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Research article

# Determinants of cloud computing integration and its impact on sustainable performance in SMEs: An empirical investigation using the SEM-ANN approach

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A R T I C L E I N F O

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A B S T R A C T

Although extant literature has thoroughly investigated the incorporation of cloud computing services, examining their influence on sustainable performance, particularly at the organizational level, is insufficient. Consequently, the present research aims to assess the factors that impact the integration of cloud computing within small and medium-sized enterprises (SMEs) and its subsequent effects on environmental, financial, and social performance. The data were collected from 415 SMEs and were analyzed using a hybrid SEM-ANN approach. PLS-SEM results indicate that relative advantage, complexity, compatibility, top management support, cost reduction, and government support significantly affect cloud computing integration. This study also empirically demonstrated that SMEs could improve their financial, environmental, and social performance by integrating cloud computing services. ANN results show that complexity, with a normalized importance (NI) of 89.14%, is ranked the first among other factors affecting cloud computing integration in SMEs. This is followed by cost reduction (NI = 82.67%), government support (NI = 73.37%), compatibility (NI = 70.02%), top management support (NI = 52.43%), and relative advantage (NI = 48.72%). Theoretically, this study goes beyond examining the determinants affecting cloud computing integration by examining their impact on SMEs' environmental, financial, and social performance in a comprehensive manner. The study also provides several practical implications for policymakers, SME managers, and cloud computing service providers.

## 1. Introduction

Cloud computing has emerged as one of the most significant technological advancements of the past decade, revolutionizing how organizations operate and conduct business [1]. The cloud computing paradigm enables firms to access on-demand computing

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resources, software, and applications over the Internet, reducing the need for costly hardware and software investments [2]. The integration of cloud computing has been widespread among organizations, from large corporations to small and medium enterprises (SMEs) [3]. The synchronization of data between local on-premises servers and remote Software as a Service (SaaS) applications and cloud services is known as cloud integration [4]. This process enables access to a wide range of computing resources, including applications, networks, and services, with minimal effort to interact and manage with the service provider [5]. Organizations are expected to employ efficient and innovative technologies to maintain adequate levels of productivity within their ecosystems [6]. Cloud computing provides a cost-effective and flexible solution to achieve these objectives by providing access to IT resources [7,8].

The integration of cloud computing is critical in various industries, particularly SMEs, that should not be left out of these opportunities [9]. SMEs are vital to Malaysia's economy, representing 97.2% of all companies [10]. SMEs substantially promote economic expansion and progress, generate employment opportunities, and stimulate innovation [11,12]. In the Malaysian context, these enterprises constitute 37.4% of the nation's gross domestic product (GDP) and 47.8% of the overall workforce, emphasizing their critical contribution to the country's economic well-being [10]. However, SMEs often encounter challenges in adopting new technologies due to limited resources, knowledge, and expertise [6,13]. The integration of cloud computing can offer numerous benefits to SMEs, including improved flexibility, scalability, cost savings, and productivity. The integration of cloud computing services into SMEs has the potential to improve their sustainable performance substantially [14] and contribute to the achievement of the Sustainable Development Goals (SDGs) established by the United Nations Development Program (UNDP) [6]. For example, cloud computing can facilitate collaboration and communication between SMEs and their partners, suppliers, and other stakeholders, thereby promoting Goal 17, which focuses on partnerships for the SDGs [15].

Additionally, cloud computing can allow SMEs to reduce their IT infrastructure and maintenance costs, allocating resources more appropriately to core business operations [16]. This promotes SDG 8, which aims to promote sustained and inclusive economic growth and decent work for all [17]. Cloud computing allows small businesses to access information and services that were previously unattainable due to prohibitive costs or insufficient resources. This advantage facilitates innovation, technology adoption, and the enhancement of competitiveness in the marketplace [18]. This promotes SDG 9, which aims to promote sustainable industrialization, build resilient infrastructure, and promote innovation. Furthermore, cloud computing can promote environmental sustainability by reducing the carbon footprint of small businesses, as they do not need to invest in a large and energy-consuming IT infrastructure [19,20]. This promotes SDG 13, which focuses on urgent action to combat climate change.

There has been a growing emphasis on sustainable growth in the business world [19]. Organizations are increasingly striving to integrate sustainability into their operations by focusing not only on economic performance but also on excelling in social and environmental dimensions [21,22]. The emergence of cutting-edge technologies, such as cloud computing services, has accelerated this shift. To achieve a balance between economic and operational performance, organizations must improve their capabilities and promote sustainable performance [23]. Although the integration of cloud computing services is well-established, research on the impact of these services on sustainable performance, particularly environmental, financial, and social performance, remains limited [22]. While substantial research studies examined the adoption and usage of cloud computing services in organizations (e.g. Refs. [1,5,24]), there is a gap in the literature regarding the specific role of cloud computing services in improving SMEs' sustainable performance. Moreover, existing literature on cloud computing adoption and usage has primarily focused on the individual level, neglecting perspectives at the organizational level. A recent study has supported these claims and emphasized the importance of studying the influence of advanced technologies, such as cloud computing, on sustainability dimensions, specifically at the organizational level [25,26].

To address these gaps, this research aims to evaluate the determinants affecting cloud computing integration in SMEs and their influence on sustainable environmental, financial, and social performance. To achieve this aim, this study has constructed a research model based on the Technology-Organization-Environment (TOE) framework [27] for predicting the determinants affecting cloud computing integration in SMEs and its consequent impact on sustainable environmental, financial, and social performance. The proposed model was then tested by gathering data from SMEs in Malaysia using a hybrid partial least squares-structural equation modeling (PLS-SEM) and Artificial Neural Network (ANN) approach. The rationale for adopting this hybrid approach is based on the fact that PLS-SEM is solely capable of addressing linear relationships [28]. To compensate for this limitation, ANN is integrated into the methodology, as it capable of handling linear and non-linear relationships while simultaneously ranking significant predictors [29].

## 2. Theoretical background

Information systems research utilizes various adoption and diffusion theories to understand, explain, and predict the adoption and deployment of new technologies by individuals or organizations. These theories share similarities in content and objectives but differ in practical applications [30,31]. They explore emerging technology adoption and diffusion from diverse perspectives to clarify the rationale, extent, and processes of technology adoption and implementation [32,33]. Adoption theories identify factors influencing technology adoption and analyze these determinants [31,34]. Maruping et al. [35] argue for prioritizing behavioral expectation and actual use as predictors of IT use in organizations rather than solely relying on the behavioral intention framework.

The current research employs the TOE framework as the principal theoretical foundation to construct the research model that predict the integration of cloud computing at the organizational level. The TOE framework, proposed by Depietro et al. [27], is frequently employed in information systems adoption research at the organizational level [36,37]. This research assesses the TOE framework's suitability for developing a comprehensive model elucidating cloud computing service adoption in SMEs and its potential impact on their sustainable performance.

Various technology adoption studies have applied the TOE framework, including cashless payment systems for business transactions [37], health insurance systems [38], digitalization of manufacturing operations [39], geographical information technologies [40], knowledge management-based cloud computing services [41,42], and blockchain by organizations [43]. The research findings substantiate the efficacy of the TOE framework for analysing organizational conduct pertaining to the adoption of technological innovations. The framework was designed to explain innovation adoption within organizations, focusing on three main dimensions: technology, organization, and environment [44]. The technological dimension encompasses innovation features that can affect adoption, such as relative advantage and compatibility with existing technologies. The organizational dimension considers attributes such as size and managerial hierarchy, which may impact the adoption process. The environmental dimension addresses external factors, including competitors and government policies, that can influence adoption decisions.

The TOE framework provides a comprehensive and robust foundation to understand innovation adoption and use, considering multiple factors influencing technology adoption and use [39,45]. Research indicates that multidimensional models offer better explanatory power than those considering only one dimension [46]. The TOE model adopts an interactive perspective, assuming that organizational transformations are influenced by both the internal actors and the attributes of the workplace setting [47,48]. This perspective allows researchers to study all factors and their interactions within a dynamic framework, providing a comprehensive understanding of the adoption of emerging technologies.

SMEs significantly contribute to economic growth in developing countries [11]. However, sustainability has been slow to gain traction in this sector [49]. This study aims to investigate the predictors of cloud computing integration and examine the impact of integrating cloud computing services on the sustainable performance of SMEs. Understanding the relationship between cloud computing integration and sustainable performance is vital, as it can provide insights into the potential benefits of this technology for SMEs [22]. This study aims to enrich the existing literature on sustainable development in SMEs by exploring the role of technology in fostering sustainability, specifically by investigating the effects of cloud computing integration on sustainable performance. Previous research in this domain has been somewhat deficient in analyzing the impact of technology on promoting sustainability in SMEs.

