acceptance and utilisation dynamics.

The literature has provided varying assessments of the effects of ICT on bilateral and international commerce (Freunda & Weinhold, 2004; Bojnec & Fertö, 2009; Yadav, 2014; Lin, 2014; Wang & Li, 2017; Nath & Liu, 2017; Wang & Choi, 2018; Tay, 2018; Azu & Nwauku, 2021; Rodriguez-Crespo *et al.*, 2021; Özsoy *et al.*, 2022; Abendin *et al.*, 2022; Kere & Zongo, 2023; Billon, Rodríguez-Andrés & Rodríguez-Crespo, 2023; Dumor *et al.*, 2023; Shanmugalingam, Shanmuganeshan, Manorajan, Kugathasan, & Pathirana, 2023; Islam *et al.*, 2024). For example, Freunda and Weinhold (2004) employed a gravity model to analyse data from 56 nations between 1995 and 1999. They discovered that a 10% increase in web hosts

resulted in a 1% increase in trade. Their research emphasised that the Internet substantially impacted trade flows in developing countries, particularly the most impoverished.

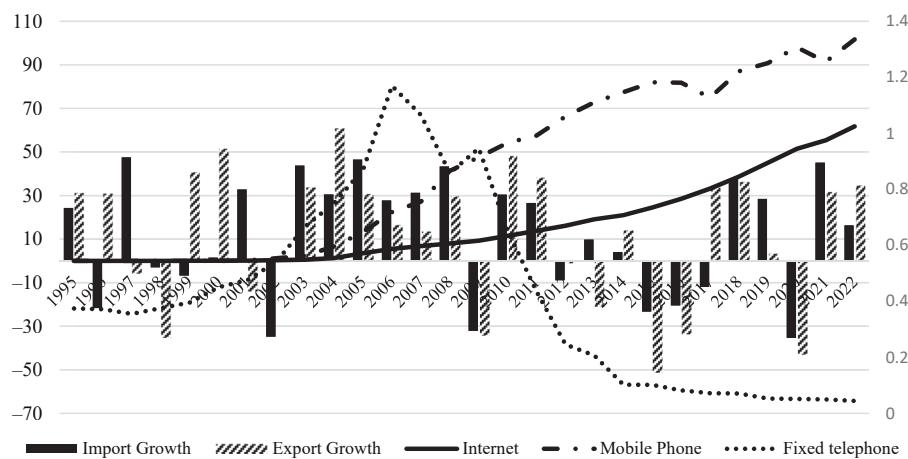
Similarly, Bojnec and Fertö (2009) implemented the gravity model method to evaluate the influence of the Internet on the export of manufactured products across OECD nations from 1995 to 2003. The results of their panel regression analysis demonstrated that the utilisation of the Internet has a substantial positive impact on industrial exports and alleviates the negative consequences of distance. Yadav (2014) discovered that the extensive margin of export and import behaviour for enterprises was positively influenced by Internet use, while the intensive margin was not significantly affected. This was based on data from 52 Asian and African nations between 2006 and 2010. Lin (2014) demonstrated that bilateral trade would increase by 0.02-0.04% for every percentage point increase in internet use by utilising a gravity model to analyse data from approximately 200 nations between 1990 and 2006. Using panel data from 2000 to 2016, Wang and Choi (2018) investigated the influence of ICT on the trade volumes of the BRICS nations. Their research revealed that ICT had a more favourable impact on exports than on imports, with the effect diminishing as it progressed through the value chain. Furthermore, they discovered that the influence of ICT on trade increases over time, with labour-intensive nations benefiting more than resource-intensive ones. Tay (2018) found that internet connectivity significantly affects service trade and export but not service import, while fixed broadband and telephone subscriptions had the most substantial impact on all three forms of service trade.

The study by Dumor *et al.* (2023) explores the influence of ICT on bilateral trade and economic growth in Eastern African Belt and Road Initiative (BRI) countries, using a panel data structural gravity approach. It finds that greater access to ICT enhances bilateral exports and economic growth, especially within the East African Community (EAC), though more investment in ICT infrastructure is necessary to sustain this progress. Islam *et al.* (2024) examine how education human capital impacts ICT-trade relationships, showing that ICT usage significantly boosts merchandise export flows, particularly for countries with higher education levels. Wang and Li (2017) identify ICT as a source of comparative advantage in international trade, where a country's export in an industry increases with improved ICT development and research intensity. Nath and Liu (2017) highlight that ICT development positively influences the trade of services, particularly ICT-enabled services like financial and business services. Shanmugalingam *et al.* (2023) find that e-commerce is crucial in boosting international trade among Asian countries, emphasising the importance of technology and telecommunications policies for enhancing trade.

Azu and Nwauko (2021) evaluated the impact of digital technology on service commerce in West Africa from 1995 to 2020 by employing a panel ARDL model. Their results were consistent with those of Wang and Choi (2018), suggesting that digital transformation has a substantial positive impact on service exports in the medium and long term, but has a less significant effect on imports. Rodriguez-Crespo *et al.* (2021) employed a gravity model to analyse data from 55 countries between 2004 and 2013, demonstrating that ICT has a significant and favourable impact on bilateral trade. The most significant effect was shown by mobile phone usage. Özsoy *et al.* (2022) found that ICT can accelerate the manufacturing of high-tech goods in developing nations. Their study, using panel data from 2007 to 2017, indicated that the ICT development index significantly impacts the export of high-tech items. Abendin *et al.* (2022) also discovered a beneficial impact of ICT on bilateral commerce in West Africa, utilising data from 2000 to 2018. Kere and Zongo (2023) demonstrated that intra-African commerce, particularly internet use, is positively influenced by ICT usage, while imports of primary items and total commodities are negatively impacted.

3. ICT usage and trade in Nigeria

Figure 1 presents a comprehensive overview of Nigeria's trade growth and ICT development from 1995 to 2022. It showcases the import and export growth rates alongside the proliferation



Note(s): Primary Y-Axis-Nigerian Export; Import; Internet Usage & Mobile Phone subscription Secondary Y-Axis- Fixed Telephone Subscription

Source(s): World Development Indicator (WDI) and UNCTAD

Figure 1. ICT usage and trade growth in Nigeria

of ICT, indicated by the percentage of individuals using the Internet, mobile cellular subscriptions per 100 people, and fixed telephone subscriptions per 100 people. In the mid-1990s, Nigeria had minimal ICT infrastructure, with virtually no Internet usage and extremely low mobile and fixed telephone subscriptions (Azu *et al.*, 2021; Azu & Nwauko, 2021). During this period, trade growth exhibited significant volatility, with substantial fluctuations in both import and export growth rates (See Figure 1).

As we move into the early 2000s, the data shows a marked increase in Internet usage and mobile cellular subscriptions. By 2002, there was a notable jump in Internet usage to 0.32% of the Population and mobile subscriptions to 1.21 per 100 people, reflecting the beginning of a rapid ICT adoption phase. This period coincides with fluctuating trade growth, indicating that while ICT infrastructure was being established, its direct impact on stabilising trade growth was not immediately apparent. Import and export growth rates continued to show substantial variability, with years of significant positive and negative development.

In the latter years, particularly from 2010 onwards, there is a clear correlation between the expansion of ICT and trade growth. Internet usage surged from 11.5% in 2010 to 61.74% in 2022, and mobile cellular subscriptions dramatically increased from 54.24 to 101.69 per 100 people. This period also saw a general trend of more stable trade growth despite some years of decline, such as in 2015 and 2020. The increased connectivity likely facilitated better communication, efficient market transactions, and access to global markets, contributing to more consistent trade performance. However, despite these advancements, fixed telephone subscriptions declined over time, highlighting a shift towards mobile and internet-based communication technologies as primary tools for trade and economic activities.

4. Methodological notes

4.1 Model specification and data

In evaluating the influence of digitalisation on service trade in West African countries, Azu and Nwauko (2021) augmented a gravity model presented by Choi (2010) as follows:

$$\ln X/M_{it} = \delta_0 + \delta_1 \ln T_{it} + \delta_2 \ln Y_{it} + \delta_4 \ln M2_{it} + \mu_{it} \quad (1)$$

Where X/M_{it} represented service export and import; T_{it} is a vector of digitisation that is proxied with the internet penetration rate (T_1) and mobile telephone subscription (T_2); Y_{it} is a vector of Market size (G_{it}) is proxied with Real GDP ($G_{1,it}$) and Population ($G_{2,it}$) and financial depth measured with broad money supply (M2). In the interest of this research, Equation (1) is modified to realise the objectives of this research as follows:

$$\ln X/M_{it} = \delta_0 + \delta_1 \ln T_{it} + \delta_2 \ln Y_{it} + \delta_3 \ln F_{it} + \delta_4 \ln R_{it} + \mu_{it} \quad (2)$$

The dependent variable X/M_{it} stands for export X_{it} and import M_{it} in various traded sectors in Nigeria. In this research, trade is captured in 10 different sectors based on SITC classification: 0-Food and Animals; 1-Beverage and Tobacco; 2-Crude Materials, inedible, except Fuel; 3-Mineral Fuel; 4-Animal and Vegetable oil, fat and Waxes; 5-Chemical and related products; 6-Manufactured Goods; 7-Machinery and Transport; 8-Miscellaneous Manufactured articles; 9-Commodities and Transactions not classified elsewhere in the SITC. T_{it} represents a vector of ICT captured in three perspectives: internet penetration rate ($T_{1,it}$), mobile telephone subscriptions ($T_{2,it}$) and fixed telephone subscriptions ($T_{3,it}$). All the ICT variables are taken as a percentage of the Population. It is expected that ICT will be instrumental to an increase in trade since available literature has affirmed that it reduces trade costs (Yadav, 2014; Lin, 2014; Wang & Choi, 2018; Freunda & Weinhold, 2004).

