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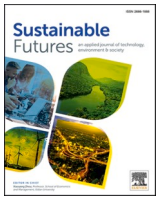

# Determinants of technology adoption in small and medium-sized enterprises

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ABSTRACT

Small and medium-sized enterprises (SMEs) are critical to economic growth, yet their adoption of technology remains a significant challenge in many developing economies. This study investigates the factors influencing technology adoption among SMEs in Namibia, a context often underrepresented in mainstream innovation literature. Drawing on the Technology–Organization–Environment (TOE) framework, the research uniquely tests the mediating role of entrepreneurship education in the technology adoption process. A mixed methods design was adopted, combining survey responses from 97 SME owners/managers in Windhoek with qualitative insights gathered through open-ended questions. Quantitative analysis using PLS-SEM revealed that organizational factors, such as managerial support and internal capabilities and environmental factors, including external support and competitive pressure, showed statistically significant positive effects on technology adoption. Conversely, technological factors such as cost, complexity, and perceived incompatibility showed a negative and statistically insignificant relationship, but qualitative findings highlighted their practical importance as key barriers in the Namibian context. Mediation analysis showed that entrepreneurship education did not mediate the relationship between TOE factors and technology adoption, likely due to limited practical applicability and contextual alignment of current education programs. This study makes a dual contribution to literature by demonstrating how contextual constraints can moderate the relevance of established adoption frameworks in developing economies and by offering integrated insights to inform policy and SME support programs.

## 1. Introduction

In recent years, the adoption of digital technologies by small and medium-sized enterprises (SMEs) has become a central driver of productivity, competitiveness, and sustainability, especially in developing economies [1–5]. SMEs play a vital role in job creation, poverty reduction, and economic diversification. In Sub-Saharan Africa, they constitute >90 % of the private sector and generate the bulk of employment opportunities [6,7]. Despite growing global interest in SME digital transformation, limited research addresses how firms in lower-income contexts respond to technology adoption pressures and constraints [8].

In Namibia, SMEs contribute approximately 12 % of gross domestic product and employ around 20 % of the national labor force [9]. However, these firms operate under persistent constraints, including limited digital infrastructure, high technology and utility costs, unreliable electricity, insufficient ICT skills, and underdeveloped institutional support systems [10,11]. These conditions reduce SMEs' innovation capacity and hinder their ability to compete in an increasingly digitized marketplace.

While government initiatives such as the MSME Policy and the Fifth National Development Plan [12] have sought to improve SME performance through grants, infrastructure investments, and skills development, the results have been uneven and fragmented. Barriers like limited

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market access, expensive commercial property, weak internal management, and competition from foreign firms further exacerbate the operational difficulties of SMEs in Namibia [10,13]. Consequently, many of these enterprises fail within their first five years of operation [11].

Extant literature widely acknowledges that technology adoption can enhance SME performance by improving innovation, communication, production efficiency, and market reach [1,14–16]. For example, mobile and e-commerce technologies have helped firms streamline marketing efforts, reduce transaction costs, and increase competitiveness in digital marketplaces [17,18]. Yet, in Namibia, research specifically focused on the determinants of SME technology adoption remains scarce. This absence underscores the need for empirical inquiry into the context-specific enablers and inhibitors shaping digital transitions in underdeveloped entrepreneurial ecosystems.

Although several international studies use frameworks like the Technology Acceptance Model (TAM) and the Diffusion of Innovation (DOI) theory to explain adoption behavior, these approaches often overlook critical external influences such as regulatory environments, infrastructure limitations, and institutional fragmentation, all of which are highly relevant in the Namibian context. The Technology–Organization–Environment (TOE) framework [19] provides a more comprehensive model by encompassing internal firm capabilities, technological readiness, and external environmental pressures.

This study applies the TOE framework to examine technology adoption among Namibian SMEs and further explores the mediating role of entrepreneurship education, a variable frequently promoted in African policy discourse but under-investigated in empirical research. While entrepreneurship education is widely believed to strengthen entrepreneurial behavior and innovation capacity [20], its influence on digital technology adoption within SMEs, especially in resource-constrained environments, has not been adequately tested.

Namibia offers a particularly compelling empirical setting for this investigation. Compared to other countries like South Africa, Malaysia, or Nigeria, Namibia's entrepreneurial infrastructure remains relatively underdeveloped, and public-private collaboration is often limited in scope and scale [10,21]. SMEs operate under structural and institutional constraints that make technology adoption both necessary and difficult. These unique features present an opportunity to test the assumptions and boundaries of the TOE model in a high-need, low-support environment. This study aims to address the following research objectives: first, to examine the technological, organizational, and environmental factors affecting technology adoption among SMEs in Namibia. Second, to determine whether entrepreneurship education mediates the relationship between TOE dimensions and technology adoption. Finally, to explore the contextual challenges SMEs face in adopting digital technologies.

Although the global relevance of technology adoption frameworks is well recognized, there remains a shortage of localized evidence from countries like Namibia. Most prior research has concentrated on middle- and high-income economies with relatively advanced infrastructure and policy frameworks. Moreover, few studies examine entrepreneurship education as a mediating mechanism in the TOE model. This study fills three specific research gaps - an empirical gap regarding adoption determinants in Namibia, a contextual gap in TOE's application to low-resource environments, and a theoretical extension gap in understanding the interaction between entrepreneurship education and technology adoption. In doing so, it contributes both to academic theory and to practical policy dialogue around SME development in emerging economies.