Most prior research in this area has focused predominantly on the consequences of sustainability rather than the antecedent conditions [49,50]. Moreover, previous research has primarily examined social, environmental, or economic performance separately, with limited attention to exploring all three components concurrently [21,22]. Therefore, this study adopts a comprehensive approach that accounts for technological, organizational, and environmental factors influencing SMEs' adoption of cloud computing services. Additionally, the study predicts the potential influence of cloud computing integration on SMEs' sustainable performance, with

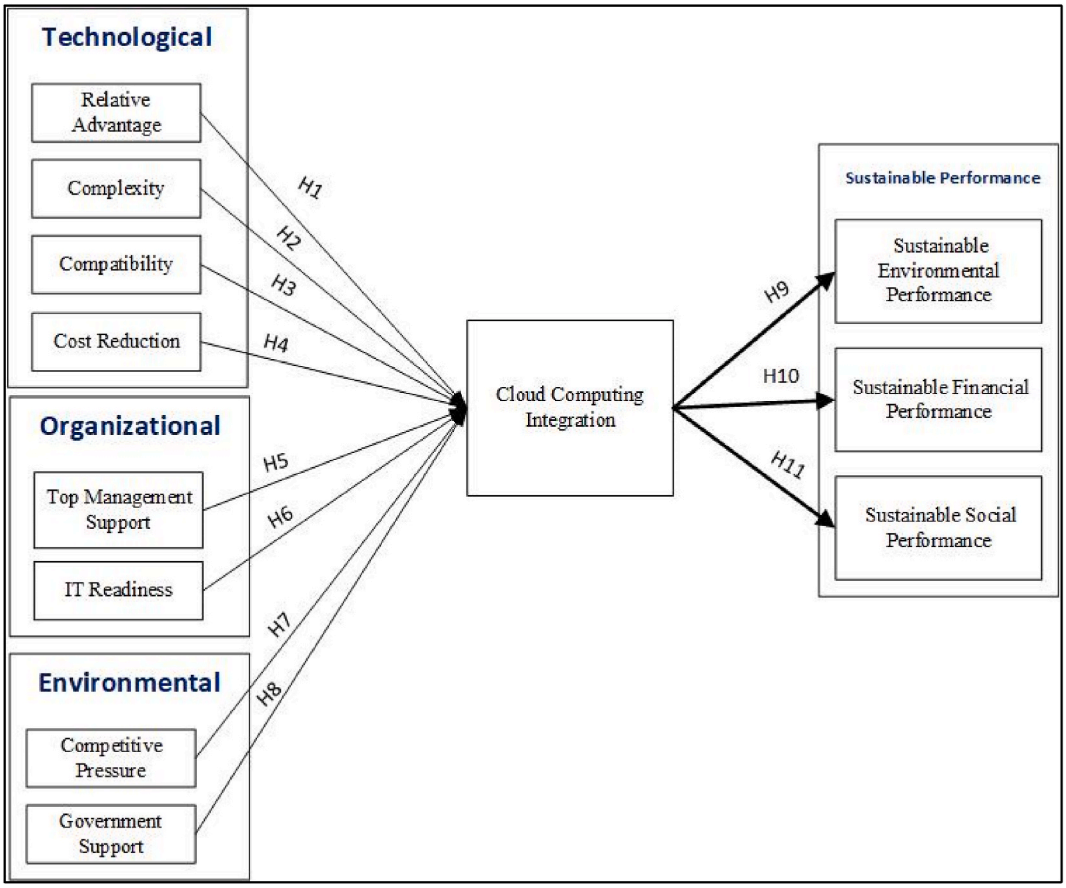


**Fig. 1.** Research model.

environmental, financial, and social sustainability serving as key performance indicators. The developed research model is depicted in Fig. 1.

### 2.1. Relative advantage

Relative advantages pertain to the anticipated benefits and appeal of utilizing the technology compared to other applications [51]. Moore and Benbasat [52] stated that relative advantage measures the perceived usefulness or perceived benefits on the same scale in TAM [53]. The term "relative advantage" in this research pertains to the benefits cloud computing services can provide SMEs, such as enhanced business operations, improved productivity, flexibility, and the ability to access information anywhere and anytime. Cloud computing is recognized as a cost-effective and flexible technological innovation, enabling SMEs to adopt advanced business solutions throughout their organization, while reducing infrastructure and maintenance costs [42,54]. Furthermore, cloud computing services offer viable tools to facilitate business performance and deliver affordable solutions, enabling enterprises to enhance their routine operations more efficiently [42]. Studies conducted in the past have shown that SME decision-makers give significant importance to relative advantage when making decisions regarding adoption (e.g. Refs. [55,56]). Thus, this study hypothesizes that relative advantage positively impacts cloud computing services integration. Increased benefits obtained by SMEs through the utilization of cloud computing services are positively correlated with their likelihood of adoption in business operations. Consequently, the present research posits the following hypothesis.

**H1**. There is a positive relationship between relative advantage and the integration of cloud computing.

### 2.2. Complexity

Complexity is a fundamental concept in the examination of technology adoption and innovation. Within the scope of organizational implementation, complexity can be characterized as "the extent to which an innovation is perceived as difficult to understand and utilize" [51]. **Davis** [53] positively described complexity in TAM by employing the term "ease of use" at the individual level, which is defined as "the degree to which a person believes that using a particular system would be effortless". Moore and Benbasat [52] indicate that complexity measures the same perceived ease of use scale in TAM [53], but from the opposite perspective. The complexity of emerging technologies may also affect its adoption and usage rate; organizations may be less inclined to adopt or use a technology with high complexity [6,57]. Notably, many SMEs perceive cloud computing services as intricate and unsuitable workplace tools [11,58]. Multiple studies have demonstrated a significant relationship between the perceived technical difficulty and technology utilization [59–61]. In this study's context, complexity refers to the perceived level of difficulty in comprehending and using cloud computing services from the SMEs' perspective. Based on these considerations, the study hypothesizes that.

**H2**. There is a negative relationship between complexity and the integration of cloud computing.

### 2.3. Compatibility

Compatibility plays a vital role in the adoption of new technologies. It refers to "the degree to which a new technology aligns with the current beliefs, values, and needs of potential adopters" [52,62]. Compatibility can influence both the initial adoption intention and continued use of innovation within an organization [11,63]. There have been many studies investigating the adoption and use of emerging technologies in organizations, which have consistently shown that the compatibility of these technologies is a significant factor in their adoption and usage [11,64–66]. The congruence between new and existing technology impacts an organization's adoption process and ongoing usage [11,65]. Consequently, decision-makers should regard cloud computing services as compatible with their requirements throughout the entire process, not solely during the initial adoption phase, as cloud services evolve over time [48,67]. In this study, compatibility is defined as "the extent to which cloud computing services correspond with an SME's existing technological capabilities, needs, and skillsets". Thus, the implementation of cloud computing services relies on their coherence with the users' existing systems, attitudes, value systems, beliefs, and procedures. Based on these considerations, the following hypothesis is proposed.

**H3**. There is a positive relationship between compatibility and the integration of cloud computing.

### 2.4. Cost reduction

Cost reduction is a significant factor that motivates integrating cloud computing services in organizations. It is defined as the process of minimizing the total cost of using cloud computing services while achieving the desired outcome [68]. Cost reduction is a key reason organizations adopt cloud computing services, as they can reduce the cost of building an organization's system cost-efficiently [69]. Cloud computing services offer a novel platform for efficient and cost-effective resolution of legacy system issues [70]. The up-front infrastructure acquisition cost is reduced by using cloud computing services, leading to greater benefits for organizations [41]. The pay-*as*-you-go cost structure model adopted by cloud service providers enables organizations to outsource their IT resources. This leads to cost savings in low upfront costs, data storage, scalability, and resource elasticity [71]. Furthermore, cloud computing services eliminate the need for software installation and offer a subscription model, resulting in cost savings [72]. SMEs benefit significantly from cloud computing services as they reduce the start-up costs associated with technology adoption [73]. Cloud computing offers low start-up expenses, enabling SMEs to reduce software procurement, experimentation, and implementation costs [74]. SMEs can effectively manage system maintenance and routine upgrade costs while simultaneously reducing operational expenses by paying solely for their requisite services [70]. These cost savings enable SMEs to focus on their core business operations and grow their businesses. Therefore, this study proposes the following.