On the other hand, Y_{it} stand for current GDP, which provides a real-time, accurate representation of economic activity at market prices, making it particularly relevant for examining the immediate effects of ICT advancements on trade. It includes inflation and price changes, offering a comprehensive view of the economy and the impact of ICT investments on trade sectors under current conditions. F_{it} is the labour participation rate that captures the percentage of the labour force employed and can reflect the economic activity and productivity levels in different sectors. Finally, R_{it} is the nominal exchange rate, which is crucial as it directly affects the cost of imports and exports, influencing trade balances and the competitiveness of domestic industries in the global market. Table 1 presents the source of data and a priori expectation.

4.2 Estimation technique

This study examines ten traded sectors based on SITC single digits over 28 years from 1995 to 2022. It employs the panel-ARDL model, proposed by Pesaran and Smith (1995) and Pesaran, Shin, and Smith (1999), contingent on the stationarity of the variables, whether integrated at I(1) or I(0). Therefore, stationarity tests such as the Im-Pesaran-Shin (IPS) panel unit-root test (Im *et al.*, 2003), which accounts for dependence between individuals and heterogeneity across cross-sections, are essential. The panel ARDL technique is reliable for estimating panel data

Table 1. Data sources and expected signs of coefficients

Variables	Expectation	Sources
Export (E_{it})	Dependent	UNCTAD
Import (M_{it})	Dependent	UNCTAD
Internet penetration rate ($T_{1,t}$)	Positive (+)	World Development Indicator (WDI)
Mobile telephone ($T_{2,t}$)	Positive (+)	World Development Indicator (WDI)
Fixed telephone ($T_{3,t}$)	Positive (+)	World Development Indicator (WDI)
Nominal GDP (Y_t)	Positive (+)	World Development Indicator (WDI)
Exchange rate (R_t)	Positive (+)	World Development Indicator (WDI)
Labour force (F_t)	Positive (+)	World Development Indicator (WDI)

that meet its criteria, allowing for the estimation of both long- and short-run coefficients using the Mean Group (MG) estimator to address bias from heterogeneous slopes in dynamic panels.

The MG estimator averages the long-run ARDL model parameters across individual countries, providing consistent estimates but potentially inefficient with homogeneous slopes. Conversely, Pesaran *et al.* (1999, 2001) suggest the Pooled Mean Group (PMG) estimator for more efficient estimation when long-run coefficients are homogeneous across groups, allowing short-run parameters to be heterogeneous. The choice between MG and PMG depends on the Hausman (1978) test, which evaluates whether MG and PMG estimates differ significantly. A p-value below 0.05 rejects the null hypothesis, favouring MG, while a p-value above 0.05 supports using the more efficient PMG.

Generally, the Panel ARDL ($p, q, q \dots, q$) model can be specified as follows.

$$Z_{it} = \sum_{j=1}^p \gamma_{ij} Z_{i,t-j} + \sum_{j=0}^q \varphi_{ij} V_{i,t-j} + \sigma_i + \varepsilon_{it} \quad (3)$$

Where Z_{it} is the dependent variable, $(V'_{it})'$ is $K*1$ vector that allowed to be purely $I(0)$ or $I(1)$ or cointegrated; γ_{ij} is the coefficient of the lagged dependent variable called scalar; φ_{ij} are $k*1$ coefficient vectors; σ_i is the unit-specific fixed effects; $i = 1, \dots, N$; $t = 1, 2, \dots, T$; p, q are optimal lag orders; ε_{it} is the error term. In this study, the re-parameterised Panel ARDL ($p, q, q \dots, q$) error correction model is formulated as follows:

$$\begin{aligned} \Delta \ln X / M_{it} = & \beta_i \left[\ln X / M_{i,t-1} - \gamma'_i (\ln T_{i,t} + \ln Y_{i,t} + \ln F_{i,t} + \ln R_{i,t}) \right] + \sum_{j=1}^{p-1} \omega_{ij} \Delta \ln X / M_{i,t-j} \\ & + \sum_{j=0}^{q-1} \delta'_{ij} \Delta \ln T_{i,t-j} + \sum_{j=0}^{q-1} \delta'_{ij} \Delta \ln Y_{i,t-j} + \sum_{j=0}^{q-1} \delta'_{ij} \Delta \ln F_{i,t-j} + \sum_{j=0}^{q-1} \delta'_{ij} \Delta \ln R_{i,t-j} + \theta_i \\ & + \varepsilon_{it} \end{aligned} \quad (4)$$

Notes: β_i = group-specific speed of adjustment coefficient (expected that $\theta_i < 0$)

γ'_i = vector of long-run relationships

$ECT = [\ln X / M_{i,t-1} - \gamma'_i (\ln T_{i,t} + \ln Y_{i,t} + \ln F_{i,t} + \ln R_{i,t})]$ the error correction term

$\omega_{ij}, \delta'_{ij}$ represent the short-run dynamic coefficients. All variables are in natural logarithm.

Azu *et al.* (2021) and Azu and Nwauko (2021) chose the panel ARDL estimation technique because it accounts for the lagged forms of both dependent and independent variables. This approach effectively captures the true impact of ICT on trade, as the implementation of ICT requires time for adoption and integration, thus reflecting its effects on exports and imports over time.

5. Estimation and results

The descriptive statistics in Table 2, Panel A summarise the key characteristics of the variables used in the study. With 280 observations for each variable, the means, standard deviations, and ranges (minimum and maximum values) offer insight into the data distribution. For instance, the mean of exports ($\ln X_{i,t}$) is 12.2524 with a standard deviation of 2.4707, indicating variability in export values. Imports ($\ln M_{i,t}$) have a higher mean of 13.8265, reflecting larger average import values, while the mean for internet penetration rate ($\ln T_{1,i,t}$) is 1.1239, suggesting relatively lower ICT adoption. The negative mean value of the fixed telephone subscriptions ($\ln T_{3,i,t}$) at -1.3034 indicates lower baseline fixed telephone usage. The GDP ($\ln Y_{i,t}$) has a mean of 26.2487, showing relatively high economic output, while the labour force

Table 2. Summary statistics and correlation matrix

Variables	$\ln X_{i,t}$	$\ln M_{i,t}$	$\ln T_{1,i,t}$	$\ln T_{2,i,t}$	$\ln T_{3,i,t}$	$\ln Y_{i,t}$	$\ln F_{i,t}$	$\ln R_{i,t}$
<i>Panel A descriptive statistics</i>								
Obs	280	280	280	280	280	280	280	280
Mean	12.2524	13.8265	1.1239	1.7825	-1.3034	26.2487	4.0911	4.8652
Std. Dev	2.47066	1.93973	2.7927	3.4095	1.0586	0.6724	0.0088	0.8383
Min	6.08678	2.77259	-4.7293	-4.4215	-3.1149	24.8033	4.0679	3.0858
Max	18.5942	16.8587	4.1230	4.6219	0.1566	27.0762	4.1014	6.0544
<i>Panel B correlation matrix</i>								
$\ln X_{i,t}$	1							
$\ln M_{i,t}$	0.4737	1						
$\ln T_{1,i,t}$	0.2973	0.3754	1					
$\ln T_{2,i,t}$	0.2921	0.3633	0.9831	1				
$\ln T_{3,i,t}$	-0.1785	-0.2163	-0.5086	-0.385	1			
$\ln Y_{i,t}$	0.3021	0.3671	0.799	0.7734	-0.5615	1		
$\ln F_{i,t}$	-0.1334	-0.1655	-0.499	-0.3764	0.913	-0.4154	1	
$\ln R_{i,t}$	0.223	0.2931	0.8778	0.835	-0.5608	0.4676	-0.6304	1

Source(s): Author's computation

($\ln F_{i,t}$) and exchange rate ($\ln R_{i,t}$) show moderate means of 4.0911 and 4.8652, respectively. The standard deviations highlight the data spread, with mobile telephone subscriptions ($\ln T_{2,i,t}$) and internet penetration rate ($\ln T_{1,i,t}$) showing the highest variability.