## 2. Literature review

### 2.1. Theoretical foundations of the study

The Technology-Organization-Environment (TOE) framework developed by Tornatzky et al. [19] is widely used in analyzing technology adoption behavior in firms. It integrates internal (technological and organizational) and external (environmental) factors. While the TOE framework has been validated across multiple contexts, most empirical applications are situated in developed or emerging economies with stable infrastructure and institutional environments [1,4,22]. This limits the framework's generalizability to resource-constrained contexts like Namibia, where informal structures and weak institutional support influence adoption dynamics. Technology adoption also depends on innovation and knowledge management and sharing across systems, especially in weak institutional support contexts [23–25]. The TOE framework is a mature and well-recognized model for predicting a company's propensity to embrace information technology [26,27]. Thus, the TOE framework is suitable for assessing the elements that influence a company's choice to adopt new technological breakthroughs since it encompasses the business's technical, organizational, and environmental aspects [28]. Previous research [1,4,5,22,26,28–32] have also used the Technology-Organization-Environment (TOE) framework to investigate the technology adoption process. Prior studies have not sufficiently addressed this contextual limitation [27,33]. This study fills this gap by empirically validating the TOE framework in the Namibian SME sector.

#### 2.1.1. Technological factors

Diverse theoretical frameworks consider technology a critical determinant influencing the adoption of new technological innovations [5]. The technical context refers to the feasibility and importance of technological progress, while the organizational context relates to the capabilities and framework of the decision-making process within the company [1,4]. The concept encompasses internal components that have the potential to influence both current and future information technology (IT) systems [34]. The technical aspects under investigation in this research were the perceived utility, simplicity of use, compatibility, cost, market transparency, and security of the technology [5,16,32,35,36]. Existing research typically reports a positive relationship between technological characteristics such as ease of use, compatibility, and relative advantage, and adoption [5,31]. However, findings from Sub-Saharan African settings are mixed. For instance, Bettoni et al. [37] and Stieglitz et al. [38] highlight barriers such as limited technological literacy, infrastructure, and cost-related concerns. These inconsistencies suggest the need for localized investigation. The current study evaluates whether these factors exert the same influence in Namibia, where digital infrastructure and affordability remain key issues [10].

#### 2.1.2. Organisational factors

Internal elements within an organization making up the organizational context include top management support, previous IT experience, information intensity, innovativeness, organizational size, and preparedness [5,39–42]. Within the scope of this study, these elements include supportive management, organizational structure, adaptability in organizational culture, and financial resources [1,27,29,30,32,35]. Although organizational readiness and leadership support have been found to facilitate technology adoption [30,40], many studies do not consider the managerial capacity constraints common in African SMEs.

#### 2.1.3. Environmental factors

The environmental context clarifies the interplay between competitive environmental issues and the zeal of industries, markets, and the regulatory framework [5,34]. These elements include external support (from the government, private sector, international donors, and other external stakeholders), competition pressure, and the industry cluster [4,26,31,32,35,43,44]. While external pressure and support are often associated with increased adoption [35], empirical evidence across African countries shows varied results. For example, Ta and Lin [5] report a strong influence of environmental support in Vietnam, but Bhardwaj et al. [30] find no significant relationship in India. This inconsistency constitutes what Miles [45] identifies as a "contradictory evidence gap."

This study responds to this gap by exploring how environmental factors operate under Namibia's regulatory and support structures.

### 2.2. Entrepreneurship education

Anwar et al. [20] identified entrepreneurship education as a critical factor in predicting entrepreneurial inclination. The objective is to provide students with the knowledge and skills to promote entrepreneurial success in various educational settings, including elementary and secondary classrooms as well as graduate university programs [20,46–48]. Hence, this research used entrepreneurship education to mediate the relationship between the TOE framework and technology adoption in SMEs.

### 2.3. Research model and hypothesis development

#### 2.3.1. Technological factors and technology adoption

Technological factors represent the perceived characteristics of a technology that influence its adoption, such as relative advantage, compatibility, complexity, and cost [32,35]. In SMEs, where resources are limited, the perceived utility and simplicity of technologies are critical enablers of adoption [1,4]. The TOE framework identifies the technological context as a core determinant of innovation adoption. Thus, it is hypothesized that:

**H1**. ***Technological factors positively impact technology adoption in Namibian SMEs.***

#### 2.3.2. Organizational factors and technology adoption

Organisational factors include the firm's size, leadership commitment, available skills, and internal readiness for change [39,40]. According to the TOE framework, these internal conditions shape how an SME evaluates, implements, and supports technological innovations. Previous studies confirm that managerial support and a culture of innovation strongly predict adoption outcomes [29,30]. Therefore:

**H2**. ***Organisational factors positively affect technology adoption in Namibian SMEs***

#### 2.3.3. Environmental factors and technology adoption

Ta and Lin [5] indicate that environmental factors are the most crucial determinant in pairwise comparisons of the hierarchical structure for technology adoption in Vietnam's small and medium-sized enterprises (SMEs). According to Bag et al. [1], technology adoption is enhanced by favorable environmental variables such as competitive pressure, external assistance, and regulatory and legislative considerations. This conclusion aligns with the results reported by Eze, Chinedu-Eze, et al. [29] in Nigeria. Prause [35] identifies market unpredictability and intense rivalry as primary drivers for technology adoption in Japanese SMEs. In contrast, Low et al. [31] reveal that environmental variables do not have a beneficial effect on the ability of SMEs in Malaysia to embrace technology. Similarly, Bhardwaj et al. [30] provide evidence that security concerns and external help have little impact on adopting technology in Indian SMEs. The environmental context includes industry pressure, regulatory frameworks, and support from external institutions [5,31]. The TOE framework emphasizes that external stimuli, such as government policies and market competitiveness, can act as push or pull factors in adoption decisions. In resource-constrained environments, external support often compensates for internal capability gaps [43]. Hence:

