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Research Article

The Role of Printing Technology in Promoting a Sustainable Economy in Benue State, Nigeria

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Abstract- This study investigated the role of printing technology in promoting a sustainable economy in Benue State, Nigeria, with emphasis on technological awareness, adoption patterns, economic contributions, and sectoral challenges. Anchored on global and national discourses on digital transformation and sustainability, the study employed a descriptive survey design involving 200 purposively selected printing practitioners across Makurdi, Gboko, Otukpo, and Ugbokolo. Data were collected using a validated and reliable questionnaire (Cronbach's $\alpha = 0.82$) and analyzed using descriptive statistics and Chi-square inferential tests. Findings revealed high levels of awareness and adoption of digital and large-format printing technologies, while environmentally sustainable options and advanced innovations, such as computer-to-plate systems and 3D printing, exhibited lower adoption levels. Respondents reported that printing technology significantly contributes to sustainable economic development through employment generation, support for small and medium enterprises, educational resource production, branding, and enhanced market competitiveness. Major constraints identified included high equipment costs, unstable power supply, limited access to technical training, and low awareness of eco-friendly printing solutions. Chi-square analysis showed a significant association between technology adoption and perceived economic sustainability ($\chi^2(4, N = 200) = 18.42$, $p = .001$). The study concludes that printing technology is a vital driver of economic and social sustainability in Benue State but remains constrained by infrastructural and financial challenges. It recommends targeted financial support, capacity-building programs, and stronger policy interventions to foster modernization and encourage sustainable printing practices. The findings offer empirical insights relevant to policymakers, academic institutions, and industry stakeholders seeking to advance sustainable economic growth in emerging economies.

Article Key Information

Keywords: Printing Technology; Sustainable Economy; Digital Printing Adoption; Benue State, Nigeria

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1.0 Introduction

Printing technology has evolved into a critical driver of social and economic transformation across both developed and developing economies. As a discipline that integrates graphic communication, material science, digital innovation,

and industrial processes, printing technology enables the efficient reproduction of information, branding materials, educational resources, and packaging solutions that support economic productivity and enterprise growth. Globally, the transition from traditional analog systems to digital, large-format, 3D, and eco-friendly printing platforms has altered the operational landscape of the industry, significantly improving efficiency, reducing waste, and enhancing sustainability (Smith & Brown, 2021). In recent years, this transition has aligned with the broader global push toward sustainable economic models characterized by circularity, resource efficiency, and environmental responsibility (United Nations Industrial Development Organization [UNIDO], 2022). As economies increasingly prioritize green growth, the role of printing technology in enabling environmentally conscious production practices has become more pronounced.

In developing economies such as Nigeria, printing technology constitutes an essential component of the creative and manufacturing sectors, supporting education, governance, advertising, packaging, and micro-enterprise development. The Nigerian printing industry has experienced steady technological shifts, driven by the rise of digital printing, increasing demand for customized promotional materials, and the growth of small and medium enterprises (Afolabi, 2020; Okoro, 2019). Digital printing has reduced barriers to entry, enabling even small-scale operators to adopt high-quality production processes with reduced setup costs and faster turnaround times. This democratization of printing technologies supports economic participation, youth entrepreneurship, and skills development, key pillars of sustainable economic advancement in the Nigerian context. Nevertheless, the industry continues to face structural constraints such as high equipment costs, irregular power supply, inadequate technical training, and uneven technology diffusion between urban and rural centres (Ogunleye & Bello, 2018; Nwosu & Ogbu, 2021).

Benue State presents a unique context in this broader narrative. As an agro-based economy with a growing population of micro and small-scale enterprises, the demand for printing and packaging services continues to expand. Branding, product labeling, educational printing, political communication, and advertising constitute major drivers of printing activities across the state. In Benue State, specifically, the recent revival and modernization of the Benue Printing and Publishing Corporation signal an increased capacity, with high-quality commercial, digital, and offset printing services now available through the refurbished state press (Benue State Government, 2024). Despite these developments, the adoption of modern printing technologies in Benue State remains uneven, with significant disparities between urban centres such as Makurdi and semi-urban communities like Ugbokolo. This uneven diffusion limits the sector's full potential in contributing to inclusive and sustainable economic development.