**H4**. There is a positive relationship between cost reduction and the integration of cloud computing.

### *2.5. Top management support*

Top management support has been identified as a crucial factor in organizations' successful adoption and sustained usage of new technology [75,76]. Top management's vision, commitment, and participation have consistently been found to impact successful IS implementation and adoption significantly [77,78]. Previous research on innovation and information systems adoption has frequently examined the role of top management support within organizations. It has been demonstrated that the degree of success in implementing information systems is affected by the level of support provided by top management [48,67]. A positive correlation exists between top management support and the sustained utilization of emerging technologies, such as cloud computing services [11]. Consequently, the personal perspectives and instincts of SME decision-makers are crucial in strategic decision-making regarding the degree of technology adoption. In order to encourage the adoption and sustained usage of cloud computing services in SMEs, it is essential to secure buy-in and support from upper management, as the decision to implement and utilize these services is not solely within the purview of IT personnel. The decision to adopt cloud computing services necessitates backing from top management and decision-makers within SMEs. Thus, the study proposes the following.

**H5**. There is a positive relationship between top management support and the integration of cloud computing.

### *2.6. IT readiness*

IT readiness refers to the level to which IT-related components are in place and utilized to fulfill business objectives and relay information for informed decisions [79]. IT readiness is a critical organizational factor influencing the continued use of cloud computing services by SMEs. This encompasses the degree to which technology infrastructure, relevant systems, IT human resources, and technical business competencies are established to achieve SME objectives and facilitate informed decision-making. IT readiness is a significant factor influencing the integration of cloud computing by SMEs, playing a pivotal role in predicting innovation diffusion. Several empirical studies have examined this factor [47,80–82]. Technical readiness (technological infrastructure) and IT personnel's knowledge (human resources facilitating IS adoption) are the two primary components underpinning IT readiness [83,84]. A deficiency in skills and technical expertise among employees may hinder the adoption and execution of innovations until the required technical proficiency is attained. Organizational IT readiness positively influences the adoption of diverse technological innovations by organizations [80,81,85]. Cloud computing services can play a crucial role in an SME's value chain, provided the necessary infrastructure and technical skills are present [85,86]. Consequently, we propose the following hypothesis.

**H6**. There is a positive relationship between IT readiness and the integration of cloud computing.

### *2.7. Competitive pressure*

Competitive pressure is "the degree of pressure an organization experiences from competitors within its sector" [87]. It is a vital factor that impacts adopting and using new and relevant technologies in competitive environments, as organizations continuously evaluate technological advancements to maintain a competitive advantage [48]. SMEs, in particular, face intense pressure due to globalization and the rapid growth of IT, which continually affect customers' needs and preferences. The increasing number of competitors and the continual growth of IT may potentially oust SMEs from particular sectors. Nevertheless, the way SMEs utilize and incorporate business intelligence and information into their offerings can influence their reactions. Competitive pressure impacts the diffusion of IT innovation, especially when organizations discern the potential of such technology to strengthen their competitive position and improve their performance.

Prior empirical research has identified competitive pressure as a crucial factor driving emerging technologies adoption [48,88,89]. Studies have demonstrated that organizations are more inclined to persistently utilize innovative technologies when they acknowledge that their competitors have obtained competitive advantages and developed marketing dynamism through the continuous use of such technologies. As a result, competitive pressure may compel SMEs to adopt and maintain the use of cloud computing services to improve service quality and secure competitive advantages. Accordingly, the following hypothesis is proposed.

**H7**. There is a positive relationship between competitive pressure and the integration of cloud computing.

### *2.8. Government support*

The second environmental factor influencing SME decision-makers in the adoption of cloud computing services is government support. According to Safari et al. [90], government support encompasses various forms of assistance provided by authorities to promote IT innovation adoption within organizations. This support becomes particularly crucial for SMEs with limited financial resources. Governments can provide targeted incentives, including reduced subscription fees, to motivate SMEs to adopt cloud computing services [91]. SMEs often depend on government assistance to enable their business operations, particularly in the realm of cloud services expertise and other essential services [85]. Consequently, the performance of SMEs may be positively or negatively impacted by the use of cloud computing services [92].

To facilitate and promote cloud computing services, governments can implement appropriate legislation, provide targeted incentives like reduced subscription fees, invest in IT infrastructure, and cultivate a skilled workforce, particularly in developing nations [93]. Without government intervention, SMEs might face greater risks in adopting and utilizing IT innovations due to their size and resource constraints, increasing their reliance on external support compared to larger companies [94,95]. Therefore, organizations often necessitate government assistance during IT adoption and development, especially in developing countries. Prior research has verified the positive influence of government support and incentives on organizational decisions to adopt emerging technologies [48,96]. Based on these findings, the following hypothesis is proposed.

**H8**. There is a positive relationship between government support and the integration of cloud computing.

### *2.9. Cloud computing integration and sustainable performance*

Cloud integration involves data synchronization between local on-premises servers, remote SaaS applications, and cloud services [4,97]. In the context of this study, cloud computing integration refers to incorporating cloud-based technologies and services into the operations of SMEs. This integration can involve using cloud storage solutions, cloud-based software applications, and other cloud-based services to improve the efficiency and effectiveness of various business processes [55,98]. Integrating cloud computing services into the structure and functions of SMEs is anticipated to be a significant transformative change as it has the potential to impact the business environment at all levels of operation [22]. Cloud computing services are expected to significantly enhance organizational performance and productivity, making them a crucial driver for businesses [24,99].

The literature suggests that emerging technologies can significantly impact organizations' sustainable performance, and cloud computing services are no exception [22]. Cloud computing services can enable SMEs to reduce their energy consumption and carbon footprint by leveraging the shared infrastructure of cloud providers [49,100,101]. Additionally, cloud computing can facilitate remote work and reduce the need for physical office space, leading to a reduction in the environmental impact of commuting and building operations [49,102,103]. Cloud computing services can also improve the financial sustainability of SMEs by reducing the costs associated with IT infrastructure, maintenance, and support. Lowering costs can free up resources for investment in other areas that can improve the organization's overall sustainability, such as employee training, social responsibility initiatives, and sustainable supply chain management.

A comprehensive approach to performance is essential for all stakeholders in the value chain to accomplish their strategic objectives. This approach goes beyond conventional performance metrics and encompasses social, financial, and environmental performance indicators. The integration of cloud computing services in SMEs can positively impact their environmental, social, and financial sustainability performance, making it an essential consideration for SMEs looking to improve their sustainability practices. Thus, the following hypotheses are proposed to investigate the relationship between cloud computing integration and sustainable performance.

**H9**. There is a positive relationship between cloud computing integration and SMEs sustainable environmental performance.

**H10**. There is a positive relationship between cloud computing integration and SMEs sustainable financial performance.

**H11**. There is a positive relationship between cloud computing integration and SMEs sustainable social performance.

## 3. Research method

### *3.1. Research instrument*

This study employed a quantitative technique to investigate the predictors of cloud computing integration and its impact on sustainable performance in Malaysian SMEs. By employing a quantitative research method, this study aims to provide empirical evidence to support the relationship between cloud computing integration and sustainable performance in SMEs. The target population for this research consists of SMEs, which constitute a significant proportion of the private sector and play a crucial role in the Malaysian economy.

To investigate the proposed relationships among the constructs within the developed model, it is essential to devise reliable and valid measurement scales for each construct, drawing from established sources. Relative advantage, compatibility, and complexity were measured using items adapted from Refs. [11,51,52,85,104], while the top management support items were adapted from Refs. [55,105]. The cost reduction items were adapted from Refs. [68,106]. The IT readiness items were obtained from studies conducted by Refs. [55,107], while the competitive pressure items were adapted from Oliveira et al. [108]. The government support items were adapted from Refs. [106,109]. The elements of cloud computing integration were adapted from Ref. [110], while the elements of environmental performance, financial performance, and social performance were adapted from Refs. [21,49]. Following the studies carried out by Refs. [80,111], the items were measured using a 5-point Likert scale. The scale included response options ranging from 1 (strongly disagree) to 5 (strongly agree) and was used to elicit relevant responses for subsequent analysis. This measurement approach is known for its high validity and reliability, making it appropriate for quantifying feedback [65]. To ensure the reliability of the survey items, a pilot study was conducted with 35 respondents. The findings revealed that all Cronbach's alpha values were above 0.7, which is an indicator of the reliability of the constructs used in the study [112].

### 3.2. Sampling and data collection

The study used a purposive sample approach, focusing on decision-makers who had understanding of cloud computing services and understood its impact on the long-term success of SMEs, such as CEOs, IT managers, or owners. The directory of SMEs, sourced from SME Corporation Malaysia, supplied the email list for this study. SME Corporation Malaysia is responsible for offering business advisory services and formulating policies and strategies for Malaysian SMEs. To ascertain the applicability of the sample, a screening question was incorporated into the survey to verify that the respondents' organizations employed cloud computing services. By using this method, it was ensured that the participants had the expertise and information necessary to give meaningful and reliable answers.