The correlation matrix in Table 2, Panel B illustrates the relationships between the variables. Notably, exports ($\ln X_{i,t}$) and imports ($\ln M_{i,t}$) have a moderate positive correlation of 0.4737, suggesting that exports increase as imports increase. ICT-related variables internet penetration rate ($\ln T_{1,i,t}$) and mobile telephone subscription ($\ln T_{2,i,t}$) show strong positive correlations with each other (0.9831), indicating that internet and mobile subscriptions are closely linked. However, fixed telephone subscriptions ($\ln T_{3,i,t}$) negatively correlates with most variables, especially internet penetration rate ($\ln T_{1,i,t}$) (-0.5086), suggesting that higher internet usage is associated with lower fixed telephone subscriptions. GDP ($\ln Y_{i,t}$) positively correlates with most variables, particularly internet penetration rate ($\ln T_{1,i,t}$) (0.799), indicating that higher GDP is associated with greater ICT adoption. Interestingly, the exchange rate ($\ln R_{i,t}$) shows positive correlations with most variables, especially with internet penetration rate ($\ln T_{1,i,t}$) (0.8778), suggesting a relationship between the exchange rate and the ICT variable. These correlations provide a preliminary understanding of how these variables interact, guiding further analysis of the impact of ICT on trade.

The IPS unit root test results in Table 3 indicate that most variables are integrated at order I (1), becoming stationary only after first differencing. Specifically, exports ($\ln X_{i,t}$), imports ($\ln M_{i,t}$), fixed telephone subscriptions ($\ln T_{3,i,t}$), nominal GDP ($\ln Y_{i,t}$), and labour force participation rate ($\ln F_{i,t}$) are non-stationary at level but stationary at first Difference, implying they are I(1). On the contrary, the internet penetration rate ($\ln T_{1,i,t}$), mobile telephone subscriptions ($\ln T_{2,i,t}$), and exchange rate ($\ln R_{i,t}$) are stationary at the level, indicating they are I(0). Therefore, the mixed integration orders of the variables support the suitability of the panel-ARDL model for further analysis.

5.1 Short-and long-run impact of ICT on export in Nigeria

The export model was estimated thrice for the internet penetration rate model ($X_{it}T_1$), mobile telephone subscriptions model ($X_{it}T_2$), and fixed telephone subscriptions model ($X_{it}T_3$) respectively to avoid the issue of multicollinearity (Azu & Nwauko, 2021; Azu *et al.*, 2021). Before estimating the long-run and short-run impact of ICT variables on sectorial export in

Table 3. IPS unit root test

Variables	Level	Trend	1st difference	Trend	Remark
$\ln X_{i,t}$	0.2004	-0.2927	-11.1591***	-9.5824***	I1
$\ln M_{i,t}$	0.2584	1.0426	-10.5845***	-9.0187***	I1
$\ln T_{1,i,t}$	-3.2604***	4.4297	0.2125	-0.9582	I0
$\ln T_{2,i,t}$	-2.2688**	3.0698	-2.4333***	-3.2912***	I0
$\ln T_{3,i,t}$	5.2673	2.3674	-1.8863**	-1.7867*	I1
$\ln Y_{i,t}$	1.8736	-0.4175	-5.7548 ***	-3.5412***	I1
$\ln F_{i,t}$	1.4026	1.3275	-4.3607***	-2.3164***	I1
$\ln R_{i,t}$	-1.6684**	-1.6441*	-7.2669***	-6.0248***	I0

Source(s): Author's computation

Nigeria, it's essential to establish a long-run relationship. In the Panel ARDL technique, a bound test for cointegration is unnecessary. Instead, the long-run relationship is determined using the error correction term (ECT), as shown in Table 4. According to Banerjee *et al.* (1998), the export models meet the criteria with a negative ECT (-1) of -0.241, -0.659, and -0.299, for internet penetration rate, mobile telephone subscriptions and fixed telephone subscriptions, respectively, and all significant at 1% level. These indicate an adjustment speed of 24.1, 65.9, and 29.9% toward long-run equilibrium. The negative value of the ECT, typically ranging between -1 and 0, implies the absence of serial correlation and instability issues commonly caused by structural breaks in panel data, as suggested by Sovbetov (2018) and Sovbetov and Saka (2018).

In the long run, the estimated coefficient for the internet penetration rate is negative (-0.587). Still, it is not statistically significant, indicating that changes in internet penetration do not have a reliable impact on exports in this model. On the other hand, the coefficient for mobile telephone subscriptions is also negative (-0.352) and statistically significant at the 1% level. This significant negative coefficient implies that a 1% increase in mobile telephone subscriptions would result in a 35.2% decrease in exports, assuming all other factors remain constant. This suggests a potentially adverse effect of mobile phone proliferation on export activities, possibly due to increased consumer focus on domestic consumption or other factors

Table 4. Short-and long-run impact of ICT on sectorial export in Nigeria

Long run Variables	$X_{it}T_1$	$X_{it}T_2$	$X_{it}T_3$	Short run			
				Variables	$X_{it}T_1$	$X_{it}T_2$	$X_{it}T_3$
-	-	-	-	ECT	-0.241*** (0.0644)	-0.659*** (0.0773)	-0.299*** (0.0629)
-	-	-	-				
$L2.\ln Y_{i,t}$	1.350 (0.930)	1.034*** (0.174)	0.582*** (0.112)	$D.\ln Y_{i,t}$	1.765 (1.235)	0.155 (0.842)	0.596 (0.892)
$L2.\ln T_{i,t}$	-0.587 (0.390)	-0.352*** (0.101)	0.0638 (0.123)	$D.\ln T_{i,t}$	-0.724** (0.347)	-0.219** (0.0897)	-0.530*** (0.141)
$\ln F_{i,t}$	80.83*** (27.52)	86.06*** (13.53)	36.79** (15.73)	$D.\ln F_{i,t}$	6.218 (14.03)	-14.55 (11.73)	38.58*** (11.16)
$L2.\ln R_{i,t}$	2.699** (1.107)	2.132*** (0.393)	0.657*** (0.0798)	$D.\ln R_{i,t}$	1.858 (1.339)	0.0161 (0.907)	0.584 (0.971)
-	-	-	-	Constant	-88.42*** (23.59)	-247.9*** (29.14)	-46.64*** (9.615)
Obs	280	280	280	Obs	280	280	280

Note(s): Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Source(s): Author's computation

not captured in this analysis. Meanwhile, the estimated impact of fixed telephone subscriptions is positive but not statistically significant, indicating that changes in fixed telephone subscriptions do not have a reliable or substantial effect on export levels in the long run. This lack of significance may suggest that fixed telephone lines are less relevant in influencing trade activities compared to mobile telephony and internet penetration in the context of this study.

In the short run, the results show more consistency compared to the long run. The internet penetration rate's estimated coefficient is -0.724 , statistically significant at the 5% level, indicating a 1% increase in internet penetration results in a 72.4% decrease in exports. This suggests that increased internet access might shift focus towards domestic markets. Similarly, the coefficient for mobile telephone subscriptions is -0.219 and significant at the 5% level, meaning a 1% increase leads to a 21.9% decrease in exports. For fixed telephone subscriptions, the coefficient is -0.530 and statistically significant, implying a 1% increase in fixed telephone subscriptions results in a 53.0% decrease in exports. These findings indicate that increases in internet penetration, mobile phone subscriptions, and fixed telephone subscriptions negatively affect export levels in the short run, possibly due to increased domestic consumption or resource reallocation away from export activities.

Concerning individual sectors and considering internet penetration rate (See Appendix I), only Beverage and Tobacco (1); Crude Materials, inedible, except Fuel (2); Mineral Fuel (3) and Commodities and Transactions not classified elsewhere in the SITC (9) reported negative coefficient of -2.712 , -1.034 , -0.945 and -1.809 respectively and statistically significant. Concerning mobile telephone subscriptions (Appendix II), Crude Materials (2), inedible, except Fuel; 3-Mineral Fuel (3), and -Machinery and Transport (7) also reported negative coefficients of -0.295 , -0.287 and -0.599 , respectively and statistically significant. Finally, fixed telephone subscriptions (Appendix III) reported negative coefficients of -0.686 , -0.661 , -0.654 , and -1.427 for Crude Materials, inedible, except Fuel (2) 3-Mineral Fuel (3), Manufactured Goods (6) and Miscellaneous Manufactured articles (8) respectively. This aligns with the overall short-run result and reflects the findings in Azu and Nwauko (2021) and Wang and Choi (2018) that these digitalisation elements usually negatively influence exports.

