Fostering Sustainable Technological Development in SMES from Developing Nations Within the Framework of the Digital Economy and Resource-Constrained Environments

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Abstract

This research examines the direct influence of Digital Orientation (DO), the Internet of Things (IoT), and Digital Platforms (DP) on sustained Digital Innovation (DI) within the Digital Marketplace (DM) and resource-constrained environments. This study examined the mediating function of DP in these relationships. The study employed a quantitative approach, collecting data from 397 CEOs and managing executives of Small and Medium Enterprises (SMEs) in developing nations. Correlations and Structural Equation Modelling (SEM) methods were utilized for hypothesis analysis and testing. The findings indicated that DO, IoT, and Digital Platforms (DP) are significant precursors to sustained DI. The findings suggest that DP serves as an intermediary in the relationship between DO and sustained DI and the connection between IoT and sustained DI. Technological advancements have compelled company organizations to adopt innovative thinking and adjust their operational frameworks correspondingly. Sustainable DI (SDI) is a vital requirement of the current decade to address society's escalating expectations sustainably. Organizations, particularly SMEs, must navigate these obstacles and swift technology changes by employing cost-effective business strategies. Frugal innovation is a crucial component of SDI that allows SMEs to minimize resource consumption and waste while promoting sustainable economic activity. Thus, they cultivate and acquire benefits in this very competitive digital landscape. This inaugural research demonstrates the synergistic integration of DO, IoT, and digital mediums in fostering SDI within the rapidly growing digital industry.

Keywords: Small and Medium Enterprises; Digital Economy; Sustainability; Developing Country.

I. INTRODUCTION

The advent of Digital Innovation (DI) and technology can propel social and economic advancement (Cheng & Wang, 2022). Technological progress has transitioned the conventional commercial economy into a computerized framework, with the economic transformation heavily reliant on big data and modern technology. DI is no longer exclusive to software corporations; even the globe's most valuable businesses now operate in the Digital Economy (DE) (Wang et al., 2024).

The complexities and technical dynamism make attaining technological advancement in the DE challenging. All business types have these issues, particularly Small and Medium Enterprises (SMEs) (Melo et al., 2023). This technical advancement can optimize chances for SMEs. The alterations brought about by digital technologies in organizational business models provide a significant challenge for all entities, particularly for SMEs. The impact of digital transitions on SMEs as either an opportunity or an issue is contingent upon their strategic approach to addressing it. SMEs in the DE require DI to address significant problems and enhance technological proficiency. SMEs are crucial market players, particularly during structural transformation in the digital economy; thus, examining their capacity for sustainable management within this context is essential.

They still need to pay attention to specific significant and impactful precedents of sustained DI, such as Digital Platforms (DP), digital introductions, and the Internet of Things (IoT) (Basaure et al., 2020). Therefore, an extensive research study is necessary to address this study gap. The present study addresses the study gap and demonstrates that SMEs attain sustained technological growth by integrating Digital Orientations (DO), IoT, and DP (Kindermann et al., 2021). An examination by the World Economic Forum revealed that 84% of current IoT can facilitate and promote the attainment of the Sustainable Developmental Goals (SDGs) (Pizzi et al., 2020). Digitalization gives novel chances to attain SDGs. Industrial IoT is projected to substantially benefit the global economy by 2030, with potential increases when factoring in consumers and government IoT initiatives, such as innovative city projects.

Sustainable enterprises pursue individual and communal interests, focusing on social, economic, and ecological objectives. The alignment of sustainability objectives with digital technology has recently gained significance in business and governmental sectors. Yet, a research void exists in the academic domain about this particular subject. Digital sustainability refers to organizational initiatives that seek to achieve SDGs via DP applications. To address sustainability objectives, firms should pursue DI more intricately by building comprehensive business models centered on this purpose. Organizations significantly influence the management of the SDGs' significant problems within the global economic sector.

Embodying and operating "digital" is a critical prerequisite for attaining the SDGs. New digital business models allow supply chains to reduce needless waste and digitally alter how they generate long-term value and enhance customer relationships. Businesses evolve without adversely affecting the resource-constrained environment.