The self-administered questionnaires were sent to the selected participants, accompanied by a cover letter explaining the study's purpose, the voluntary nature of participation, and confidentiality assurance. The online survey tool, SurveyMonkey, was used to facilitate the survey distribution and response collection. The self-administered questionnaire method was chosen due to its efficiency, convenience, and cost-effectiveness [113]. Participants were given a specified timeframe to complete the questionnaire. After the deadline, the responses were collected, and the data were screened for incomplete or inconsistent responses. For the purposes of this research, 415 valid questionnaires were obtained.

### 3.3. Data analysis

Previous studies were used as a guide to test the research hypotheses and verify the research model [7,114–117]. This research employs a two-step analytical approach involving Partial Least Squares-Structural Equation Modeling (PLS-SEM) with Artificial Neural Network (ANN) techniques. In the initial phase, PLS-SEM was employed to recognize the determinants and their substantial influence on the integration of cloud computing and its impact on the sustainable performance of SMEs. Variance-based PLS-SEM was chosen due to the complexity of the model and the large number of indicators [112]. Furthermore, PLS-SEM was chosen because this research is exploratory, not confirmatory [118].

While PLS-SEM has attained widespread utilization as a conventional approach for scrutinizing intricate associations among manifest and unobserved variables [118], ensuring the robustness of the structural model is crucial. As suggested by Sarstedt et al. [119], one essential method for addressing endogeneity issues in the structural model involves employing the Gaussian Copula Approach. Endogeneity can arise from various sources, such as omitted variables, measurement error, and simultaneity, resulting in inaccurate inferences and biased estimates of the relationships between variables [120]. Consequently, following the recommendations of [119], this study conducted post hoc analyses and robustness checks to assess potential endogeneity using the Gaussian Copula Approach. By incorporating this technique, we can enhance the validity and reliability of the study's findings.

However, PLS-SEM cannot examine non-linear relationships among constructs, which is why the ANN approach was used in conjunction with PLS-SEM to rank the normalized significance of substantial variables [49,121,122]. Additional research has also emphasized the infrequent employment of SEM in tandem with AI algorithms [123]. In the subsequent phase, the ANN technique was employed to contend with the infringement of the linearity assumption inherent in PLS-SEM and determine the predictors' significance. The ANN approach was selected because it facilitates the identification of complex linear and non-linear relationships among factors in the developed model [124,125]. Furthermore, ANN is less sensitive to violations of statistical assumptions and can provide a better fit to the data in cases where traditional linear models fail [124,125]. It is also recognized as a powerful tool for modeling complex relationships and uncovering hidden patterns in datasets [126]. Furthermore, the ANN approach provides better and more sophisticated predictions than traditional regression algorithms [9,127–129].

## 4. Findings

### 4.1. Non-response and common method bias

Following the approach of previous research [114], this study utilized independent *t*-tests to examine differences between all key variables in the research model. The results indicated that no significant differences were identified. We conducted a chi-squared test for independence to verify our findings further, revealing no significant differences [130]. As a result, we conclude that there is no evidence of non-response bias in the dataset used for this study.

This study conducted the Harman single-factor test to address potential common method bias resulting from data collected from a single source. According to the findings, the single factor explained 37.28% of the total variance, which falls below the recommended threshold of 50% [131]. Therefore, common method bias was deemed to be a non-issue. The Variance Inflation Factor (VIF) was also used to test for common method bias, as recommended by Ref. [132]. The PLS algorithm was applied and showed that the VIF values for all constructs were below the threshold of 3.3, indicating that the instrument used in this study is free from common method bias.

### 4.2. Measurement model assessment

The construct validity and reliability were assessed to evaluate the measurement model, in line with the recommendations of Ref. [118]. This involved evaluating both convergent and discriminant validity. Cronbach's alpha (CA) and composite reliability (CR) were used to assess the internal consistency of the measurement items, with a benchmark value of 0.70 considered satisfactory for exploratory research studies. As shown in Table 1, the results revealed CA values ranging from 0.855 to 0.913 and CR values ranging from 0.896 to 0.935, exceeding the benchmark value of 0.70. Thus, the internal consistency reliability is confirmed. Additionally, all AVE values were higher than 0.50, confirming convergent validity. This study assessed discriminant validity (DV) using the Heterotrait–Monotrait (HTMT) ratio of correlations, as recommended by Ref. [133]. As depicted in Table 2, DV was confirmed, as all values were below the threshold criterion of 0.85 (HTMT <0.85).

### 4.3. Structural model assessment

The PLS-SEM technique was utilized in this study, and a bootstrapping procedure with 5000 iterations was employed to test the

**Table 1**
Measurement model assessment results.

| Constructs | Items | Factor Loadings | CA | CR | AVE |
|---|---|---|---|---|---|
| Cloud computing integration | CCINT1 | 0.753 | 0.882 | 0.914 | 0.679 |
| | CCINT2 | 0.841 | | | |
| | CCINT3 | 0.833 | | | |
| | CCINT4 | 0.844 | | | |
| | CCINT5 | 0.846 | | | |
| Compatibility | CMP1 | 0.809 | 0.864 | 0.902 | 0.647 |
| | CMP2 | 0.829 | | | |
| | CMP3 | 0.825 | | | |
| | CMP4 | 0.823 | | | |
| | CMP5 | 0.733 | | | |
| Complexity | CMX1 | 0.745 | 0.864 | 0.902 | 0.649 |
| | CMX2 | 0.812 | | | |
| | CMX3 | 0.821 | | | |
| | CMX4 | 0.836 | | | |
| | CMX5 | 0.811 | | | |
| Competitive pressure | CPP1 | 0.809 | 0.871 | 0.911 | 0.720 |
| | CPP2 | 0.871 | | | |
| | CPP3 | 0.842 | | | |
| | CPP4 | 0.872 | | | |
| Cost reduction | CTS1 | 0.780 | 0.855 | 0.896 | 0.632 |
| | CTS2 | 0.784 | | | |
| | CTS3 | 0.816 | | | |
| | CTS4 | 0.788 | | | |
| | CTS5 | 0.808 | | | |
| Environmental performance | ENVS1 | 0.871 | 0.869 | 0.911 | 0.719 |
| | ENVS2 | 0.891 | | | |
| | ENVS3 | 0.857 | | | |
| | ENVS4 | 0.768 | | | |
| Financial performance | FIS1 | 0.856 | 0.880 | 0.917 | 0.734 |
| | FIS2 | 0.870 | | | |
| | FIS3 | 0.868 | | | |
| | FIS4 | 0.832 | | | |
| Government support | GVS1 | 0.816 | 0.902 | 0.927 | 0.717 |
| | GVS2 | 0.846 | | | |
| | GVS3 | 0.856 | | | |
| | GVS4 | 0.860 | | | |
| | GVS5 | 0.856 | | | |
| IT readiness | ITR1 | 0.827 | 0.894 | 0.921 | 0.701 |
| | ITR2 | 0.836 | | | |
| | ITR3 | 0.839 | | | |
| | ITR4 | 0.818 | | | |
| | ITR5 | 0.866 | | | |
| Relative advantage | RLA1 | 0.846 | 0.899 | 0.925 | 0.711 |
| | RLA2 | 0.835 | | | |
| | RLA3 | 0.847 | | | |
| | RLA4 | 0.855 | | | |
| | RLA5 | 0.833 | | | |
| Social performance | SOS1 | 0.874 | 0.882 | 0.918 | 0.737 |
| | SOS2 | 0.858 | | | |
| | SOS3 | 0.846 | | | |
| | SOS4 | 0.854 | | | |
| Top management support | TMS1 | 0.857 | 0.913 | 0.935 | 0.741 |
| | TMS2 | 0.863 | | | |
| | TMS3 | 0.852 | | | |
| | TMS4 | 0.857 | | | |
| | TMS5 | 0.876 | | | |