**H3**. ***Environmental factors positively impact technology adoption in Namibian SMEs***

#### 2.3.4. Mediating role of entrepreneurship education on TOE and technology adoption

Entrepreneurship education often enhances an individual's entrepreneurial self-efficacy [49]. In Ethiopia, the choice of enterprises to use technology is favorably influenced by the degree of education [50]. The paucity of studies evaluating the mediating function of entrepreneurship education on the TOE framework and technology adoption indicates a theoretical extension gap, as defined by Miles [45] in the notion of research gaps. Entrepreneurship education enhances the knowledge, skills, and confidence needed to recognise and exploit technological opportunities [20,48]. While TOE explains the context of adoption, entrepreneurship education may serve as a behavioural and cognitive mechanism linking those contexts to actual adoption decisions. However, few studies have empirically tested this mediating role, particularly in SMEs in developing countries, highlighting a gap that this study addresses. Thus, we propose:

**H4a**. ***Entrepreneurship education mediates the relationship between technological factors and technology adoption in Namibian SMEs***

**H4b**. ***Entrepreneurship education mediates the relationship between organizational factors and technology adoption in Namibian SMEs***

**H4c**. ***Entrepreneurship education mediates the relationship between environmental factors and technology adoption in Namibian SMEs***

### 2.4. Challenges of technology adoption in SMEs

Obstacles associated with implementing new technologies in SMEs have been extensively studied worldwide. On a global scale, Vrontis et al. [7] unveil challenges related to limited knowledge and resources for technology in Malaysian SMEs. Other studies [8,50] underscore the challenges of inefficient frameworks, strategies, tools, and high competition. Stieglitz et al. [38] highlight the recruitment of novice personnel and inadequate training for current staff to enhance their skill sets. Jere and Ngidi [27] unveil a dearth of governmental representatives and policy as the challenges facing SMEs in adopting technology.

From the African perspective, Bettoni et al. (2021) reveal limited data, a scarcity of artificial intelligence, assessment methods, scant customized solutions, inadequate skills, and technology complexity. In addition, Mokwena and Hlebela [33] unveil integration issues, the absence of open standards, and perceived security concerns. In Namibia, the literature presents scant evidence regarding the challenges facing SMES in adopting technology, which indicates an empirical gap concerning the taxonomy of Miles [45] on research gaps.

### 2.5. Research model

In Fig. 1, the research model is shown. The model posits that technological factors have a direct influence on the adoption of technology, as shown by relevant research [1,27,29,31]. The research confirmed this correlation by empirically examining hypothesis 1 (H1). In addition, the model includes the assumption that organizational factors have a direct impact on the adoption of technology in small and medium-sized enterprises (SMEs), as supported by existing research [1,29–31,35,40]. To establish the validity of this correlation, the research examined hypothesis 2 (H2). The model demonstrates a clear influence of environmental variables on the adoption of technology, as supported by existing research [1,5,26,35], which was confirmed in this study by testing hypothesis 3 (H3). The model's premise posits that entrepreneurial education mediates the linkage between the TOE framework and technology adoption. The study validated the indirect effects by testing hypotheses 4a, 4b, and 4c (H4a, H4b, H4c) through hypothesis 4d (H4d).

## 3. Methodology

### 3.1. Research design

This study adopted a concurrent explanatory mixed methods design

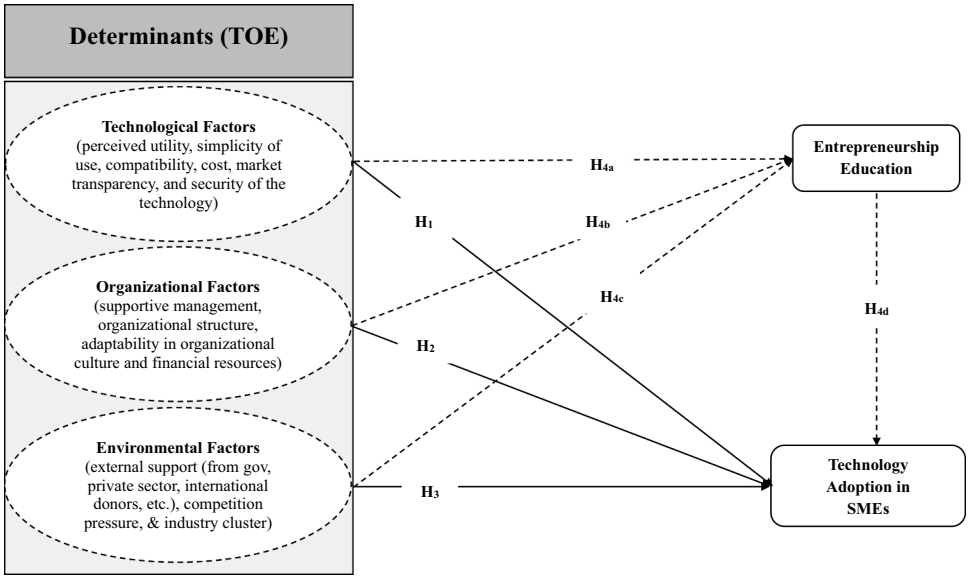


**Fig. 1.** Research model.
Source: Authors' construction (2024).

based on the pragmatist paradigm [51], allowing the integration of both quantitative and qualitative data to better address the multidimensional nature of technology adoption in Namibian SMEs. The quantitative approach was used to test relationships between the TOE constructs and technology adoption, while the qualitative component provided explanatory depth and contextual richness, particularly to interpret unexpected or non-significant statistical results (e.g., the lack of influence from technological factors and the mediating role of entrepreneurship education). This dual approach strengthened the validity of the findings and supported a more nuanced understanding of both internal and external challenges faced by SMEs in adopting technology.