This study employed quantitative study methods and standardized pretested surveys for data collection. Correlation and Structural Equation Modeling (SEM) methods were employed for hypothesis analysis and testing (Moshagen & Bader, 2024). The indirect impact of the mediation study was performed using Process and the Sobel test. The research's goals were fulfilled by analyzing the firsthand experiences of 397 CEOs and Managing Directors.

II. BACKGROUND

Existing evidence indicates that SMEs recognize and are driven by these possible cost savings. According to a 2011 survey on EU business owners' attitudes toward ecological innovation (EI), 52% of SMEs regard high energy prices as a significant driver of EI, while 50% view anticipated

future rises in electricity prices as a crucial motivator. The significance of this factor fluctuates across different industries. In the ICT industry, lowering costs is a primary incentive, with SMEs providing new solutions to prolong the life of existing technology, conserve energy via cloud computing, and diminish electronic waste disposal expenses. This conclusion is evidenced by the eco-adopter category of SMEs in Europe, with 63% indicating resource efficiency as a cost-reduction strategy.

Almost two-thirds of SMEs report satisfaction with their returns on expenditures regarding resource efficiency. While comparable survey data for SMEs in emerging and developing nations is limited, research on ecological innovation in Brazil identifies the "economic necessity for business sustainability" as a critical driver of EI. The primary impetus, however, is the imperative to save Amazonian ecosystems, which are heavily dependent on local firms, and the enduring sustainability of essential resources is crucial for prolonged economic viability. This indicates that incentives for firms to adopt environmentally friendly practices differ by country.

The funding of SMEs will significantly impact numerous SMEs, most of whom cannot access banking services owing to the absence of robust financial service providers in the retail sector. The finance sector is essential for the advancement of the shadow economy. It facilitates utilizing the monetary supply through savings, available for national growth as capital to invest.

SMEs exhibit far more significant development and profitability variability than large firms by their inherent nature. The SME Growth Policy states that financing is essential for SMEs to establish and grow enterprises, innovate and acquire new products and personnel, or enhance production facilities and produce new commodities (Gherghina et al., 2020).

SMEs often express that more access to financing and elevated loan costs is needed to improve their growth and profitability. Recent trends in Latin America and East Asia demonstrate that SMEs are more prone to loan rejections during financial crises than significant corporations. The crucial contribution of SMEs to economic growth is widely acknowledged. In several countries, the significance of SMEs in the growth cycle continues to dominate policy discourse.

Government initiatives to promote the development of SMEs have been implemented at all levels. SMEs can evolve and counterbalance the economic power of more giant corporations, facilitating local and worldwide democratization and accelerating the established comprehensive economic and societal objectives, including poverty reduction, as seen in SMEs. The study indicates that SMEs constitute around 25% of imports from the research and 35% of imports from Asia.

This research is grounded in two principal theories: (1) the Theory of Invention and (2) the Dynamic Capacity Theory (DCT). The Theory of Innovation has three principal components: (1) Sector-specific Systems, (2) Technical Systems, and (3) Socio-Technical Systems. This study broadened the scope of these three factors of SDI. The Sectoral System emphasizes the pathways for sector-specific synergies to enhance performance and creativity, linking it to sustained technological advancement. A Technological System represents the progression of technology via the use of contemporary knowledge and expertise to improve overall innovation. A Socio-Technical System refers to transformative breakthroughs and transitional advancements grounded on technology to benefit humanity. The second foundation of the conceptual structure

is grounded in DCT, which pertains to businesses' abilities to be adaptable and inventive to attain sustained success. Timely modifications in a firm's plans and operations are essential for adopting innovative techniques to maintain success. SDI is the primary issue for companies functioning in today's changing resource-constrained environment. Figure 1 illustrates the theoretical basis of this investigation.

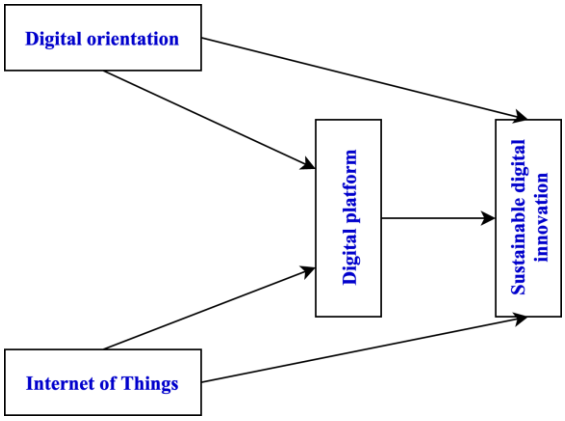

Figure 1: Relationship Analysis

III. MATERIALS AND METHODS

3.1. Data Collection

A cross-sectional design was employed to examine the relationships among the components of the proposed model. A representative group was identified using a list of SMEs sourced from the SME Developmental Authority and the Small Industrial Development Boards. Data were obtained from directors and managing members of SMEs through sampling for convenience.