**Table 2**
Heterotrait-monotrait ratio (HTMT).

| | CCINT | COM | CPP | CMX | CST | ENVS | FIS | GVS | ITR | RLA | SOS | TMS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CCINT | | | | | | | | | | | | |
| COM | 0.553 | | | | | | | | | | | |
| CPP | 0.388 | 0.553 | | | | | | | | | | |
| CMX | 0.594 | 0.789 | 0.522 | | | | | | | | | |
| CST | 0.568 | 0.603 | 0.563 | 0.583 | | | | | | | | |
| ENVS | 0.464 | 0.510 | 0.478 | 0.484 | 0.542 | | | | | | | |
| FIS | 0.453 | 0.465 | 0.463 | 0.502 | 0.498 | 0.762 | | | | | | |
| GVS | 0.511 | 0.528 | 0.707 | 0.519 | 0.585 | 0.539 | 0.450 | | | | | |
| ITR | 0.338 | 0.560 | 0.693 | 0.478 | 0.514 | 0.493 | 0.456 | 0.634 | | | | |
| RLA | 0.510 | 0.584 | 0.473 | 0.707 | 0.528 | 0.424 | 0.486 | 0.425 | 0.372 | | | |
| SOS | 0.325 | 0.305 | 0.345 | 0.363 | 0.289 | 0.599 | 0.650 | 0.285 | 0.294 | 0.340 | | |
| TMS | 0.461 | 0.404 | 0.398 | 0.497 | 0.526 | 0.494 | 0.471 | 0.439 | 0.390 | 0.514 | 0.372 | |

proposed relationships. Table 3 presents the results of the structural model. It can be seen that the model explains 42% of the variance in cloud computing integration, 17% of financial performance, 17.4% of environmental performance, and 9% of social performance. As expected, the results show that the relative advantage (H1, $\beta = 0.105$, $t = 1.960$), complexity (H2, $\beta = -0.174$, $t = 2.971$), compatibility (H3, $\beta = 0.148$, $t = 2.745$), cost reduction (H4, $\beta = 0.188$, $t = 4.074$), top management support (H5, $\beta = 0.114$, $t = 2.515$), and government support (H8, $\beta = 0.230$, $t = 4.090$) significantly influence cloud computing integration. However, the effects of IT readiness (H6) and competitive pressure (H7) on cloud computing integration were not significant. Additionally, the positive influence of cloud computing integration on environmental performance (H9, $\beta = 0.418$, $t = 10.348$), financial performance (H10, $\beta = 0.413$, $t = 9.789$), and social performance (H11, $\beta = 0.301$, $t = 7.995$) is supported by the findings.

The study also assessed the effect size ($f^2$) using the thresholds established by Ref. [134], where 0.02, 0.15, and 0.35 indicate small, medium, and large effects, respectively. The results in Table 3 indicate that the effect sizes range from small to medium. However, competitive pressure and IT readiness do not significantly impact cloud computing integration.

### *4.4. Structural model robustness check*

PLS-SEM has become a standard tool for analyzing complex interrelationships between observable and latent variables [118]. Ensuring the robustness of the structural model is crucial. To address endogeneity concerns, it is recommended to employ the Gaussian copula method, as suggested by Hair et al. [118]. Endogeneity, which can arise from omitted variables, measurement error, and simultaneity, can lead to inaccurate inferences and biased estimates of variable relationships [120,135]. Thus, this research employed the Gaussian copula method by utilizing SmartPLS 4-based bootstrapping (with 5000 samples) to assess potential endogeneity, thereby improving the validity and reliability of the results.

The research model examined the effects of TOE factors on cloud computing integration and their subsequent impact on environmental performance, financial performance, and social performance. After accounting for endogeneity, none of the investigated factors showed a statistically significant impact on cloud computing integration at the 0.05 level. Additionally, after controlling for endogeneity, cloud computing integration did not demonstrate a statistically significant impact on environmental performance, financial performance, or social performance at the 0.05 level. As shown in Table 4, the final test results indicated that the explanatory variables in the model were not significantly endogenous. This observation proves that endogeneity bias is not a substantive concern in this research.

### *4.5. Artificial neural network analysis*

In this phase, the significant independent variables identified by the SEM are utilized to develop ANN models. Four sets of ANN

**Table 3**
Structural model results.

| H | Structural path | Path coefficient | *t*-value | *p*-values | Decision | $f^2$ | VIF | $R^2$ |
|---|---|---|---|---|---|---|---|---|
| 1 | Relative advantage → cloud computing integration | 0.105 | 1.960 | 0.025 | Accepted | 0.010 | 1.850 | 0.420 |
| 2 | Complexity → cloud computing integration | −0.174 | 2.971 | 0.001 | Accepted | 0.022 | 2.414 | |
| 3 | Compatibility → cloud computing integration | 0.148 | 2.745 | 0.003 | Accepted | 0.017 | 2.196 | |
| 4 | Cost reduction → cloud computing integration | 0.188 | 4.074 | 0.000 | Accepted | 0.034 | 1.784 | |
| 5 | Top management support → cloud computing integration | 0.114 | 2.515 | 0.006 | Accepted | 0.015 | 1.486 | |
| 6 | IT readiness → cloud computing integration | −0.081 | 1.597 | 0.055 | Rejected | 0.006 | 1.896 | |
| 7 | Competitive pressure → cloud computing integration | −0.061 | 1.137 | 0.128 | Rejected | 0.003 | 2.092 | |
| 8 | Government support → cloud computing integration | 0.230 | 4.090 | 0.000 | Accepted | 0.046 | 1.980 | |
| 9 | Cloud computing integration → environmental performance | 0.418 | 10.348 | 0.000 | Accepted | 0.211 | 1.000 | 0.174 |
| 10 | Cloud computing integration → financial performance | 0.413 | 9.789 | 0.000 | Accepted | 0.205 | 1.000 | 0.170 |
| 11 | Cloud computing integration → social performance | 0.301 | 7.995 | 0.000 | Accepted | 0.099 | 1.000 | 0.090 |

**Table 4**
Summary of Gaussian Copula results.

| Explanatory variable path | Path coefficient | *p*-values |
|---|---|---|
| GC (Relative Advantage) → Cloud Computing Integration | −0.197 | 0.180 |
| GC (Complexity) → Cloud Computing Integration | −0.038 | 0.435 |
| GC (Compatibility) → Cloud Computing Integration | −0.340 | 0.072 |
| GC (Top Management Support) → Cloud Computing Integration | −0.247 | 0.056 |
| GC (Cost Reduction) → Cloud Computing Integration | 0.010 | 0.478 |
| GC (IT Readiness) → Cloud Computing Integration | 0.461 | 0.062 |
| GC (Competitive Pressure) → Cloud Computing Integration | 0.156 | 0.275 |
| GC (Government Support) → Cloud Computing Integration | 0.099 | 0.291 |
| GC (Cloud Computing Integration) → Environmental Performance | 0.037 | 0.442 |
| GC (Cloud Computing Integration) → Financial Performance | −0.151 | 0.288 |
| GC (Cloud Computing Integration) → Social Performance | 0.038 | 0.433 |

models are created, each focusing on one of the endogenous constructs: cloud computing integration, financial performance, environmental performance, and social performance. The first ANN model (Fig. 2) includes six constructs in the input layer: "relative advantage, complexity, compatibility, top management support, cost reduction, and government support". Cloud computing integration is placed as the output layer. In the second, third, and fourth ANN models, cloud computing integration is added as the input layer, while environmental performance, financial performance, and social performance are predicted by the output layer individually.