### 3.2. Measurement of constructs

This study employed a reflective measurement model in the operationalisation of the latent constructs as shown in Fig. 1. The established literature was used to extract the adapt indicators for each construct to ensure content and construct validity. A five-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree) was used for the respondents to indicate their level of agreement with a series of statements corresponding to each indicator.

#### 3.2.1. Technological factors

Technological factors were operationalised to assess the perceived technology attributes influencing SME adoption. The scale, adapted from Ming et al. [32] and Prause [35], measured six dimensions: perceived utility, simplicity of use, compatibility, cost, market transparency, and the security of the technology, a concern noted by Bhardwaj et al. [30]. The scale exhibited strong internal consistency with a Cronbach's alpha of 0.90.

#### 3.2.2. Organisational factors

Drawing from Asa et al. [39] and, Clohessy and Acton [40], this construct measured internal firm characteristics shaping innovative capacity. The scale evaluated four key dimensions: supportive management, a flexible organisational structure, adaptability in organisational culture, and the availability of financial resources. This scale exhibited adequate reliability with a Cronbach's alpha of 0.85.

#### 3.2.3. Environmental factors

Environmental factors were measured using indicators of external pressures and support systems, based on Ta and Lin [5] and Bag et al. [1]. The items captured the influence of three dimensions: the availability of external support [43], the degree of competition pressure and the normative influence of the firm's industry cluster [35]. The environmental factors scale showed good internal consistency (Cronbach's alpha = 0.85).

#### 3.2.4. Entrepreneurial education

As the mediating variable, entrepreneurial education was operationalised based on the work of Anwar et al. [20] and Nowiński et al. [48]. The scale assessed the perceived impact of education on an entrepreneur's competencies, including their technology-related knowledge and skills, their confidence and self-efficacy [49], and their ability for opportunity recognition. The scale's reliability was confirmed with a Cronbach's alpha of 0.84.

#### 3.2.5. Technology adoption

The dependent variable, technology adoption, was measured as the strategic integration of technology, with a scale adapted from Bag et al. [1] and Leong et al. [4]. The indicators assessed the depth and breadth of technology use for enhancing operational efficiency, improving products and services, and strengthening the SME's competitive position. The scale demonstrated high internal consistency (Cronbach's alpha = 0.86).

### 3.3. Data collection procedures

The research used a structured online questionnaire designed in Google Forms to gather data. The questionnaire consisted of closed-ended questions for the quantitative component of the study and open-ended questions for the qualitative component. Specifically, the first section of the questionnaire covers demographic characteristics. This was succeeded by sections focused on gathering data on technological, organizational, environmental, and technology adoption factors, which were obtained from previous research conducted by Abbad et al. [43], Buli & Yesuf [52], Fadeyi et al. [53], Ghobakhloo et al. [54], Kademeteme & Twinomurinzi [55], Kyakulumbye & Pather [56], Leong et al. [4], Muzari et al. [57], and Selase et al. [16]. The third segment explored entrepreneurial education by building upon the hypotheses of previous research conducted by Chowdhury and Alam [58], Nowiński et al. [48], and Reyad et al. [59]. The sample comprised 97 SME owners

and managers based in Windhoek, Namibia's capital and main commercial hub. Participants were selected using a non-probability purposive sampling method, which is widely used in exploratory SME research [54,56]. The sampling frame included SMEs formally registered with the Ministry of Industrialisation and Trade and those affiliated with local SME support organizations. Although the sample size of 97 is within acceptable bounds for PLS-SEM analysis [60], it is considered relatively small in relation to the national SME population. Hence, this limits the generalizability of findings beyond Windhoek.

For the qualitative component, data was collected through open-ended questions embedded in the same online questionnaire used for the quantitative survey. Respondents were SME owners and managers who voluntarily provided detailed responses to open-ended prompts focused on the barriers to technology adoption. To enhance the credibility and trustworthiness of qualitative data, the study followed the criteria of Nowell et al. [61]: responses were analysed through reflexive thematic analysis, codes were iteratively refined, and cross-validation was conducted by two researchers to ensure consistency in theme development. The questions were influenced by previous studies conducted by Costa and Castro [18], Eze, Chinedu-Eze et al. [29], Kyakulumbye and Pather [56], and Smidt and Jokonya [62].

The survey was designed to mitigate potential social desirability bias by ensuring respondent anonymity and confidentiality. Respondents were informed that their responses would be used exclusively for academic purposes and that no identifying information would be collected or disclosed. The questionnaire items were carefully phrased in a neutral and non-judgmental manner to minimize response bias. Despite these safeguards, the potential for self-report bias cannot be completely eliminated in research.

### 3.4. Ethical approval statement

Ethical clearance for the study was granted by the Namibian-German Institute for Logistics (NGIL) under the Namibia University of Science and Technology (NUST), and an official approval letter was issued to authorize the research.

### 3.5. Data analysis

Descriptive analysis and partial least squares structural equation modeling (PLS-SEM) were used to evaluate the quantitative data in SmartPLS 4 software. The use of PLS-SEM arises from its capacity to adequately address non-normality in the analysis of complex models [63]. Ultimately, the research used Cronbach's alpha and composite reliability and validity measures to establish the dependability of the convergent and discriminant validity. The research used reflexive thematic analysis in ATLAS.ti to analyze the qualitative component. From this perspective, the research guaranteed reliability regarding its credibility, transferability, dependability, and confirmability [61].