Sampling is the technique that enables a researcher to deduce characteristics of a population based on data derived from a smaller subset of that group. The majority of empirical research employs non-probability as well as probability sampling methods, considering the characteristics of the population. Due to the unknown features of the group being studied for the current investigation, a technique known as non-probability sampling was employed to choose the sample from the relevant population. The data from developing nations will allow the research to apply to other emerging economies.

The organization of SMEs differs from that of large firms and has distinct characteristics. SMEs are essential for the economic growth of both industrialized and developing nations. SMEs in developing nations significantly enhance the living standards of individuals by providing over 75% of the GDP. Approximately 82% of developing nations' workforce is engaged by SMEs, constituting almost 90% of the country's total economic entities. Given the transition from a conventional to a DE, it is urgent to revise the framework of SMEs to adapt to rising economies. The present study focused on SMEs and experimentally examined the correlation between their DO and sustained DI. SMEs were assessed via their business internet pages, online purchasing connections, e-commerce platforms, and other DO.

The SMEs were chosen for the data gathering, and the data were gathered from those SMEs in developing nations' provinces. Four distinct criteria were established for data collection. For six years, SMEs have had to engage in online commercial operations for a comprehensive DO. SMEs possess their websites. SMEs want to employ more than 100 individuals. SMEs must establish an IT Department responsible for enhancing their digital infrastructure.

Information was gathered with the assistance of four competent assistants for research. The research helpers were able to collect 397 valid replies. The questionnaire consisted of two sections. Section 1 had three inquiries: responder age, level of education, and experience. Section 2 posed inquiries regarding digital introductions, the IoT, DP, and SDI. All measures were assessed with a 5-point Likert scale ranging from "Strongly Disagree (SD) = 1" to "Strongly Agree (SA) = 5."

The Likert scale is extensively utilized in quantitative studies as a standardized data-gathering method readily understandable to participants. The structured scale enables participants to select the choice that reflects their views and opinions on an idea or issue. The research employed the Likert scale in the present study due to its quantitative research methodology.

3.2. Measures

The research utilized pre-tested components from other studies to ensure the validity and dependability of the scales employed in this study.

- ***DO***

DO enables a company to embrace digital methods and use contemporary technology through practical guidance. Using digital technology allows SMEs to achieve the advantages of being first movers in the operating sector. DO was assessed using a four-item scale.

- ***IoT***

The IoT is a technical innovation facilitating global interaction and connection through the Internet and interconnected gadgets. The IoT is one of the most effective instruments for executing all corporate operations. The IoT was assessed using a nine-item scale. Most of the IoT-related questions included in the survey are closely aligned with SDI.

- ***Digital Platform***

DP denotes online interfaces that link various companies and facilitate the regulation of interactions for reciprocal advantages. The DP was assessed using an eight-item assessment.

- ***SDI***

SDI facilitates the use of cutting-edge digital technologies to develop innovative solutions that solve financial, social, and ecological business challenges in the long term. It is a predominant amalgamation of digital technology and organizational structure aimed at sustainably developing corporate operations grounded in EI. The components of sustainable technological development were modified to emphasize cost reduction for SMEs and waste minimization, considering the resource shortage prevalent in developing nations.

3.3. Fuzzy Method

In recent years, the fuzzy Analytical Hierarchy Procedure (AHP) has demonstrated significant advantages in many decision-making criteria inside fuzzy contexts. The extensive data employs

a precise point estimate technique for deriving priorities in fuzzy AHP, including extension analysis and quadratic Fuzzy Preference Processing (FPP). Fuzzy AHP was developed to handle ambiguous and personal input information more effectively than classic Multi-Criteria Decision Making (MCDM) methods. Fuzzy AHP employs the concept of fuzzy sets to aid scientists and managers in transforming vague and ambiguous linguistic inputs from specialists, like "a lot more significant," into precise decision ranges that are more manageable for choice-makers. This is an essential aspect to evaluate thoroughly as the picking of projects grows globally.