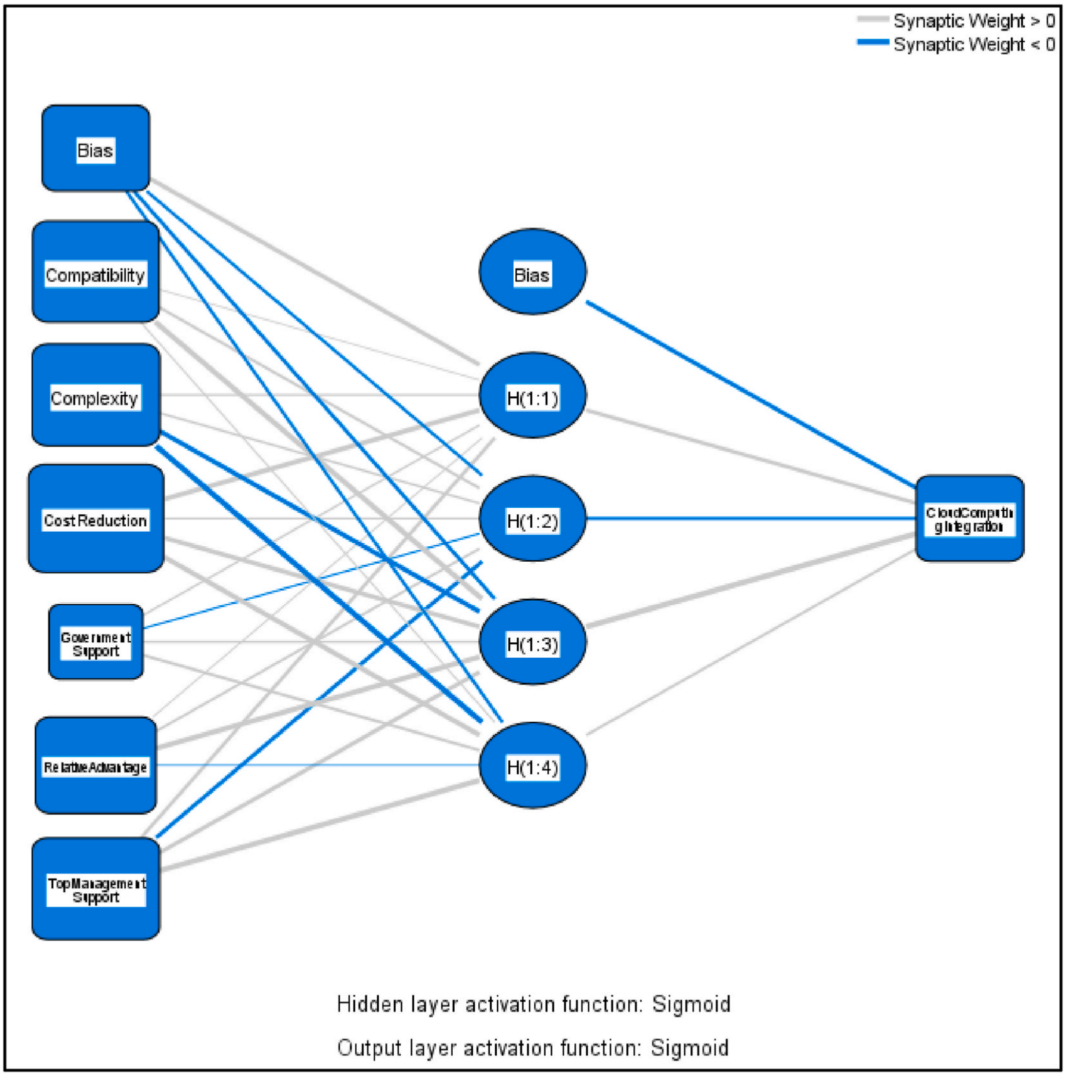


**Fig. 2.** ANN model A.

Figs. 3–5 illustrate the input and output layers of the second, third, and fourth ANN models.

The efficiency of the network models is assessed by checking the root mean square error (RMSE). Ooi et al. [114] argued that a smaller RMSE value indicates a better predictive ability of the ANN model. As demonstrated in Table 5, the mean values of RMSE in model A (training = 0.126, testing = 0.117), model B (training = 0.150, testing = 0.136), model C (training = 0.152, testing = 0.155), and model D (training = 0.161, testing = 0.155). The high reliability using ANN models is used to detect linear-nonlinear relationships [73].

### 4.6. Sensitivity analysis

By conducting a sensitivity analysis, the relative significance of the predictors has been determined and ranked based on their normalized values. As shown in Table 6, complexity, with normalized importance of 89.14%, is ranked the first among other factors affecting cloud computing integration in SMEs. This is followed by cost reduction (NI = 82.67%), government support (NI = 73.37%), compatibility (NI = 70.02%), top management support (NI = 52.43%), and relative advantage (NI = 48.72%).

## 5. Discussion

Companies, especially SMEs, can benefit from cloud computing in many ways, and it can help them perform more sustainably. This study investigated the technological, organizational, and environmental determinants and sustainable outcomes of cloud computing integration in SMEs. Furthermore, the study used the ANN approach to rank the influence of the TOE factors. The PLS findings revealed that relative advantage, complexity, compatibility, top management support, cost reduction, and government support significantly influence cloud computing integration among SMEs. The PLS results also confirmed the significant impacts of cloud computing integration on financial, environmental, and social performance. According to ANN results, complexity has the greatest influence among the six significant drivers of cloud computing integration, followed by cost reduction, government support, compatibility, top management support, and relative advantage.

### 5.1. Technological context

The findings confirmed the significant influences of all technological factors. The significant influence of relative advantage on cloud computing integration aligns with the findings of [55,63], who found a positive association between relative advantage and cloud computing. This finding implies that awareness of cloud computing benefits, such as improving business operations, facilitating faster task completion, enhancing the quality of operations, increasing production, and facilitating access to information anywhere and at any time, motivates SMEs to implement cloud computing. Accordingly, cloud computing vendors and service providers should communicate the benefits of cloud computing with SME managers. Vendors and governments should provide awareness programs on cloud computing benefits for SME managers to gain support and commitment.

We found complexity as an inhibitor in SMEs' integration of cloud computing. This finding aligns with the studies on technology adoption among SMEs [59–61]. Contrary to our result, Low et al. [136] found that complexity does not significantly affect cloud computing adoption. The majority of their sample consisted of large firms, and the size of the firms is likely to explain this contrary