## 4. Results of the study

### 4.1. Demographic results

Table 1 shows the profile description for the surveyed SMEs. The table illustrates that among the 97 respondents, 57.73 % represent the female gender, and 42.27 % represent views from male-owned SMEs. This implies a notable increase in SMEs owned or managed by females, a role that men have traditionally dominated. Evidence also shows that 55.67 % of owners and managers for SMEs in Windhoek were at most 40 years old, signifying that the said SMEs are owned and managed by the youth. Overall, these results conform to prior findings of Nautwima and Asa [21] regarding manufacturing SMEs in Windhoek. Regarding the years of operation, the results show that the response rate reduces with the duration of operation.

In contrast, regarding business size, the results indicate that 64.95 % of the represented SMEs were small enterprises. Broadly, these results align with the postulations of early studies [11,21]. This underscores the fact that numerous small enterprises fail precisely within their first five years of operation before expanding to medium-sized enterprises.

**Table 1**
Profile description.

| Profile | Category | Frequency | Percentage |
|---|---|---|---|
| Gender *(N = 97)* | Female | 56 | 57.73 |
| | Male | 41 | 42.27 |
| Age *(N = 97)* | At most 20 years | 3 | 3.09 |
| | 21–30 years | 17 | 17.53 |
| | 31–40 years | 34 | 35.05 |
| | 41–50 years | 23 | 23.71 |
| | 51–60 years | 11 | 11.34 |
| | Over 60 years | 9 | 9.28 |
| Position *(N = 97)* | Owner | 63 | 64.95 |
| | Senior manager | 24 | 24.74 |
| | Middle manager | 10 | 10.31 |
| Years of operation *(N = 97)* | <3 years | 37 | 35.05 |
| | 3–6 years | 34 | 38.14 |
| | 7–10 years | 19 | 19.59 |
| | Over 10 years | 7 | 7.22 |
| Business size *(N = 97)* | Small (11–30 employees) | 63 | 64.95 |
| | Medium (31–100 employees) | 34 | 35.05 |

Source: Authors' compilation (2024).

### 4.2. Quantitative data analysis

#### 4.2.1. Measurement model assessment

The research assessed the measures' reliability and internal consistency using composite reliability (CR) and Cronbach's alpha (CA), both of which should be at least 0.70 [60,63]. Table 2 demonstrates the reliability and internal consistency metrics above the 0.70 level, indicating dependability. The research assessed convergent validity using the average variance extracted (AVE), which should be >0.50 [60,64]. Based on the findings shown in Table 2, the constructs indicated good convergent validity. Furthermore, the study evaluated discriminant validity using the Fornell-Lacker criteria, which are met when the square root of the AVE exceeds the corresponding correlation values [65], and the Heterotrait-Monotrait (HTMT) ratio, which is met when correlation ratios are at most 0.85 [66]. As seen in Table 2. The study confirms both convergent and discriminant validity.

#### 4.2.2. Structural model and hypothesis testing

The quantitative component of the research was to investigate the factors that influence technology adoption within the TOE framework. The study examined the impact of technological, organizational, and environmental factors (TOE) on technology adoption, with entrepreneurship education as a mediating factor. The structural model was estimated using the PLS bootstrapping option with 5000 samples and 97 cases in SmartPLS 4. As evident in Fig. 2, the results indicate a direct negative impact of technological factors on technology adoption with an impact size of −0.024, which is, however, not statistically significant, given a p-value of 0.815. Besides that, organizational and environmental factors reveal direct positive effects on technology adoption with corresponding effect sizes of 0.584 and 0.221, which are statistically significant based on the p-values of 0.000 and 0.013, respectively.

#### 4.2.3. Mediation analysis

The percentile bootstrapping option was used in the mediation study with 5000 samples and 97 cases to examine the indirect and direct effects [67,68]. In that regard, Nitzl et al. [69] explain that statistically significant indirect and non-statistically significant direct effects indicate complete mediation, significant indirect and significant direct effects indicate partial mediation, and insignificant indirect and direct

**Table 2**
Reliability and validity results.

| | CA | CR | AVE | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|
| Entrepreneurship Education | 0.84 | 0.89 | 0.68 | **0.82** | | | | |
| Technological Factors | 0.90 | 0.94 | 0.84 | 0.30 | **0.92** | | | |
| Environmental Factors | 0.85 | 0.90 | 0.68 | 0.29 | 0.52 | **0.83** | | |
| Organizational Factors | 0.85 | 0.90 | 0.63 | 0.50 | 0.31 | 0.29 | **0.80** | |
| Technology Adoption | 0.86 | 0.90 | 0.65 | 0.33 | 0.53 | 0.69 | 0.26 | **0.80** |

Source: Authors' compilation (2024).