3.4. Variables Analyzed

The analysis encompassed the following factors:

- Employed technological remedies: Participants were offered a selection of 15 distinct electronic devices and were permitted to identify which ones they now utilize. The methods encompassed existing solutions such as websites and futuristic innovations, including blockchain, 3-D printing, and industry and service robots.
- Outcomes of digitization: The research analyzed the objectives businesses sought to attain through digitization, encompassing effortless remote work, more significant data accessibility, enhanced operational quality and effectiveness, distinction, cultural transformation, and incorporation into supply chains.
- The difficulties experienced by businesses: The research evaluated the obstacles faced during the digitization process. Primary obstacles were the need for money for digitization and more qualified personnel. The study assessed the financial dimensions of digitization, encompassing initial expenditures and recurring maintenance expenses.
- Support requirements for digitization: The research examined the support requirements for businesses in multiple facets of digitalization, encompassing the formulation of the digitization strategy, augmentation of staff digital skills and expertise, funding digital initiatives, the digitalization procedure, the application of electronic solutions, and the identification of appropriate service providers.

IV. RESULTS AND DISCUSSIONS

The research employed descriptive statistics, correlation analysis, and SEM to evaluate the hypotheses. To examine the intermediary function of digital platforms. This research employed correlation, descriptive association, multiple linear regression approaches, and SEM to analyze the data in developing nations. Corrective factor evaluation assessed the discriminant reliability utilizing AMOS 7.0 software. The objective of the current investigation was to identify the linear correlations among the variables included in the proposed model. To analyze the linear connections, the research utilized a covariance method. A covariance-based method quantifies the simultaneous variation of two random factors. Variance-based methods indicate the dispersion of a dataset relative to its implies, whereas covariance-based methods assess the directional connection between research variables.

The construct's dependability was assessed using Cronbach's alpha value. The findings indicate that the approach is well-calibrated based on the information presented. The construct's

dependability was assessed employing Cronbach's alpha value. The findings suggest that the model is appropriately aligned with the data.

4.1. Measurement

Confirmatory Factor Analysis (CFA) assessed contract reliability and model adequacy. The dependability, discriminant validity, and convergence validity were adequate. The dependability was validated, ranging from 0.68 to 0.79, indicating that the model employed in this study is dependable. Discriminant reliability and concept validity were established by confirmatory factor analysis, with factor loadings exceeding 0.75. The research has used a method to assess the Averaged Variance Extraction (AVE), and the findings indicate that the AVE value is above 0.50, while Cronbach's alpha is more significant than 0.70.

4.2. Correlation Results

Quantitative evaluation aids in comprehending the interrelationship of variables, whereas correlation indicates the degree of link. The research identifies SDI as the factor that depends, with the primary independent factors being IoT and digital approach. To evaluate the impact of unrelated factors on DI, it is essential to assess correlation. This study performed a correlation study. The results demonstrated a favorable correlation between DO and sustained innovation in technology. The results expanded upon a prior hypothesis recognizing DO as a determinant of intangible qualities. The research posited that the IoT is connected to SDI, and the correlation findings demonstrated a favorable association between IoT and SDI. The IoT cultivates platforms and enhances technological advancements. The DP is strongly correlated with sustained DI.

The DP establishes an ecosystem as the primary catalyst for technological advancement. The research employed Variation in Inflation Factors (VIF) to mitigate the danger of convergence. The VIF scores were below the cutoff threshold of 10.0. Therefore, multicollinearity is not a concern in the study.

4.3. The Mediating Function of DP in the Relationship between DO and SDI

A considerable value of the indirect impact validates the mediator's function. The findings indicate that the DP intermediates DO and sustained DI. The research employed the Soble test evaluation, yielding a Z score 5.73, which was statistically significant.

4.4. The mediator's function of DP in IoT and SDI

The result illustrates the mediating function of the DP in the relationship between IoT and sustained DI. The findings indicate that the DP intermediates IoT and sustained DI. The research employed the Soble test evaluation, revealing a vital Z score of 6.84.