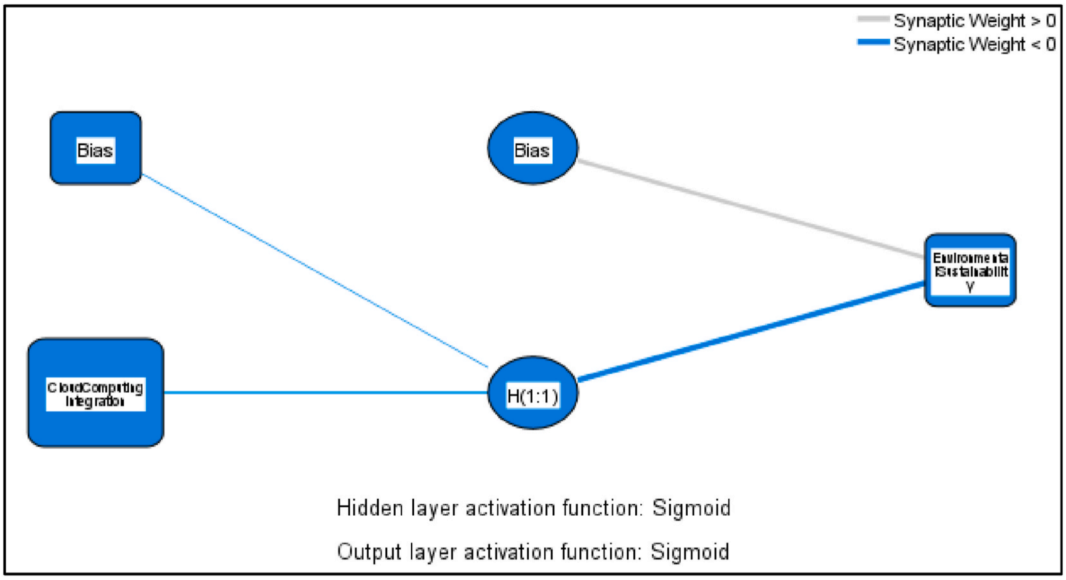


**Fig. 3.** ANN model B.

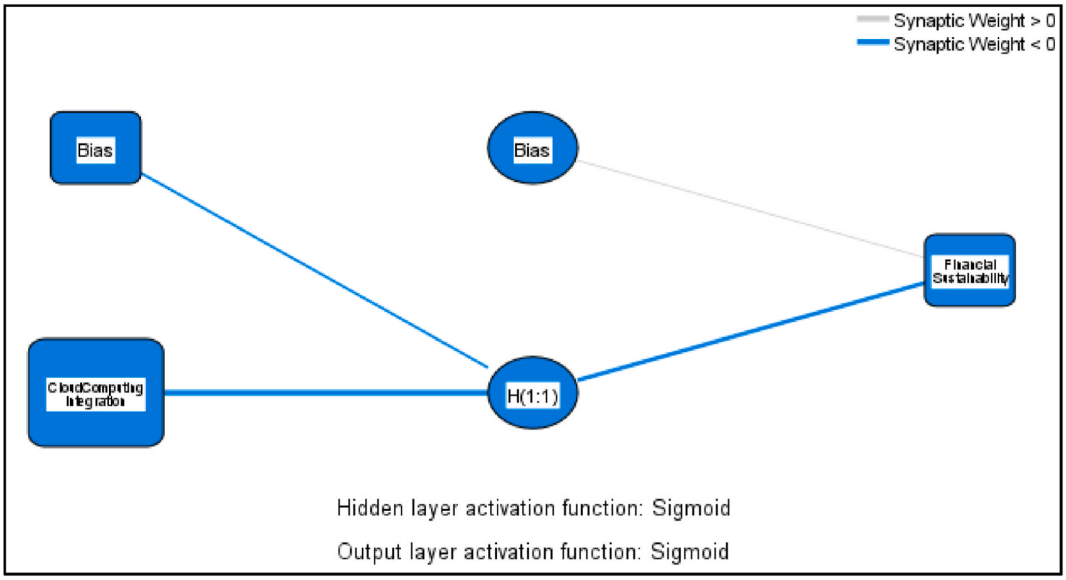


**Fig. 4.** ANN model C.

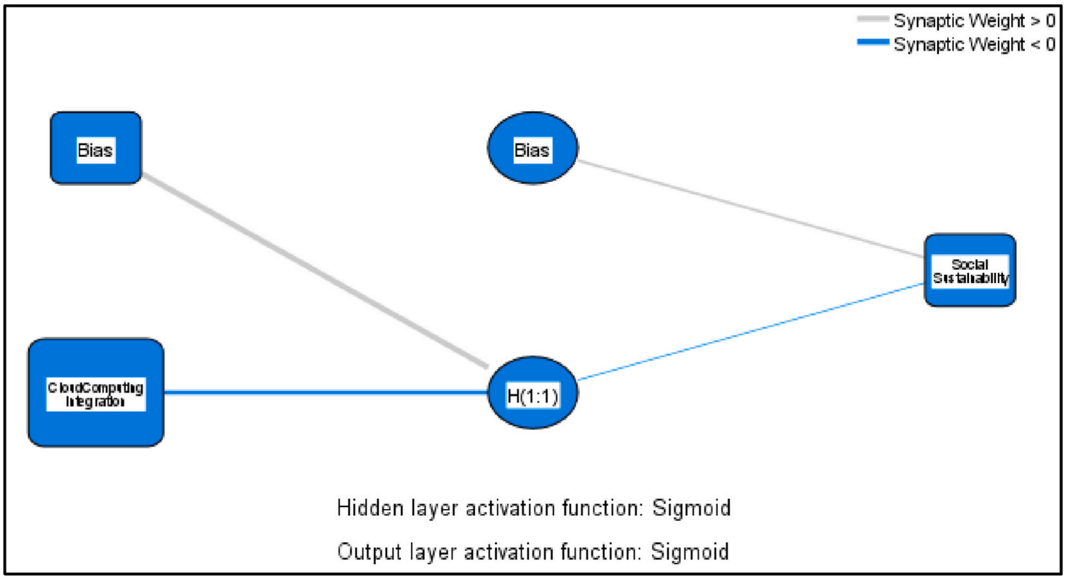


**Fig. 5.** ANN model D.

result. Asiaei and Nor [58] stated that the lack of in-house expertise makes adopting new technologies challenging for SMEs. A lack of confidence among SME managers in the ability of their firms to successfully implement cloud computing is a potential reason for the significant influence of complexity on cloud computing integration in SMEs. ANN results revealed that complexity is the most influential determinant of cloud computing integration. Accordingly, vendors should give special attention to the complexity and provide technical support and training programs to address the concerns of SME managers regarding the complexity of cloud computing integration.

The study found compatibility as a significant driver of cloud computing integration, which is consistent with previous research [11,64–66]. Technology that is incompatible with existing processes and practices requires large adjustments that require human skill and experience [48,67,136]. Lack of consistency between cloud computing and the current technical architecture and work style of SMEs may make its integration challenging, as SMEs may not be able to address the potential implementation problems due to a lack of human skills. As such, governments and vendors should play a role and address managers' concerns concerning the difficulty of integration caused by incompatibility.

According to findings, cost reduction significantly influences cloud computing integration. The use of cloud computing can reduce

**Table 5**
RMSE values.

| Network | Model A | | Model B | | Model C | | Model D | |
|---|---|---|---|---|---|---|---|---|
| | RMSE (Training) | RMSE (Testing) | RMSE (Training) | RMSE (Testing) | RMSE (Training) | RMSE (Testing) | RMSE (Training) | RMSE (Testing) |
| 1 | 0.1296 | 0.1212 | 0.1491 | 0.1184 | 0.1500 | 0.1620 | 0.1583 | 0.1687 |
| 2 | 0.1237 | 0.1275 | 0.1457 | 0.1662 | 0.1530 | 0.1406 | 0.1582 | 0.1683 |
| 3 | 0.1258 | 0.1102 | 0.1544 | 0.1535 | 0.1568 | 0.1450 | 0.1606 | 0.14614 |
| 4 | 0.1281 | 0.1118 | 0.1493 | 0.1343 | 0.1494 | 0.1741 | 0.1630 | 0.1517 |
| 5 | 0.1249 | 0.1200 | 0.1488 | 0.1395 | 0.1513 | 0.1572 | 0.1662 | 0.1237 |
| 6 | 0.1225 | 0.1201 | 0.1488 | 0.1395 | 0.1523 | 0.1658 | 0.1598 | 0.1537 |
| 7 | 0.1256 | 0.1139 | 0.1559 | 0.1351 | 0.1536 | 0.1280 | 0.1597 | 0.1563 |
| 8 | 0.1300 | 0.1185 | 0.1492 | 0.1291 | 0.1557 | 0.1774 | 0.1655 | 0.1307 |
| 9 | 0.1257 | 0.1030 | 0.1510 | 0.1203 | 0.1513 | 0.1467 | 0.1595 | 0.1570 |
| 10 | 0.1191 | 0.1206 | 0.1517 | 0.1198 | 0.1507 | 0.1562 | 0.1580 | 0.1929 |
| Mean | 0.1255 | 0.1167 | 0.1504 | 0.1356 | 0.1524 | 0.1553 | 0.1609 | 0.1549 |
| Standard deviation | 0.0032 | 0.0069 | 0.0029 | 0.0153 | 0.0024 | 0.0154 | 0.0030 | 0.0196 |

**Table 6**
Sensitivity analysis.

| Network | Compatibility | Complexity | Cost reduction | Government support | Relative advantage | Top management support |
|---|---|---|---|---|---|---|
| 1 | 0.185 | 0.189 | 0.218 | 0.058 | 0.162 | 0.188 |
| 2 | 0.098 | 0.253 | 0.234 | 0.204 | 0.111 | 0.100 |
| 3 | 0.120 | 0.254 | 0.193 | 0.220 | 0.118 | 0.095 |
| 4 | 0.293 | 0.232 | 0.075 | 0.194 | 0.046 | 0.161 |
| 5 | 0.196 | 0.186 | 0.140 | 0.159 | 0.157 | 0.162 |
| 6 | 0.170 | 0.170 | 0.213 | 0.207 | 0.095 | 0.144 |
| 7 | 0.231 | 0.197 | 0.144 | 0.225 | 0.070 | 0.134 |
| 8 | 0.120 | 0.251 | 0.265 | 0.200 | 0.134 | 0.031 |
| 9 | 0.116 | 0.263 | 0.262 | 0.135 | 0.119 | 0.106 |
| 10 | 0.149 | 0.175 | 0.246 | 0.178 | 0.138 | 0.114 |
| Mean Importance | 0.1677 | 0.2170 | 0.1989 | 0.1778 | 0.1150 | 0.1234 |
| Normalized Importance % | 70.02% | 89.14% | 82.67% | 73.37% | 48.72% | 52.43% |
| Ranking | 4 | 1 | 2 | 3 | 6 | 5 |

the costs of investment in in-house systems, purchasing and upgrading software applications, and the costs of operations, resources, and staff [70,72,137]. As SMEs have a low tolerance for the costs and risks associated with IT investments, the desire to reduce costs and expenditures motivates them to adopt cloud-based solutions. By adopting cloud computing, SMEs can only pay for the services they use. According to ANN results, cost reduction is the second most influential driver of cloud computing integration. As such, cloud computing service providers should provide flexible pricing models and emphasize in their marketing campaigns how cloud computing can reduce the costs of SMEs.

### *5.2. Organizational context*

Among the tested organizational factors, top management support significantly influenced cloud computing, and the impact of IT readiness was not supported. The importance of top management support in cloud computing adoption was supported in previous studies [75,76]. The earlier studies on SMEs also confirmed the critical role of top management support in technology implementation [70,73,80]. Top managers play a key role in determining whether cloud computing should be adopted, and their vision determines the level of support and resources given to cloud computing integration. Cloud computing can be effectively implemented when managers provide the necessary resources and support.

The effect of IT readiness on cloud computing was not supported. Low et al. [136] also found an insignificant relationship between technological readiness and cloud computing adoption. This result is inconsistent with the findings of [72,73], who found that adequate technological and computer-literate human resources significantly influence big data implementation. The contradictory findings between cloud computing and big data studies regarding the importance of technological readiness can be explained by the nature of these technologies. Firms need to have sufficient technological infrastructures, such as the Internet of Things (IoT) and sensors, to gain quality data and consequently benefit from investments in big data. As such, technological readiness is a crucial factor in implementing big data analytics. On the other hand, firms heavily invested in in-house technological infrastructures are less likely to require cloud services as they currently possess the necessary infrastructure. As such, a high technological readiness level may not lead to higher cloud computing adoption. Furthermore, a key advantage of cloud computing is accessing systems and software applications without investing heavily in hardware or software. As such, the lack of technological readiness may not be an obstacle to implementing cloud computing. Instead, it may motivate SMEs to implement and take advantage of cloud computing.