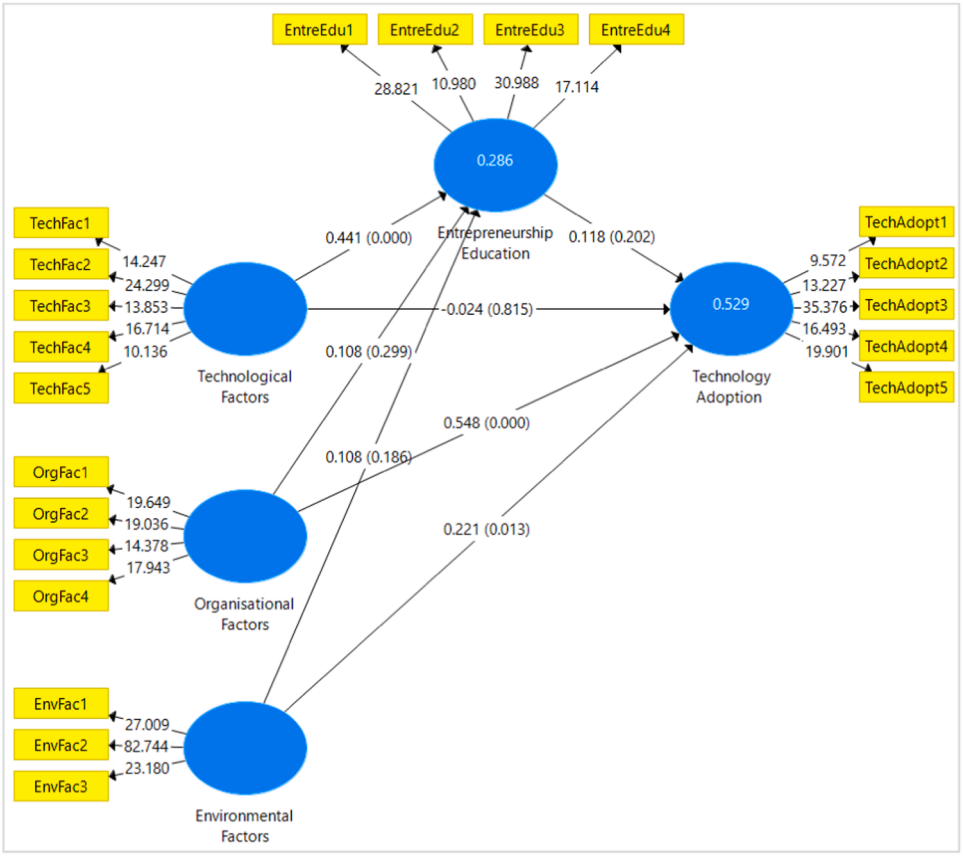


**Fig. 2.** Structural model.
Source: Authors' extraction from the analysis (2024).

effects indicate no mediation.

As shown in Fig. 2, the indirect effects of entrepreneurship education on the relationships between TOE factors and technology adoption are not statistically significant, implying that entrepreneurship education does not mediate between TOE factors and technology adoption in SMEs.

#### 4.2.4. *Hypothesis testing*

About the direct effects, the results shown in Fig. 2 and Table 3 demonstrate a direct negative and not statistically significant impact of technological factors (TechnoFactors) on technology adoption ($\beta = -0.024$; $t = 0.23$; $p = 0.82 > 0.05$). This indicates that H1 is not supported because it shows a negative rather than a positive impact of technological factors on technology adoption. Aside from that, the direct effect of organizational factors (OrganFactors) on technology adoption is positive and statistically significant ($\beta = 0.548$; $t = 6.06$; $p = 0.00 < 0.05$). These findings confirm H2, as shown in Table 3. Finally, the direct effect of environmental factors (EnviroFactors) on technology adoption is also positive and statistically significant ($\beta = 0.221$; $t = 2.46$; $p = 0.01 < 0.05$). Thus, H3 is supported.

**Table 3**
Hypotheses results.

| | T-statistics | P-values | Hypothesis |
|---|---|---|---|
| TechnoFactors → TechnoAdopt | 0.23 | 0.82 | Not Supported |
| OrganFactors → TechnoAdopt | 6.06 | 0.00 | Supported |
| EnviroFactors → TechnoAdopt | 2.46 | 0.01 | Supported |
| TechnoFactors → EntrepEdu → TechnoAdopt | 1.15 | 0.25 | Not supported |
| OrganFactors → EntrepEdu → TechnoAdopt | 0.75 | 0.45 | Not supported |
| EnviroFactors → EntrepEdu → TechnoAdopt | 0.72 | 0.47 | Not supported |

Source: Authors' compilation (2024).

Regarding the indirect effect, evidence reveals a statistically insignificant indirect effect of entrepreneurship education on the relationship between technological factors and technology adoption [$\beta = 0.050$ ($0.441 \times 0.118$); $t = 1.15$; $p = 0.25 > 0.05$]. This indicates that entrepreneurship does not mediate the relationship between technological

factors and technology adoption. Hence, H4a is not supported. Similarly, the indirect effect of entrepreneurship education on the relationship between organizational factors and technology adoption is also not statistically significant [$\beta = 0.013$ ($0.108 \times 0.118$); $t = 0.75$; $p = 0.45 > 0.05$)]. Thus, H4b, which suggests that entrepreneurship mediates the relationship between organizational factors and technology adoption, is not supported. Equally, evidence also shows a statistically insignificant indirect effect of entrepreneurship education on the link between environmental factors and technology adoption [$\beta = 0.013$ ($0.108 \times 0.118$); $t = 0.72$; $p = 0.47 > 0.05$)], illustrating no mediation effect of entrepreneurship education. Thus, H4c is not confirmed.

### 4.3. Qualitative data analysis

#### 4.3.1. Challenges for technology adoption in Namibian SMEs

The research used ATLAS.ti software will conduct a reflective thematic analysis of the challenges of technology adoption in Namibian SMEs. This method was used in the study because it allows for exact data interpretation without changing the participants' original meaning [70, 71]. In that context, the research divided the difficulties into internal ones, which SMEs can manage, and external ones, which they cannot control.

Fig. 2 depicts internal obstacles such as inefficient management and leadership structures, a lack of skills and competence, insufficient financial resources, and limited access to foreign know-how. These findings are consistent with previous research [7,37,38], highlighting challenges related to insufficient human and financial resources. External difficulties include inefficient technological education institutions, poor physical infrastructure, low domestic technological demand, expensive soft infrastructure costs, and limited government backing. These findings are consistent with those of Jere and Ngidi [27], who found that external stakeholders provided minimal help. The research filled an empirical vacuum in the literature by investigating these difficulties in the context of Namibia.