5.2 Short-and long-run impact of ICT on import in Nigeria

Again, the import model was estimated thrice for internet penetration rate ($M_{it}T_1$), mobile telephone subscriptions ($M_{it}T_2$), and fixed telephone subscriptions ($M_{it}T_3$) respectively to avoid the issue of multicollinearity (Azu & Nwauko, 2021; Azu et al., 2021). The estimated error correction term (ECT) in Table 5 meets the criteria for establishing a long-run effect. With negative ECT values of -0.0873 , -0.608 , and -0.744 for internet penetration rate, mobile telephone subscriptions, and fixed telephone subscriptions, respectively, all statistically significant, there is an adjustment speed of 8.7, 60.8, and 74.4% towards long-run equilibrium. The ECT's negative value, typically between -1 and 0 , indicates the absence of serial correlation and instability issues commonly caused by structural breaks in panel data, as suggested by Sovbetov (2018) and Sovbetov and Saka (2018) (see Table 5).

From Table 5, the import direction seems to have benefited more from ICT variables in the long run. The internet penetration rate reported a positive but not statistically significant coefficient. However, mobile telephone subscriptions showed a positive coefficient of 0.179 , statistically significant at 1%, indicating that a 1% increase in mobile subscriptions results in a 17.9% increase in imports. Fixed telephone subscriptions had an even higher positive coefficient of 0.415 , also significant at 1%, suggesting that a 1% increase in fixed telephone subscriptions leads to a 41.5% increase in imports. These findings imply that in the long run, ICT advancements, particularly in mobile and fixed telephone subscriptions, significantly boost import activities in Nigeria, highlighting the role of communication technology in enhancing trade dynamics.

In the short run, internet penetration presents a negative coefficient of -0.915 , statistically significant at 5%, suggesting a 91.5% decrease in imports. This indicates that increased

Table 5. Short-and long-run impact of ICT on sectorial import in Nigeria

Long run Variables	$M_{it}T_1$	$M_{it}T_2$	$M_{it}T_3$	Short run Variables	$M_{it}T_1$	$M_{it}T_2$	$M_{it}T_3$
–	–	–	–	ECT	–0.0873** (0.0378)	–0.608*** (0.0692)	–0.744*** (0.103)
–	–	–	–	$D.\ln Y_{i,t}$	2.652* (1.419)	–1.132* (0.619)	–1.181* (0.693)
$L2.\ln Y_{i,t}$	–3.831 (3.961)	0.0859 (0.111)	0.627*** (0.0484)	$D.\ln T_{i,t}$	–0.915** (0.420)	–0.0129 (0.0470)	–0.507*** (0.0995)
$L2.\ln T_{i,t}$	1.382 (1.223)	0.179*** (0.0240)	0.415*** (0.0696)	$D.\ln F_{i,t}$	3.069 (28.34)	8.679 (19.23)	10.84 (19.61)
$\ln F_{i,t}$	–171.4 (181.9)	15.70*** (5.849)	–21.55** (8.647)	$D.\ln R_{i,t}$	2.923* (1.621)	–1.236** (0.591)	–1.100 (0.675)
$L2.\ln R_{i,t}$	–5.496 (5.362)	–0.0183 (0.116)	0.402*** (0.0385)	Constant	73.33** (31.61)	–31.87*** (3.672)	62.75*** (8.789)
–	–	–	–	Obs	280	280	280
Obs	280	280	280	Obs	280	280	280

Note(s): Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Source(s): Author's computation

internet access might divert resources away from import activities. Similarly, fixed telephone subscriptions report a negative coefficient of –0.507, significant at 1%, implying a 50.7% reduction in imports with a 1% increase in fixed telephone subscriptions. This might be due to a shift in focus towards more traditional communication methods over trade activities. Although mobile telephone subscriptions also report a negative coefficient in the short run, it is not statistically significant, indicating that its impact on imports is unclear. These findings highlight ICT's complex and potentially adverse effects on short-run import activities in Nigeria.

In analysing individual sectors, internet penetration negatively impacted the Mineral Fuel (3) sector with a significant coefficient of –1.955, indicating a substantial decrease in exports (Appendix IV). Mobile telephone subscriptions did not show statistically significant results in the short run for any sector, suggesting their impact on sector-specific exports is minimal (Appendix V). Conversely, fixed telephone subscriptions (Appendix VI) had significant negative effects across multiple sectors: –0.564 for Food and Animals (0), –0.525 for Beverage and Tobacco (1), –0.857 for Crude Materials, Inedible, except Fuel (2), –1.135 for Animal and Vegetable Oil, Fat and Waxes (4), –0.430 for Manufactured Goods (6), and –0.572 for Machinery and Transport (7). These results highlight that traditional communication methods, like fixed telephones, are associated with decreased exports in these sectors.

5.3 Discussion of findings

The findings of this study align with previous literature on the varied effects of ICT on trade, particularly the contrasting impact on exports and imports. Freunda and Weinhold (2004) noted that internet usage positively affects trade in developing countries, though resources can be diverted toward domestic markets, similar to the negative long-term relationship between mobile phone subscriptions and exports found here. This is consistent with Wang and Choi (2018), who showed that ICT enhances domestic consumption more than international trade, particularly in the short run. Similarly, Nath and Liu (2017) highlighted that ICT's influence on services trade is stronger for ICT-enabled services like financial and business services, implying that certain trade sectors may benefit more than others. The short-term disruptions in export activities in this study echo Azu and Nwauko's (2021) findings, where digital transformation in West Africa caused short-term trade challenges due to the reallocation of resources toward domestic markets.

Furthermore, the long-term positive impact of ICT on imports aligns with Bojneč and Fertő's (2009) research, which demonstrated that traditional telecommunication infrastructure, such as fixed telephone subscriptions, continues to play a role in trade. This study's finding that mobile phone subscriptions foster imports is also supported by Wang and Li (2017), who emphasised that mobile technology enhances access to international markets by improving transaction efficiency and communication. Özsoy *et al.* (2022) further noted that ICT can stimulate high-tech goods manufacturing in developing nations, which may boost import demand for advanced production technologies. Similarly, Abendin *et al.* (2022) found that ICT positively influences West African bilateral commerce, which underscores the findings in this study that imports benefit from ICT-driven improvements in communication and market access.

The implications of this study build on a broader understanding of ICT's sectoral and temporal impacts on Nigeria's trade. Long-term ICT benefits, especially for imports, affirm the importance of mobile and fixed telephony in fostering international trade, as noted by Rodriguez-Crespo *et al.* (2021). However, the short-term disruptions reflect the transitional nature of ICT's role, with temporary challenges to imports and exports, as noted by Tay (2018) and Kere and Zongo (2023). Studies like Dumor *et al.* (2023) and Islam *et al.* (2024) suggest that education and infrastructure investments are critical to maximising ICT's trade benefits. These findings highlight the need for policies that mitigate short-term disruptions while enhancing long-term digital transformation benefits, particularly in a developing economy like Nigeria, as echoed by Shanmugalingam *et al.* (2023).

The findings of this study, when linked to the Technology Acceptance Model (TAM) and Theory of Reasoned Action (TRA), emphasise how perceived usefulness and rational decision-making affect ICT adoption and trade. The negative long-term impact of mobile phone subscriptions on exports aligns with TAM, suggesting that Nigerian traders may not fully recognise mobile technology's benefits for international trade, echoing Freunda and Weinhold (2004) and Wang and Choi (2018). Nath and Liu (2017) also noted that ICT's sectoral influence varies, with domestic markets often benefitting more than exports. Conversely, the positive long-term effect of ICT on imports supports TRA, as businesses adopt ICT to improve market access and logistics, consistent with Wang and Li (2017) and Bojneč and Fertő (2009). The study's results, which mirror Özsoy *et al.* (2022) and Abendin *et al.* (2022), show that ICT enhances communication and transaction efficiency for imports. However, short-term disruptions in both imports and exports reflect transitional ICT adoption challenges, as noted by Azu and Nwauko (2021), Tay (2018), and Kere and Zongo (2023), requiring focused policy efforts to maximise long-term benefits.

6. Conclusions

The study investigates the short- and long-run impacts of ICT on sectoral exports and imports in Nigeria. In the long run, internet penetration shows a negative coefficient (-0.587) but is not statistically significant, suggesting no reliable impact on exports. Mobile telephone subscriptions have a significant negative coefficient (-0.352), indicating that a 1% increase in mobile subscriptions leads to a 35.2% decrease in exports, possibly due to increased domestic consumption. Fixed telephone subscriptions have a positive but insignificant impact on exports. In the short run, internet penetration (-0.724), mobile phone subscriptions (-0.219), and fixed phone subscriptions (-0.530) all negatively affect exports significantly, highlighting a potential shift towards domestic markets or resource reallocation.

For imports, the long-run analysis shows a positive but insignificant effect of internet penetration. Mobile telephone subscriptions have a significant positive impact (0.179), and fixed telephone subscriptions have an even higher positive effect (0.415), indicating that ICT advancements boost import activities. In the short run, internet penetration (-0.915) and fixed telephone subscriptions (-0.507) significantly reduce imports, suggesting a diversion of resources from import activities. Mobile telephone subscriptions also negatively impact the

short run, but this is not statistically significant. These findings underscore ICT's complex and varying implications on Nigeria's trade dynamics, with ICT promoting imports while potentially hindering exports in the short term. To maximise the benefits of ICT for trade in Nigeria, policymakers should invest in targeted training programs that enhance traders' understanding of the utility of mobile technology for international trade, thus addressing the negative perceptions of its impact on exports. Developing robust infrastructure that integrates ICT across various trade sectors can facilitate smoother transitions during digital transformation, ultimately supporting domestic and international market access.