### 5.3. Environmental context

According to the findings, competitive pressure did not significantly impact cloud computing integration among SMEs. This finding does not align with the results of [88,89]. Two reasons may explain the insignificant impact of competitive pressure. First, as many SMEs provide products and services to large companies, implementing cloud computing is driven more by stakeholder demands than competition. This means they are more concerned with satisfying their current customers than competing with other firms for new clients. As such, competitive pressure does not significantly affect their decision to integrate cloud computing. Second, SMEs with sufficient in-house infrastructure may believe their current infrastructure is suitable to compete with other firms. Accordingly, competitive pressure may discourage them from adopting cloud computing, especially if they are concerned about security issues. Oliveira et al. [55] also found an insignificant relationship between competitive pressure and cloud computing adoption.

The results indicated that government support significantly impacted cloud computing integration. The importance of government support has been highlighted in previous studies on SMEs [94,95]. Ghobakhloo et al. [138] stated that lack of government support is one of the major barriers to SMEs' adoption of digital technologies. Adopting new technologies by small and medium-sized businesses is often challenging due to various factors, such as lack of knowledge and resources. As a result, government support for technology adoption becomes essential. Governments can support SMEs by providing financial support, infrastructure (e.g., high-quality broadband), supportive regulatory environments, and training and upskilling services [48,96].

### 5.4. Sustainable performance

The findings revealed that integrating cloud computing significantly improves SMEs' financial, environmental, and social performance. Cloud computing enhances the financial performance of SMEs by providing inexpensive and scalable on-demand hardware and software infrastructures and access to the latest technologies, reducing operational and human capital costs, enhancing the efficiency and effectiveness of operations, facilitating collaboration among stakeholders, accelerating time to market, and enabling SMEs to focus on their core operations [49,102,103]. As such, SMEs can achieve greater financial success and profitability by using cloud computing.

The study found that cloud computing integration has a significant influence on the environmental performance of SMEs. Cloud computing may directly or indirectly boost environmental performance. It can directly reduce the carbon footprints of SMEs by reducing the energy consumption of IT infrastructures by outsourcing them, reducing transportation emissions and office energy consumption by facilitating remote work, and optimizing resource consumption by providing affordable access to the latest technologies [3,49,100,101]. Cloud computing may indirectly enhance the environmental performance of SMEs by facilitating collaboration among supply chain members through the development process [3,101].

The study also confirmed the influence of cloud computing integration on the social performance of SMEs. Cloud computing can enhance SMEs' social performance by enhancing employee and customer satisfaction and reducing environmental impacts and risks to the public. By using cloud computing, SMEs can deliver better, more reliable, and faster services to customers with a greater degree of personalization, consequently enhancing their experience and satisfaction level. Cloud computing may improve the satisfaction of employees by enhancing work flexibility. By allowing employees to work from anywhere and anytime, SMEs can support employees with diverse backgrounds and needs, such as those with disabilities or family responsibilities, consequently enhancing their working experience.

## 6. Research implications

### 6.1. Theoretical contributions

The study contributes to the body of knowledge on cloud computing in several ways. First, the study assessed the influences of TOE factors on cloud computing integration among SMEs in Malaysia. Out of the TOE factors, the PLS revealed that six factors, namely relative advantage, complexity, compatibility, top management support, cost reduction, and government support, significantly affect cloud computing integration among SMEs. It is worth highlighting that all considered technological factors play a significant role. Second, the study used a hybrid approach to identify and rank predicting factors. PLS identifies significant relationships using a linear approach. ANN ranks the influence of factors using a non-linear approach. Previous studies argued that ANN is a more accurate approach to ranking the importance of factors and can serve as a complementary technique to PLS [73,122]. This study is one of the first to use the PLS-ANN approach to rank factors influencing cloud computing integration. ANN results indicate that the top three influential factors are complexity, cost reduction, and government support. Third, although previous studies have argued that cloud computing can contribute to the financial, environmental, and social performance of firms [49,102,103], there is a lack of empirical support for these influences. This study empirically demonstrated that cloud computing positively impacts SMEs' financial, environmental, and social performance.

### 6.2. Practical implications

From a practical perspective, the study provides directions to SME managers, governments, and cloud computing service providers. The study showed that complexity, cost reduction, government support, compatibility, top management support, and relative advantage are SMEs' most influential determinants of cloud computing integration. Governments and service providers should play a significant role in addressing complexity concerns as the most influential factor. Cloud computing designers should provide a user-friendly platform. To make cloud computing more user-friendly, the interface should be similar to common systems that the target users are familiar with and have experience with. Service providers should provide training programs and guarantee access to technical assistance. The government could also provide training and skill-up programs to tackle the complexity concerns. Cost reduction, the second most influential factor, should be communicated properly with SMEs. Service providers should highlight the cost-saving potential of using cloud computing in their marketing campaigns. Furthermore, they should provide flexible pricing models that allow SMEs to pay only for the services they use. The role of government support, the third most influential factor, demonstrates the importance of government incentives, training services, supportive regulatory environments, and investment in infrastructure in the diffusion of cloud computing among SMEs. Additionally, we found compatibility, top management support, and relative advantage as the other three influential drivers of cloud computing integration. Accordingly, service providers should highlight the advantages of cloud computing in their marketing campaigns, and governments should develop programs to raise managers' awareness of the benefits of cloud computing. Training and up-skilling programs may be an effective way of addressing the manager's compatibility concerns. Further, the study showed that cloud computing enhances SMEs' financial, environmental, and social performance. These findings may encourage SMEs to integrate cloud computing services into their business operations to achieve higher sustainable performance and enhance their competitive position.

### *6.3. Methodological contributions*

This research has made significant methodological contributions to the existing literature, particularly in the field of technology adoption. The integration of PLS-SEM and ANN presents an innovative methodological approach that offers numerous advantages. By leveraging the strengths of PLS-SEM, which excels at elucidating structural relationships among latent variables and managing complex models, and ANN, which is adept at capturing intricate non-linear associations, the hybrid method can achieve superior predictive accuracy. The improved accuracy can be attributed to the effective integration of linear and non-linear relationships, culminating in a comprehensive and robust model. Additionally, the hybrid approach demonstrates proficiency in handling multicollinearity, a prevalent issue in regression models, thereby improving the model's stability. Furthermore, the methodological implications of this hybrid approach include enhanced interpretability and validation. The transparent and interpretable path model provided by PLS-SEM, in conjunction with the advanced capabilities of ANN, enables researchers to capitalize on the strengths of both techniques while mitigating the "black box" nature of ANN. As a result, the integration of PLS-SEM and ANN represents a promising methodological advance with substantial implications for researchers in various fields. Additionally, this study conducted a supplementary analysis for structural model robustness checks by assessing potential endogeneity in the proposed research model using the Gaussian Copula approach. This technique enabled us to account for potential endogeneity issues. Consequently, by carrying out these supplementary analyses and addressing potential endogeneity with the Gaussian Copula approach, this study enhances the validity, reliability, and generalizability of its findings and the rigor of its methodological framework.

## 7. Conclusion

Cloud computing is a cutting-edge technology that can assist SMEs in achieving sustainable growth. Drawing on the TOE model, this research studied the technological, organizational, and environmental drivers of cloud computing integration and its influence on the sustainable performance of SMEs. The study gathered data from 415 SMEs in Malaysia. The data were analyzed through a hybrid SEM-ANN approach. According to PLS-SEM results, relative advantages, complexity, compatibility, top management support, cost reduction, and government support significantly affect cloud computing integration. The study empirically demonstrated that SMEs could achieve greater financial, environmental, and social performance by integrating cloud computing services. The ANN results indicated that complexity was the most significant driver of cloud computing integration. The study extended the literature by empirically assessing and ranking the determinants of cloud computing integration among SMEs. The findings provided directions for policymakers, SME managers, and cloud computing service providers.

There are some limitations to the study that provide directions for future research. Firstly, this study collected data from SMEs in Malaysia. The importance of determinants may differ depending on the business environment and the organizational readiness of SMEs. Accordingly, future studies are recommended to test the model of this study in other countries, especially developed ones, with different business environments (e.g., different competition levels and government support). Furthermore, studies can test the moderating effect of organizational and environmental factors, such as firm size, organizational readiness, competitive pressure, and government support. Additionally, there were no limitations to the participating SMEs in this study regarding their operating marketing. As the business model and independence of these SMEs in making decisions are different, future studies are recommended to limit their sample to either SMEs that operate business-to-business or business-to-customer markets or consider the moderating effect of operating market type. Testing the moderating effect of operating marketing type may provide an explanation for the insignificance of competitive pressure in this study.

## Author contribution statement

M. A. A., M. I., and M. A. conceived and designed the instruments. M. A. A. and A. I. A. performed the data collection. M. A. A. analyzed and interpreted the data. M. A. A., M. I., M. A., F. H., and N. J. contributed to the materials and analysis tools. All authors listed have significantly contributed to the writing of this article.

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## Declaration of interest's statement

The authors declare that they have no conflict of interest.

## Data availability

The data presented in this study are available on request from the authors.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

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