Fig. 3 was developed from analyzing qualitative data using Atlas.ti software. Responses were categorised into themes reflecting internal and external challenges to technology adoption in SMEs. Internal barriers included management inefficiencies, skill deficiencies, and limited access to international know-how (expertise), whereas external barriers included infrastructural deficits, low domestic demand, and inadequate governmental backing. Themes were visualized and linked to the TOE domains to enhance the significance of qualitative findings in interpreting quantitative results. The lack of a substantial correlation between technological parameters and adoption in the quantitative data was elucidated by qualitative input highlighting perceived incompatibility and affordability concerns. Consequently, Fig. 3 functioned as a bridge for the synthesis of findings, facilitating the triangulation and contextualization of the data.

## 5. Discussion

This study applied the Technology–Organization–Environment (TOE) framework to examine the determinants of technology adoption among SMEs in Namibia, supported by qualitative data to contextualize the findings.

The quantitative results revealed that technological factors had a negative but statistically insignificant effect on adoption. This diverges from many TOE-based studies that report a positive association (e.g., [1, 4]). However, the qualitative data help explain this inconsistency: respondents cited challenges such as high costs, poor compatibility, and technical complexity as barriers. These findings suggest that while the TOE framework highlights technological readiness, perceived relevance and affordability in local contexts can override general expectations, particularly in resource-constrained environments like Namibia.

In contrast, organizational factors, demonstrated a strong, positive and statistically significant effect on technology adoption. This is consistent with existing literature [29,40] and emphasizes that internal preparedness and top management commitment remain critical drivers of adoption. The qualitative responses reinforced this, with participants frequently highlighting the role of proactive leadership and staff involvement in successful implementation.

Similarly, environmental factors were found to positively and significantly influence adoption. Respondents cited external conditions such as government support, donor programs, and competitive pressure as motivating forces. These results align with studies like Ta and Lin [5] and Abbad et al. [43]. However, the qualitative data added nuance, revealing that although such support mechanisms exist, they are often fragmented, bureaucratic, or poorly communicated, which limits their effectiveness in practice.

Unexpectedly, entrepreneurship education did not mediate the relationship between TOE factors and technology adoption. This contrasts with findings from other regions (e.g., [20]) and may reflect context-specific limitations in Namibia. Respondents noted that existing entrepreneurship programs often lack practical relevance, follow-up support, and real-world exposure, making them insufficient to influence behavior around technology adoption in isolation.

Holistically, the qualitative data complemented and clarified the quantitative findings, particularly where statistical significance was absent or counterintuitive. The integration of both methods demonstrates that contextual barriers, such as affordability, institutional

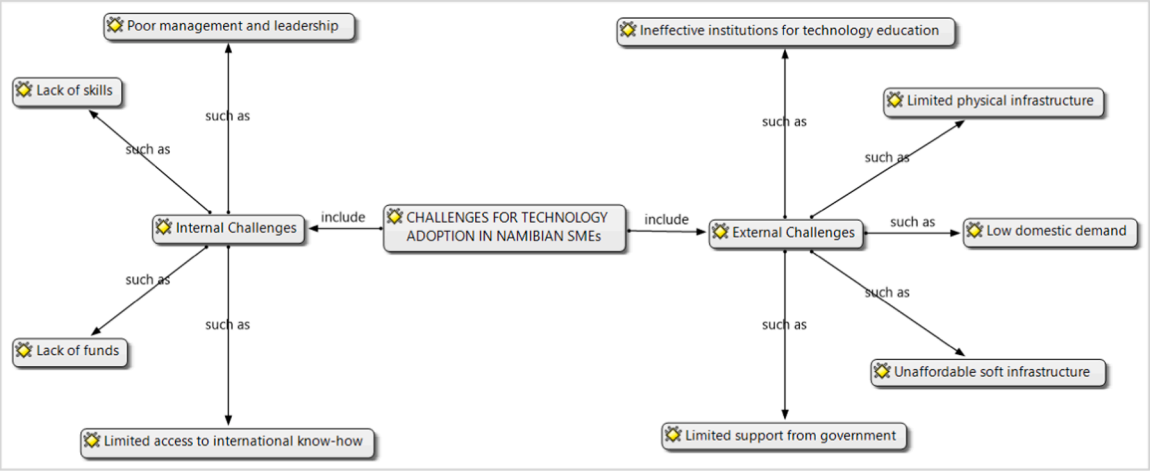


**Fig. 3.** Challenges for technology adoption in Namibian SMEs.
Source: Authors' extraction from the analysis (2024).

inefficiencies, and limited local adaptation of technology, significantly moderate how TOE factors operate in practice. This blended interpretation adds depth to the analysis and shows the value of mixed methods in producing richer, more actionable insights for both theory and policy.

This study contributes to the body of knowledge on technology adoption among SMEs by addressing three interrelated research gaps identified in prior studies. First, this study closes an empirical gap in the scant empirical evidence on the factors influencing technology adoption among Namibian SMEs. Although earlier studies mostly concentrated on middle- and high-income economies [1,4,22], little is known about adoption behaviour in underdeveloped settings, such as Namibia. Applying the TOE paradigm in this context is critical for demonstrating that organisational and environmental factors significantly influence adoption. Although technological factors are practically important, they do not show a statistically significant relationship. This suggests that traditional models may possess limited explanatory power in structurally constrained environments.

Second, this study assesses the mediating function of entrepreneurial education in the relationship between TOE dimensions and technology adoption among SMEs, addressing a theoretical extension gap. Although entrepreneurial education is advocated in African policy debates [20], it has not been empirically evaluated as a mediator in adoption models in Namibia. The results indicating that entrepreneurial education does not mediate these relationships suggest that current educational and training programs require practical relevance and contextual alignment to exert behavioural influence on technology adoption in SMEs.