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supplementary material

The supplementary material for this article can be found online.

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Exploring the effect of digital finance on financial inclusion in Uganda, a reflection from Lira City

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Abstract

Purpose – The study aims to discuss financial inclusion (FI) as a facilitator of digital financing with intention of solving challenges relating to financial exclusion.

Design/methodology/approach – Both descriptive and correlation research designs were used to understand the nexus between digital finance (DF) and FI. The study collected data from 300 respondents, which included vendors and dealers in agricultural produce, who were selected purposively and randomly.

Findings – The study found a significant contribution of DF to FI and the variations in FI due to mobile money (MM) and Internet banking are significant. MM and smartphones are very often used in performing commercial transactions due to easy accessibility compared to ATMs, the Internet and agent banking, which is always restricted.

Research limitations/implications – The study only focused on how DF platform affect financial inclusiveness in Lira City and did not explore other financial services.

Social implications – The quickest and widest adoption of MM by rural communities is mostly a factor of user-friendliness, which seem to be lacking in other bank applications or products.

Originality/value – The study offers a significant insight on challenges related to the financial inclusiveness, which is a global concern by many economies.

Keywords Digital finance, Financial inclusion, Mobile Money transfer, Internet financial products, Branchless banking

Paper type Research paper

Introduction

Digital finance (DF) has been welcomed by the world economy as a catalyst for advancing a trustworthy and widely accessible financial system. A good number of the global population are financially excluded, and the potential of the economically excluded in rural areas can be unlocked through meaningful and reliable digital financial technology (DFT), thereby lowering their susceptibility to income shocks. Developing nations have embraced the use of



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digital technologies to provide their population with inclusive finance (World Bank, 2018). The stimulation of automation and computing would help enterprises to digitalize their financial services (FS), which would be advantageous for small business owners, the government and the economy (Badruddin, 2017). Globally, the creation of cutting-edge financial goods, such as mobile platforms, has gained popularity to increase financial inclusion (FI). According to Vidyashree and Rathod (2018), the application of DFT ensures accuracy, speed and efficiency in company processes and also demonstrates that the demand for technology and innovation in the banking industry is gaining increasingly urgent attention. According to Jungo, Madaleno, and Botelho (2021), most Sub-Saharan African populations are concentrated in a variety of geographical areas and share several common traits, social values and economic standing but are financially exclusive and at a relatively low degree of economic development, and specifically, the adults did not have access to FS and goods, according to Mukherjee and Sood (2020).

Despite all attempts to make FS and products more inexpensive and accessible for the general public, FI for the general public is still very low (Oumarou & Celestin, 2021). In their study on the macroeconomic effects on mobile money (MM) in Uganda, Mawejje and Lakuma (2019) revealed that it is still difficult to acquire affordable and high-quality FS and goods in the country's fiercely competitive and expanding economy. Although financial exclusion has been significantly reduced due to DF, there is still a huge gap to be closed before reaching worldwide FI (World Bank, 2018). Inclusive financing has been a burning issue in the developing economies and a major United Nations (UN) goal (Senyo, Karanasios, Gozman, & Baba, 2022). According to Kooli, Shanikat, and Kanakriyah (2022), the barriers to the original traditional financial system have continued to fall, resulting to a substantial increase in the FI that has been recognized as a trigger in achieving the 2030 SDGs (Allen, Demirguc-Kunt, Klapper, & Peria, 2016). According to The World Bank (2020), the four generic barriers that affect financial inclusivity can be identified to include demand factors, structural, institutional and educational, while no single structure can apply above all.

The global challenge facing FI has remained a priority for world economies, and Uganda is not an exception, where most citizens lack access to FS. The location and growth of Lira City in Northern Uganda offer an idiosyncratic situation for studying the effect of digital financial services (DFS) and its impact on the economy. The circumstance why DF has been seen as promoting FI has been unclear since local studies have overlooked its complexities. In spite of the existence of more DF platforms like digital banking and MM, inequalities in access to finances have continuously increased (Uganda Bureau of Statistics (UBOS), 2022). This study intends to address how these digital platforms have affected the access, quality and usage of FS among the vulnerable communities in Lira City. In rural areas, Northern Uganda and Lira City to be specific, the community has continued to suffer from the limited access to the banking services and DFS, resulting from the exorbitant cost in the technical support, maintenance and establishment of physical branches. This study would make a significant contribution in addressing MM services, digital payments, financial literacy on the digital financial platforms and education; especially if the widening gaps in the digital technologies are not fully addressed, the citizen would still remain financially excluded. The study explored the various DFS being adopted and also established the relationships between DF and FI in Uganda.

Literature review

Digital finance

According to Ozili (2018), “digital finance (DF)” is any good, service, infrastructure and technology that enables both businesses and individuals to access their credit, savings and/or payment facilities online without having to visit a bank branch to do so. According to Rasheed, Siddiqui, Mahmood, and Khan (2019), DFS presents a chance for enterprises to perform better by utilizing digital services at a cheaper cost. DFS would act as compliments to employed groups, educated and the wealthy as a substitute for those marginalized who could not easily

access the established and formal FS (Mothobi & Kebebotsamang, 2024). Customers' trust in online banking is growing, which is important for developing technology (Kaur, Ali, Hassan, & Al-Emran, 2021), and the same study highlights how slowly developing nations are progressing in contrast to wealthy economies in adopting digital technologies for their FS. The widespread acceptance of digital tools and mobile devices has raised individual FI rates (Bill & Melinda Gate Foundation, 2019).

To better protect consumers from the pervasive fraudsters, FI advocates and proponents of DFS should improve already existing digital consumer protection regulations on the mobile platform (Okello & Ntayi, 2020). Additionally, DF shields people and businesses from the risk of having fake money circulate in the community and enables them to receive payments as quickly as possible (Ozili, 2018). The interactions in digital networks would greatly improve the financial remittance with ease and accessibility. According to the IMF (2021a, b), the financial access survey revealed that DFS has a significant presence of ATMs and bank branches access points across the less-developed countries. By attracting various consumer demographics and most financial transactions, savings and mobile access to FS are significant drivers that demonstrate how much financial institutions care about the FI of the community (Thomas & Hedrick-Wong, 2019). Through the widespread usage of mobile phones, digital payment technologies (DPT) have improved financial accessibility for communities (Chu, 2018). The implementation of DPT has opened chances to combat terrorism and money laundering by allowing customers to apply data protection analysis and raising concerns about data privacy and consumer protection (Michaels & Homer, 2018). The current debate centers on digital financial inclusion, which has encouraged previously financially excluded people to engage in the financial system (Mhlanga, 2020).

Mobile money transfer (MM)

According to Murendo, Wollni, De Brauw, and Mugabi (2018), MM is a platform that is built on mobile devices that enables users to make financial transactions using their phones. Mobile users can receive money on their cell phones and send money online thanks to MM technology, which is an electronic wallet service. Peruta (2017) reveals that the MM platform intends to extend FS to the most underserved communities. According to Finscope's (2018) estimation, MM services are used by about 56% of the population who use formal FS, and these services have increased their wealth, economic growth and sustainability. The MM system provides the community with two services, is viewed as a driving force for FI and presents a financial opportunity for service providers and agents due to the developing market. The MM agents who participated in these transactions profited greatly in the unpoluted markets. IMF (2019) posits that most financial activities involving money transfers, credit payment accessibility and micro insurance are now more convenient. Senyo and Osabutey (2020) demonstrate how the advent of MM technology provides its customers with a range of services that are incredibly practical, affordable and available. By joining the wider digital network, MM platforms influence the social debt service provided by local communities, as demonstrated by Rodima-Taylor and Grimes (2019). In order to move their funds, the unorganized sector has joined this MM network in lowering the dangers and uncertainties involved in financial transactions.

Financial transfers can now be made through MM transactions, which are a practical and effective way that allows for a variety of services, including service fees, money transfers and microcredit availability (IMF, 2019). The regulatory framework and supportive infrastructure in a country play a key role in the adoption and acceleration of MM diffusion, and this would drive FI among the poor households at a low cost (Lashitew, Van Tulder, & Liasse, 2019). Wieser, Bruhn, Kinzinger, Ruckteschler, and Heitmann (2019) established that Ugandan households that are poorer have fewer MM networks, and this significantly impacts the financial inclusivity of the community. Considerably, the smallholder farmers have been encouraged to save using MM, and these have resulted in increased savings among the farmers

as long as they are guaranteed of interest in their savings (Bastista & Vicente, 2020). According to Bastian, Bianchi, Goldstein, and Montalvao (2018), in the study on female business owners in Tanzania, it was established that there were positive effects on MM saving that empowered women financially. MM services have reached quite a large population given that approximately 25% use bank accounts, and this indicates that MM transfers increase FI by 13% (Hamdan, Lehmann-Uschner, & Menkhoff, 2022). MM transfer has positively impacted FI, and this was moderated by the reinforcement of social networks among the community (Okello, Ntayi, Munene, & Malinga, 2018). These led to the development of the first hypothesis.