4.5. Fuzzy AHP sub-barrier results

Environmental study and development funding assess long-term financial, ecological, and social viability. The research assesses income, advancement, resource-constrained environmental effects, market deficiencies, and welfare in evaluating environmentally friendly goods. MB1, weighted at 0.243, and the deficiency in information and comprehension (MB3), weighted at 0.387, were identified as significant sub-barriers from the MB viewpoint (refer to Figure 2).

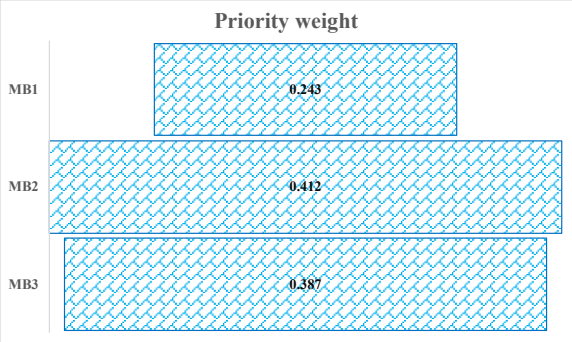

Figure 2: Market Barrier (MB) Analysis

This indicates a considerable limitation on environmentally friendly innovations in the United Arab Emirates due to a governmental policy upgrade (PB2), which weighs around 0.390. Figure 2 indicates that the primary impediment is the absence of education and assistance applications, whereas environmental legislation (PB3) and inadequate education and consultation programs (PB4) represent the less critical sub-barriers.

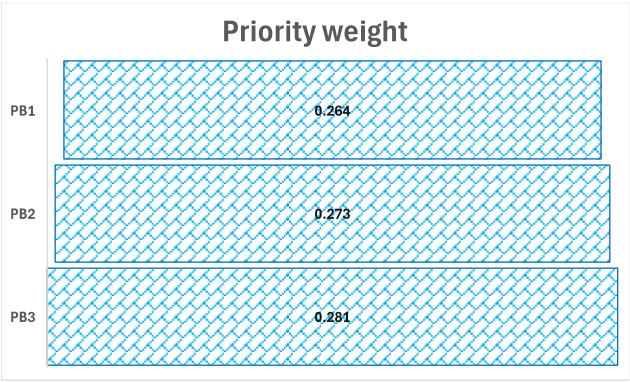

Figure 3: Political Barrier (PB) Analysis

Government action is expected to promote environmentally friendly innovations. Figure 3 illustrates the classification of sub-obstacles related to political obstacles. Ecological research and development are essential for sustained economic, resource-constrained environmental, and social sustainability. In the context of sustainable technology, revenue, development and research, ecological effects, and political constraints are all relevant to financial advancement.

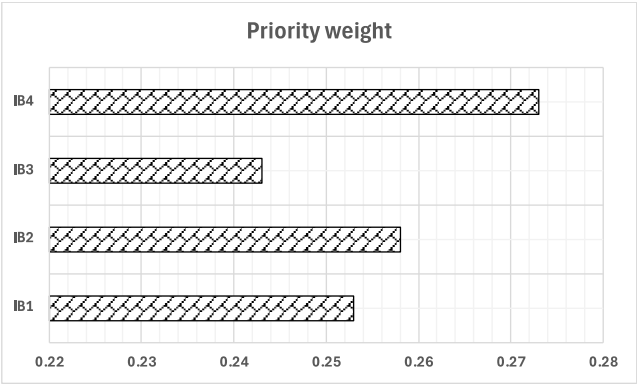

Figure 4: Information Barrier (IB) Analysis

Figure 4 indicates that a crucial weight of 0.0000 for the tested material is attributed to insufficient technical data (IB3), which correlates with a negative disposition (IB1) and financial, ecological, and societal implications. In economics, insufficient data (IB2) and limitations pertain to income, research and development, environmental damage, and political barriers (IB4). Innovative green ideas can only convert SMEs into environmentally friendly endeavors if they have sufficient technical expertise. Companies and their employees must know long-term norms and processes. It cannot discern resource-constrained environmental perspectives.