Third, this study resolves the contradictory evidence gap on the influence of environmental factors on the technology adoption of SMEs. Some prior studies show that external support improves the adoption of technology [26,35], although other scholars indicate contradictory or mixed findings, such as a study conducted in Malaysia that showed no significant effect [31]. The study indicates that environmental factors positively influence technology adoption in Namibia; however, the qualitative results show that the impact is weakened by bureaucratic inefficiencies. Hence, the results provide insights into how institutional constraints affect adoption results and contextualise the importance of external environmental factors.

## 6. Implications and recommendations

The adoption of technology has the potential to enhance the efficiency of businesses significantly and is becoming an increasingly vital factor for businesses seeking sustainable performance. However, SMEs face challenges in thoroughly engaging and surviving in markets that are becoming progressively more volatile and dynamic without sufficient technological access [62]. Given that, this research has noteworthy implications for owners/managers of small and medium-sized enterprises (SMEs) in Windhoek, Namibia, which are confronted with challenges and seek to embrace novel technologies to maximize the benefits of technology adoption and government agencies aiming to promote the utilization of technology adoption in SMEs. Firstly, the study recommends that SMEs acquire skills and knowledge by recruiting employees with pertinent technology utilization skills, accessing knowledge of international know-how, and ensuring leadership and management strategies to enhance technology adoption. Secondly, the study recommends the promotion of public-private partnerships as a strategy to stimulate the development of user-centric systems for SMEs by addressing the issue of limited funds for technology adoption. Finally, the study recommends that policymakers and donors invest in technology for SMEs by ensuring a conducive entrepreneurial ecosystem for SMEs to adopt technology and serve to their full potential effectively.

This study further recommends three policy-level initiatives to help operationalise these insights: First, establish regional digital support hubs using tailored advisory services. Investing in the establishment of decentralised SMEs digital support hubs across Namibia will help policymakers provide on-demand access to IT consulting services, training, subsidised digital tools, and infrastructure-sharing platforms. These hubs would react to two main conclusions: (a) the notable positive influence of organisational factors including internal capabilities, and (b) the contextual challenges SMEs experience with cost and incompatible technology. Particularly for SMEs in informal settlements and regional towns, such policies would decentralise access to technical skills and lower the load of high entrance charges. This is consistent with OECD global best practices for digital capacity-building in low-income countries (2021).

Second, public procurement should be reformed to encourage SMEs' adoption of technology. Technology-readiness requirements should be included into supplier eligibility for public contracts in Namibia's government procurement procedures. This will inspire SMEs to use digital tools, such as inventory control systems and e-invoicing as prerequisites for bidding on tenders. Concurrent with state-linked procurement initiatives should be a digital upskilling support program for SMEs. This makes use of the research showing that adoption is much influenced by external institutional incentives (environmental factors). Furthermore, public procurement as a policy tool has shown success in encouraging digitalisation and innovation among SMEs in other developing countries [72].

Third, policy should demand co-design of industry-based entrepreneurship education. The ineffectiveness of present entrepreneurial education in mediating technological uptake exposes a structural policy gap. Public–private curriculum co-design panels should be institutionalised by the line ministries in charge of vocational training and higher education to guarantee that entrepreneurial education combines real-time digital tools, sector-specific use cases, and post-training incubation support. As this study reveals, including industry practitioners in program delivery can assist close the relevance gap and enhance behavioural results. This strategy reflects recent empirical results in comparable Sub-Saharan settings where co-designed education enhanced SME innovation capability [20,48].

## 7. Conclusion

This study focused only on SMEs in Windhoek, in the Khomas region, which leaves a population gap in the literature. Thus, future research should focus on SMEs in other regions and remote areas. Ensuring this is essential for augmenting the generalizability of the results. A further limitation of this study is the potential for social desirability bias, given that data were gathered using self-reported measures. Participants might have understated the challenges of technology adoption or overstated positive practices to fit with perceived standards or expectations. Although anonymity was guaranteed to mitigate this impact, future research could use triangulation techniques, including field observations, follow-up interviews, or secondary data analysis, to corroborate and validate self-reported responses.

This study examined the determinants of technology adoption among small and medium-sized enterprises (SMEs) in Namibia using the Technology-Organisation-Environment (TOE) framework, while also assessing the mediating role of entrepreneurship education. Based on the findings, this study concludes that while favorable technological factors play an essential role in technology adoption for SMEs [1,27,29,31], these factors are unfavorable in Namibia's entrepreneurial ecosystem, discouraging SMEs from adopting technology. On the other hand, this analysis indicates, based on evidence from early studies [1,29–31,35,40], that organizational variables are an essential facilitator for technology adoption in SMEs. This research also resolves the literature's paradoxes, demonstrating that environmental influences favor technological adoption. Environmental factors play a critical role in pushing small businesses to adopt technology. Furthermore, although entrepreneurship education is important, this research suggests that it does not bridge the gap between technological, organizational, and environmental factors (TOE) and technology adoption in Namibian SMEs. Finally, the study reveals that SMEs in Namibia continue to face a

range of internal (e.g., limited technical skills, poor management structures) and external (e.g., inadequate infrastructure, insufficient government support) challenges that constrain their ability to leverage technology for operational efficiency and growth.

## CRediT authorship contribution statement

**Johanna Pangeiko Nautwima:** Writing – original draft, Methodology, Investigation, Conceptualization. **Bojan Obrenovic:** Writing – review & editing, Validation, Supervision, Project administration. **Asa Romeo Asa:** Writing – review & editing, Resources, Methodology, Data curation. **Helvi Nyete Johannes:** Writing – original draft, Validation, Conceptualization. **Nurbanu Abueva:** Writing – review & editing, Resources, Formal analysis.

## Declaration of competing interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No financial, professional, or personal affiliations have influenced the research presented in this manuscript.

## Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.sftr.2025.100919.

## Data availability

Data will be made available on request.

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