H1. MM has no statistical significant effect on FI.

Internet financial products

Yang, Yu, and Huang (2020) posit that Internet financial products provide Internet-based transactions and wealth management. These products promote social benefits and narrow the inequality space. The usage of MM stands at 27.9%, compared to Internet financial services at 6.6% (OECD, 2020) and 9% usage of Internet banking (IB) services among adults compared to the 7% of adults that used MM services in Lebanon. The reports focused on app-based banking, Internet and mobile banking (MB). Durai and Stella (2019) listed the FS promoted by the Internet, which include third-party payment, online lending, direct sales of funds, online insurance and banking, all of which cut down the cost of transactions and enhance the feasibility of transactions. There is a wide gap between those in the formal banks and those without and DFS would help bridge the existing gaps, specifically to the underserved areas that would enhance FI (The World Bank, 2020). According to Eton, Fabian, and Ejang (2022), financial institutions should require all bank customers to use IB.

The demand of FS has expanded and the financial institutions have also added value on their services that makes the Internet financial products to present a better network from the traditional products (Manser, Peltier, & Barger, 2021). The increased value addition and network effect would automatically scale up the use of internet FS in the market (Chen, Hu, & Ben, 2021). According to Kang and Yang (2023), Internet financial platforms and the basic services be improved and optimized to support the user loyalty. The expansion and gain in the adoption of digital financial products have contributed to increased financial literacy a cross Sub-Saharan Africa, and these have empowered clients in the making of financial decisions (McKinsey Global Institute, 2016). This led to the development of the second hypothesis.

H2. IB has no statistical significant effect on FI.

Branchless banking (BB)

Durai and Stella (2019) used the term “mobile banking,” while Haider (2018) used “mobile financing” to refer to branchless banking (BB). According to Haider (2018), BB also includes smart cards, point-of-sale devices and digital technology-based biometric identification cards. BB (agent banking) is one of the pioneering financial innovation in the new millennium (Chowdhury, 2018). The BB service allows clients to carry out cash-in and cash-out transactions through bank agents, ATMs, telecom agents and cash merchants (Digital Finance Service Indicators, 2019). The role of BB in Uganda is very crucial in the expansion of FS, and it has been established that by 2020, over 27 million Ugandans had registered MM accounts, which exceeded those with traditional bank accounts (The World Bank, 2020). ATMs and card networks promote cash withdrawals and payments outside the banking hall (Feyen, Frost, Gambacorta, Natarajan, & Saal, 2021). These services help customers to switch from one bank account to another without search costs, cutting down the marginal costs of opening bank accounts with multiple banks. When the banks invest in BB, it encourages FI, improves long-term profitability and payment rates of customers and enhances efficiency in productivity (Mohamed & Elgammal, 2024). The efficiency of BB is attributed to the ability in achieving a

huge or large number of transactions with a lower cost associated to the transactions, (Prior & Mora, 2019).

However, the penetration of BB network is higher in cities, municipalities and peri-urban centers, and substantial efforts should be made in increasing adequate number of agents in the rural areas and ensure their liquidity to meet the needs of the community (Berger, 2020). The dominance of MM transactions that account for over 50% of most transactions in Uganda has demonstrated that BB is really a dormant force on money transfer (Bank of Uganda, 2021). The adoption of digital borrowing and lending by the BB significantly improved financial empowerment for small business enterprises by providing financial inclusivity to those who access credit. The long distances of bank branches and absence of ATMs in the rural communities in Uganda have affected the livelihood of the individuals receiving the remittances, and this affects FI (Wieser *et al.*, 2019). There has been an attempt to increase the usage of electronic payments in all sectors of the economy, while there is limited evidence to substitute it away from cash (Bech, Faruqui, Ougaard, & Picillo, 2018). There is glaring evidence to show that BB is very significant for the financial inclusiveness of women who are faced with restrictions in mobility (World Bank Group, 2018). According to Ashraf (2022), the attitudes, norms and perceived behavior factors are positively significant in influencing the rural poor bounded by rational intention toward BB behavior. Considerably, Demirguc-kunt, Klapper, Singer, Jake, and Hess (2018) revealed that there seem to be fewer bank branches, and therefore, a significant proportion of the population do not have bank accounts, making financial transactions costlier in the remote and underserved areas and thus posing a challenge. These led to the development of the third hypothesis.

H3. BB has no statistically significant effect on FI

Challenges of digital finance

According to ADB (2016), the number of users of DF platforms has decreased due to a lack of knowledge about using these methods and illiteracy in financial channels. There were few incentives for low-income people, and customers are worried about the security of their finances to adopt DF. According to Aboagye and Anong (2020), to support the sustainability of the MM ecosystem, DF users faced several issues, including fraud and system hacking, infrastructural problems and consumer protection. According to Ketterer (2017), inadequate infrastructure and regulatory frameworks may be to blame for the high costs and poor quality of individual consumers' digital connectivity, which have a negative impact on their ability to access FS. Igoni, Onwumere, and Ogiri (2020) posit that security-related difficulties, insufficient digital infrastructures and subpar research are some of the problems hindering DF's expansion and development. According to Rasheed, Siddiqui, and Rahman (2018), the FS sector has been hesitant to adopt digital technology due to high transaction costs, limited network coverage and a lack of knowledge. Many financial institutions have started using DTs around the world, but this is hindering their operations because most clients, particularly in developing nations, are not yet digital (Alameda, 2020). The conventional financing options provided by the current banking system have not fulfilled their current obligations as anticipated and display several restrictive elements that have resulted in an inadequate supply of FS meant to address the problems faced by underprivileged citizens (Sapovadia, 2018). According to Aboagye and Anong's study in Ghana, the incorporation of MM appeared to be addictive for many users and had a transforming effect on those who had been first shut out of the formal financial system.

Financial inclusion (FI)

FI is described by the United Nations (2016) as a sustainable method of offering FS to the economically formal poor. An integrated FI index covering FI use, access and traditional interventions has been created by the IMF (2021a, b). FI is thought to promote access and

assignment of services delivered by the financial sector (Raichoudhury, 2020). Although the expansion of FS is a crucial objective for the world economy, The World Bank (2020) projects that two billion people remain unbanked and without access to formal financial institutions. According to Sharma, Khan, and Thoudam (2019), most of the world's poor people lack access to FS that could enable them to achieve their basic needs. According to Lenka and Barik (2018), financial institutions must give unbanked individuals access to FS that encourage economic expansion. The adoption is supported by providers of FS, including bank branches, ATMs, MM branches and bank branches. Financial service providers should encourage their clients to use affordable, secure and risk-averse DFS (Eton, Mwosi, Okello-Obura, Turyehewa, & Uwonda, 2021). Financial stability improves when people have access to savings and payment systems, whereas stability would deteriorate if more people had access to credit (Feghali, Mora, & Nassif, 2021).

Lacovou (2018) demonstrates that financial institutions are not just concerned with the community's FI through their ability to draw in a variety of customer demographics, but also with the attitudes of the public and their authorities. To expand excluded people's engagement in formal finance, policymakers, financial institutions and governments should encourage innovative solutions (Giron, Kazemikhasragh, Cicchiello, & Panetti, 2021). The same study's authors, Giron *et al.* (2021), make the case that policymakers should create new incentives for their fiscal policies so that least-developed countries can empower people who are not financially inclusive and provide them with access to income-generating opportunities. Musau, Muathe, and Mwangi (2018) opine that those financial institutions should create policies that guarantee their stability and competitiveness while considering the actions that guarantee FIs' stability in the financial sector.

Digital finance and financial inclusion

The three main advantages of digitizing FS are their accessibility, cost and product market compatibility (IFC, 2018). The advent of digital financial tools would enable unbanked customers to receive FS that might lead to FI (Chua, 2018). According to PSDU (2018), MM has mostly fueled FI in Uganda's economy, while GSMA (2017) reveals that those nations with greater cellphone penetration rates and limited FI see DF as the only way to end both financial and social exclusion. The organizations that offer FS such as insurance and credit institutions have benefited from the operation of MM, and these have hugely impacted FI (IMF, 2019). According to Ayyagari and Parahoo (2018), financial institutions have been developing new FS to suit the growing demand from their clients, which has resulted in the connection between banks and mobile phones. Lu, Wu, Li, and Nguyen (2021) opine that digital technology is making it possible for individuals to have better access to the FS offered by international banks by overcoming the traditional long-distance channels of information transmission. By decreasing paperwork, shortening lines in teller halls and enabling banks to reduce their branches and retain fewer employees, DF lowers the operating expenses of financial institutions (IFC, 2018).