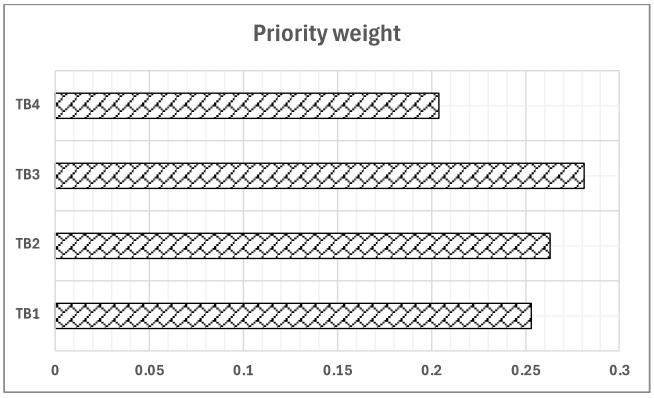

Figure 5: Ranking of Technical Barriers (TB) Analysis

Figure 5 illustrates the classification of knowledge obstacles into sub-barriers (IB). The 0.271-weight deficiency in R & D capacities (TB2) has been identified as the primary sub-barrier to green growth for SME innovations within this scientific barrier projection (as seen in Figure 5). SMEs (TB1) are characterized by technology and market uncertainty.

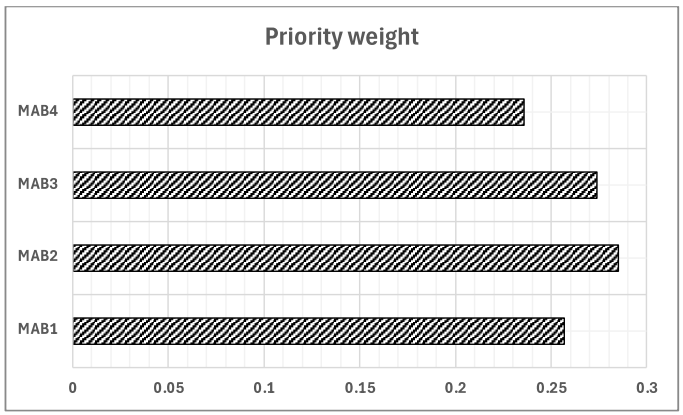

Figure 6. Managerial Barrier (MB) Analysis

Due to the United Arab Emirates' low technological resources, governments must exert considerable effort to implement green light integration. Opposition to sustainable practices (MAB3), with a weight of 0.290, is acknowledged as a significantly prevalent obstacle to green technologies among SMEs (as seen in Figure 6). The outstanding concerns were classified as insufficient involvement (MAB2), adequate funds (MAB1), and absence of incentive mechanisms (MAB4).

V. CONCLUSION

Frugal, sustainable innovation tackles ecological challenges through the durability and superior quality of goods, societal problems by sending technological advances to developing marketplaces, and financial problems by targeting lower-income marketplaces with significant potential. These objectives are achieved by limiting the functionality of goods and services to essential features while ensuring they are high quality, durable, environmentally friendly, and lasting. Numerous nations regard digital business ownership as crucial in advancing the DE. Therefore, additional investigation into digital entrepreneurship concerning its primary characteristics and drivers is essential.

The study examines DO and IoT's immediate and mediated effects on sustainable technological advancement in developing nations. Seven assumptions were formulated and evaluated in this context. The employed statistical analyses corroborated all assumptions. This study has demonstrated that DO and the IoT substantially influence the DP. This research has established a sustainable technological advancement framework utilizing digital position, IoT, and DP. The study has examined the relationship between DP and practical DI, testing the role of digital sites as an intermediary in the connections between DI and viable DI, as well as between IoT and viable DI. It has demonstrated that DI amplifies the influence of DO and IoT on the SDI of SMEs, particularly in developing markets where resources are limited. These results are significant for SMEs since they are crucial for market players. They must attain sustained DI to confront the evolving digital marketplace's substantial difficulties and enhance their technical proficiency.

More studies examine these complex features individually. Several prior investigations have integrated numerous variables into a unified study paradigm. This study concentrated on IoT and DO, which are just a subset of the several digital enablers relevant to examining digital/smart conversion or sustained DI. Subsequent studies should use AI, cognitive robots, sophisticated analytics, or augmented reality to identify a distinct technological paradigm inside a study framework.

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