DFT, like digital banking and MM, has expanded the financial reach among the population (Willige, 2023). According to Ahmad, Green, and Jiang (2020), DT supports financial transfers and payments that aid in the collection of user data that can be used to support credit history in financial lending. This viewpoint aligns with Senou, Ouattara, and Houensou's (2019) idea that the unique effects of mobile phone use and internet connectivity usage have a huge impact on FI in developing countries. Therefore, this justifies governments' increased efforts to encourage the accessibility, affordability and availability of FS that speed up FI. Isabwa (2021) states that the banking industry should construct suitable MB platforms to improve FI and give unbanked people access to FS that spur economic growth. According to Arnold and Gammage (2019), DFT and FI are not automated; thus, citizens must make a variety of parallel investments to maintain control over their income and savings. According to Lu *et al.* (2021), the policies and plans of many economies have resulted in banking system

reforms that have accelerated the transition to digital financial systems and have enabled the achievement of the FI aim. AFI (2018) demonstrates that adopting fintech technologies has excellent prospects for removing FI obstacles and bridging the utilization gap for bank accounts by leveraging the advantages of rising mobile technology usage. DFT would be an effective instrument to encourage FI among the financially excluded, but there should also be a program to alleviate the strict banking standards in the community. According to Ouma, Odongo and Were (2017), the growth of MB in rural areas is proof that MB has helped FI in developing nations like Sub-Saharan Africa. Mobile technology's ability to access credit has increased FI. This postulation is reinforced by Sinha and Hight (2017), who maintained that the use of mobile technology in developing nations fosters the development of an effective and efficient financial system that allows the financially excluded to participate in society.

MM has strengthened national and international efforts to increase FI among the rural poor despite running into numerous roadblocks that prevent it (Siano, Raimi, Palazzo, & Panait, 2020). Oumarou and Celestin (2021) posit that the population's precise use of MM services and distribution among them is a sign that they have adopted the proper digital financial access. According to Lyons, Kass-Hanna, Liu, Greenlee, and Zeng (2020), the chosen international FI plans would offer a variety of FS to the poor and vulnerable, helping them to create a more financially inclusive and resilient society. Due to the diverse social and economic backgrounds of users, FS providers and managers must create more products and services that improve FI through MM (Senyo, Osabutey, & Kan, 2020). There have been decreased associated financial expenses by financial institutions involved in supplying the FS and products, which has led to increase FI (Pham, Nguyen, & Nguyen, 2019).

Despite the factual evidence that indicates that DFS have the potential to address the persistent financial exclusion challenges in the developing economies, Grzybowski, Lindlacher, and Mothobi (2023) revealed that there has been less usage of MM in the areas that are less developed. According to Achugamoru, Alexander, Gershon, Ajibola, and Lawrence (2020), the usage of digital financial platforms has led to rural people being financially cut off from the official financial network, whereas according to Aker, Prina, and Welch (2020), the low adoption of MM in Niger drastically affected the FI of the community. Murendo *et al.* (2018) noted that the level of social networks has been a major factor that would affect the adoption of MM among households in Uganda, and this explains the gap in the financial inclusivity in the community. In the study conducted by Pelletier, Khavul, and Estrin (2020), it was established that if MM is used through the banking systems, it would yield a greater multiplier effect in the economy, thus improving the FI. According to Banna and Alam (2021), DFS brings stability in the banking sector. The DF platforms like MM and digital banking serve as a key financial access metric since the ownership marks a step toward financial mainstreaming (Shaikh, 2024).

The existence and entry points to mobile access to digital platforms offer a groundbreaking chance to advance financial access that enables more people to participate actively in the economy (World Bank, 2023). In improving the social network, the Bank of Uganda (2023) focused more on the reduction of financial exclusivity specifically to the formal financial service provider while broadening the quality and usage of formal financial products. According to Okello, Ntayi, Munene, and Akol (2017), social networks play a partial mediation relationship between financial intermediation and FI of the rural poor household in Uganda. Eton, Odubuker, Ejang, Ogwel and Mwosi (2019) established that the strides to promote financial accessibility are highly commendable, whereas Nagaaba, Batamuriza, Basuta, and Owomugisha (2025) revealed that financial institutions, funding interventions and the Government of Uganda need to embrace the appropriate FS that can be afforded by the vulnerable poor.

Methodology

The study adopted both descriptive and correlation research designs to understand the nexus between DF and FI. A descriptive design is a study design that describes and summarizes the populations and situations characteristics, while correlation design is used to examine the relationship between two or more variables under study. The choice of the descriptive design was driven by the need to understand the adoption of DF among the market vendors and dealers in agricultural products, who sell to and buy from the low-income subpopulation. The choice of the correlation design was driven by the need to understand any existing causal relationships between the dimensions of DF and FI. This study was conducted among market vendors and dealers in agricultural produce in Lira City East and Lira City West divisions. The choice of market vendors and dealers in agricultural products was driven by the nature of the businesses and the clientele customer-supplier population.

The study collected data from 180 vendors and 120 dealers in agricultural produce, who were selected purposively and randomly. Purposive sampling was adopted because it would support in-depth insights, and the respondents were relevant and were experts in the specific business under study, since they had knowledge as market vendors and produce dealers. It was also cost-effective because they were easily accessible. Additionally, adopting random sampling would eliminate sampling bias, enabling everyone within the study group to have an equal chance of participating in the study, and generalization of the findings would allow for inference to the bigger population. The key produce dealers in two city divisions were identified based on their sizes from large, medium to small and the types of the agricultural produce they were dealing in and location. A comprehensive list was generated from the target group from their association leaders, and this list helped the researchers to randomly chose the respondents without bias. The reason for the choice of both sampling techniques was to generate more understanding about the market vendors and produce dealer experiences if DF has any impact on FI.

Data analysis was both descriptive and inferential; descriptively, the study used counts and percentages to portray the use of DF. Descriptive statistics supported the study in summarizing the data and also enabled the researcher to identify patterns, while the inferential statistics helped in making references, testing hypotheses and generalization of results. Inferentially, the study used hierarchical multiple regression to measure the causal relationships of DF dimensions on FI. Hierarchical multiple regression was used to examine the relationships between the independent variable and a single dependent variable. The adoption of hierarchical multiple regression was driven by the need to measure the variation in FI due to clients' characteristics, which covertly affect FI.

Results and discussion

From gender participation, 59.1% of the participants were men and were the majority, whereas 40.9% were women. Age distribution indicates that 41.9% fell in the 31 to 40 years' age group and constituted the majority. Marital status participation indicates that 60.7% were married and included the majority. In terms of education, 40.6% of the participants were educated beyond high school and constituted the majority. The variations in the use of different channels in performing financial transactions are summarized in Table 1.

Table 1. Channels used to perform financial transactions

Variable list	Never	Often	Very often	Total
1. Internet	21.8%	41.9%	36.4%	100.0%
2. Mobile money	26.3%	18.2%	55.5%	100.0%
3. ATMs	29.9%	30.8%	39.3%	100.0%
4. Smart phone	32.8%	16.2%	51.0%	100.0%
5. Agent banking	58.1%	20.5%	21.4%	100.0%

Source(s): Field data, 2024. Authors' own work

The findings on the use of digital channels to perform financial transactions indicate that 55.5% very often use MM, 51.0% very often use smartphones, 39.3% very often use ATMs and 36.4% very often use the Internet. Generally, the percentage of participants who very often use digital channels to perform financial transactions ranged from 21.4 to 55.5%, with agent banking at the lowest extreme. Besides MM, there is some evidence that smartphones are very often used in performing financial transactions. The frequent use of MM can be attributed to no restriction of operational times, convenience, minimal impact by Internet connectivity, most shops accept payments through mobile money application (MOMO) app and MM transfers and accessibility of the agents, among others. On the other hand, the low usage of agent banking in performing financial transactions can be attributed to low trust in the communities. The lack of trust is attributed to several factors such as inaccessibility due to distance, restricted operational times due to security issues and over-controlled by the Bank of Uganda.

This study used hierarchical multiple regression to understand whether FI in Uganda is facilitated by digital financing (MM, IB, and BB). Before running the hierarchical regression, normality and linearity tests were conducted, as presented in Table 2.

The study used the Analysis of Variation (ANOVA) to test the suitability of the model, as presented in Table 3.

The ANOVA indicated by $F(4, 303) = 22.054; p < 0.05$ shows that the model is a good fit for the data. Table 4 shows the hierarchical model for FI. R^2 is the change in FI explained by the predictor variables. R^2 change is the extra change in FI when clients' characteristics are introduced in the model. B represents the unstandardized coefficients, while Beta represents the standardized coefficients when all the variables are expressed in comparable units, as shown in Table 4.

The hierarchical model was used since it helps in improving prediction and the identification of key predictor, and in this case, three predictor variables were entered: MM, IB and BB. The model was statistically significant $F(3, 304) = 16.826$ and $p < 0.01$, explaining 13% of the variations in FI. These statistics indicate that all three DF products significantly contributed to the model.

When clients' characteristics were introduced at Step 2, the total variation explained by the model was about 22%, i.e. $F(4, 303) = 22.054; p < 0.01$. The introduction of clients' characteristics in the model explained an additional 9% of the variations in FI after controlling for MM, IB and BB (R^2 Change = 9%, $F(1, 303) = 32.505; p < 0.05$). In the final model, three

Table 2. Correlations, descriptive statistics and reliability and ($N = 308$)

Variable list	FI	CC	MM	IB	BB
Financial inclusion (FI)	1				
Client characteristics (CC)	0.360**	1			
Mobile money (MM)	0.350**	0.231**	1		
Internet banking (IB)	0.279**	0.099	0.437**	1	
Branchless banking (BB)	0.119*	-0.031	0.169**	0.422**	1
Range	2.83	3.40	3.67	3.40	3.00
Mean	3.7493	3.5610	3.7219	3.6922	4.2162
Std. deviation	0.61546	0.76267	0.92196	0.66052	0.68192
Cronbach alpha	0.691	0.606	0.724	0.539	0.773

Note(s): Statistical significance: * $p < 0.05$ and ** $p < 0.01$

The correlations among the predictor variables (clients' characteristics, mobile money, internet banking, and branchless banking) were weak to moderately strong, ranging from ($r = -0.031; p < 0.05$) to ($r = 0.422; p < 0.05$). These correlations suggest that the data had no problem with multicollinearity

Secondly, clients' characteristics, mobile money, internet banking, and branchless banking were statistically associated with financial inclusion, ranging from ($r = 0.119; p < 0.05$) to ($r = 0.360; p < 0.05$). The statistics suggest that the data are reliable if used to run a multiple regression

Source(s): Authors' own work

Table 3. ANOVA^a

Model		Sum of squares	Df	Mean square	F	Sig.
1	Regression	16.560	3	5.520	16.826	0.000 ^b
	Residual	99.728	304	0.328		
	Total	116.288	307			
2	Regression	26.222	4	6.555	22.054	0.000 ^c
	Residual	90.066	303	0.297		
	Total	116.288	307			

Note(s): a. Dependent variable: financial inclusion

b. Predictors: (constant), branchless banking, mobile money and Internet banking

c. Predictors: (constant), branchless b, mobile money, Internet banking and client characteristics

Source(s): Authors' own work**Table 4.** Hierarchical regression model for financial inclusion

	R	R ²	R ² change	B	Standard for Error (SE)	Beta	t	p-value
Step 1	0.360	0.129**						
Mobile money				0.188	0.039	0.282	4.782	0.000
Internet banking				0.143	0.060	0.153	2.387	0.018
Branchless banking				0.006	0.053	0.006	0.104	0.917
Step 2	0.466	0.217**	0.087**	1.753	0.262		6.684	0.000
Mobile money				0.143	0.038	0.214	3.722	0.000
Internet banking				0.133	0.057	0.143	2.340	0.020
Branchless banking				0.028	0.051	0.031	0.557	0.578
Client characteristics				0.240	0.042	0.297	5.701	0.000

Note(s): Statistical significance: * $p < 0.05$ and ** $p < 0.01$

Dependent: Financial inclusion

Source(s): Authors' own work

predictor variables appeared to be statistically significant in explaining variations in FI. Clients' characteristics explain the highest value (Beta = 0.30; $p < 0.05$) compared to MM (Beta = 0.21; $p < 0.05$) and IB (Beta = 0.14; $p < 0.05$). Apparently, BB ($p > 0.05$) does not have a significant contribution in FI.

Discussion

The dominance of MM as the very often used financial service agrees with Finscope (2018), which estimated that around 56% of the population accessing formal FS use MM services. In Uganda, MM takes precedence over other forms of DF because of its convenience and accessibility. Consistently, the findings agree with IMF (2019) and Senyo and Osabutey (2020), who commend the importance of MM in money transfers, debt settlement and micro insurance. In Uganda, the population owning MM accounts outweighs the one owning formal bank accounts, a view that coincides with Rodima-Taylor and Grimes (2019). While MM is cherished by all population categories, it has highly facilitated the inclusion of the unbanked population. The informal sector has joined this network to transfer their finances, reducing the risks and uncertainties associated with money transactions. Besides MM, Internet banks significantly influence FI by narrowing the inequality space. This feeds into Yang *et al.* (2020) and OECD's (2020) revelation about the steady rise in app-based banking and the Internet. While the literature provides numerous examples of app-based banking such as third-party payment, online lending, direct sales of funds, online insurance and banking (Durai & Stella, 2019), there

are several examples in Uganda, which may include cash advance, prepared cards and MOMO MM transfer for MTN. This study has established that BB is the least dominant in influencing FI. BB in Uganda favors the elite class compared to the illiterate, who constitute the majority of Uganda's unbanked population. Besides, branchless banking helps customers to switch from one bank to another without physically presenting themselves in the banking hall (Haider, 2018; Digital Finance Service Indicators, 2019; Feyen *et al.*, 2021). Several studies have documented the significant effects of DF on FI (see, for example, Senou *et al.*, 2019; Lu *et al.*, 2021; AFI, 2018; Sinha & Hight, 2017; Ouma *et al.*, 2017; PSDU, 2018; GSMA, 2018). Specifically, Private Sector Development Uganda (PSDU) and Group special mobile association (GMSA), which focused on Uganda, confirm that the application of DF allows unbanked customers to access FS, thereby reducing financial and social exclusion. The aggregate contribution of MM and IB is strongly supported by Senou *et al.* (2019), who conclude that Internet connectivity usage and mobile phone proliferation have a very significant impact on FI in developing countries. Like in the rest of the world, the penetration of Internet connectivity in the banking sector is highly proliferated by customers' characteristics such as level of education, acquaintance with digital technologies, location and income level, though in rare cases. Income may thwart some people from securing smartphones, which run most of banking apps. The arguments championed in existing literature (Arnold & Gammage, 2019; Achugamou *et al.*, 2020; Lyons *et al.*, 2020; AFI, 2018) are that for developing countries to meet the target of FI, the barriers to increased use of mobile technology should be broken to bring the rural community on board, which remains relevant.

Conclusion and policy implications

The search for knowledge in the DFS and FI has attracted wide attention among scholars globally. Despite the influence of DFS in enhancing financial inclusivity among the community, empirical studies on the role of BB have been scanty. The study has found a significant contribution of DF service to FI in Lira City, Uganda. MM and smartphones are very often used in performing commercial transactions compared to ATMs, IB and agent banking. The variations in the usage of these financial products can be explained more from the perspective of acquaintance and then convenience and cost. One would also argue from the point of accessibility that the majority of citizens have smartphones rather than bank accounts, and this makes it easier to use a phone than go to the bank. The variations in FI due to MM and IB are significant; however, clients' characteristics are responsible for additional variations in FI. In the context of the unbanked population in Lira City, this study provides evidence that whereas clients' characteristics are not a financial product or a channel of financial transaction, they are essential in promoting FI. From a banking perspective, most bank application developers would argue for the convenience and use friendliness of these applications. However, the quickest and widest adoption of MM by the rural communities of Uganda is mostly a factor of user-friendliness, which seems to be lacking in other bank applications or products. If the current unbanked population is to be financially included, the new application should address the basic financial needs of the unbanked population. From a policy perspective, the government, through the Ministry of Finance, should sponsor the development of cost-free and user-friendly bank applications to attract the unbanked population. The government should also develop policies that would protect the privacy of the users of MM or DFS. Adequate infrastructure that supports the information technology should be enhanced to address the network issues that affect the transaction process or delays in remitting money once the transaction has been done. The findings also confirm the importance of digital infrastructures in the improvement of quality services and enhanced FI.

Research contribution

The DFS practitioners should be cognizant that they should be able to be competitive in the current digital world since the world is now being driven by information and communication

technology. The rise in digital revolution has created new way of doing business among the digital service providers, and for any business dealing in financial service, digitalization of their products is the way to go. The largest gains in competitiveness come from uneven access to information and digital financing would play a cardinal role in making access to finance much easier for economic growth of a country. The study dynamic would provide also some significant revelations on efficacy of DF as catalyst for access to finance. The service providers would benefit from the digital payments since it enabled clients to make secure and easy payments of goods and services at a reduced cost. Digitalization of FS has improved financial literacy and education both to the clients and service providers.

Limitations of the study

In our opinion, the category of respondents was not exhaustive enough for the study; however, we could have adopted a much wider category of respondents to enable a comprehensive analysis that would help us generalize our findings. The study could have also adopted a theory or theoretical framework that would have assessed the effect of DFS on FI. The study was done in Lira City, and generalizing the findings would be a challenge. Therefore, we recommend that future researchers should focus on these challenges and replicate the study in other regions to establish how DFS would affect FI.

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