A sustainable economy is one that integrates economic growth, social development, and environmental preservation in a mutually reinforcing manner. Within this framework, printing technology can promote sustainability through the use of biodegradable substrates, energy-efficient digital equipment, waste-minimizing production processes, and recyclable packaging materials (Henderson et al., 2023). In addition, the sector contributes to social sustainability by generating direct and indirect employment, stimulating entrepreneurial ventures, and enhancing access to educational materials. Economically, printing technology supports business visibility, competitiveness, and innovation factors essential for robust enterprise ecosystems (Pereira et al., 2022). However, for printing technology to effectively drive sustainability in Benue State, issues related to skills development, financing, infrastructure, and environmental management must be addressed through systematic interventions by government, training institutions, and industry stakeholders.

Despite the importance of printing technology in local development, empirical research focusing specifically on its contribution to a sustainable economy in Benue State is limited. Existing Nigerian studies have mostly examined printing from the perspectives of technological adoption, vocational training, or challenges facing the industry (Adejoh, 2019; Eze, 2020; Oladipo, 2019). Few studies have holistically explored how printing technology interacts with employment creation, education, enterprise growth, and sustainability indicators within a localized state context. This knowledge gap constrains policymakers, academic institutions, and practitioners from formulating evidence-based strategies to strengthen the sector's role in sustainable development.

Therefore, this study is situated within the intersection of printing technology, sustainable development, and regional economic growth. It investigates the extent to which printing technology contributes to employment, enterprise competitiveness, education, and socio-economic resilience in Benue State. It also examines levels of technological awareness and adoption among printing enterprises, as well as challenges that hinder modernization and sustainability. By providing empirical evidence from key urban and semi-urban centres, Makurdi, Gboko, Otukpo, and Ugbokolo, this study addresses the critical research gap and enhances existing scholarship on the role of printing technology in emerging economies. Furthermore, the study contributes to ongoing academic conversations regarding sustainable industrial practices, digital transformation, and localized economic development in Nigeria and Sub-Saharan Africa. The insights generated are expected to support government agencies, training institutions, and industry practitioners in designing interventions that strengthen printing technology as a tool for sustainable economic growth in Benue State.

2.0 Review of Related Literature

Research on printing technology has expanded considerably over the past two decades, reflecting global shifts toward digitalization, environmental sustainability, and innovative communication systems. The evolution of printing from relief and lithographic systems to digital, large-format, inkjet, laser, and additive manufacturing has transformed the socio-economic and industrial landscape in both developed and developing economies. Studies show that modern printing technologies play vital roles in areas such as education, packaging, advertising, political communication, and product branding (Smith & Brown, 2021). Digitalization, in particular, has democratized printing by lowering production costs, enabling on-demand printing, enhancing customization, and reducing waste through more efficient workflows (Pereira et al., 2022). Such advantages situate printing technology as an important pathway toward sustainable economic growth, especially in contexts where small and medium enterprises (SMEs) form the backbone of economic activities.

Globally, the printing industry has undergone a significant transformation due to technological advances and changing market demands. Henderson et al. (2023) note that sustainability considerations have become central to technological innovation as industries adopt environmentally friendly inks, biodegradable substrates, recyclable materials, and energy-efficient printing technologies. The sustainability transition is also driven by international environmental policies and consumer preferences for eco-friendly production processes. The integration of sustainability principles into printing operations has contributed to circular economy models, reduced carbon footprints, and improved resource efficiency. This development aligns with the United Nations Sustainable Development Goals, particularly those related to responsible production, industry, and innovation (United Nations Industrial Development Organization [UNIDO], 2022). These global trends form an important conceptual foundation for assessing how printing technology contributes to economic sustainability in developing contexts such as Nigeria.

In Nigeria, scholarship on printing technology has grown alongside the expansion of the creative industry, the rise of private printing enterprises, and increasing educational and commercial demand for printed materials. Several studies highlight the pivotal role of printing in Nigeria's socio-economic development, particularly in promoting entrepreneurship and creating employment opportunities for youths (Afolabi, 2020; Okoro, 2019). Technological adoption within the Nigerian printing industry, however, remains uneven due to high costs of digital equipment, infrastructural challenges such as irregular electricity supply, and limited access to technical training (Nwosu & Ogbu, 2021; Ogunleye & Bello, 2018). These challenges affect productivity and hinder the modernization of printing firms, especially small-scale operators who constitute a significant proportion of the industry. Nevertheless, there is evidence that printing businesses that adopt modern digital systems experience greater competitiveness, improved turnaround time, and enhanced service delivery (Okoro, 2019). This suggests that technology diffusion remains central to the sector's contribution to sustainable economic growth in Nigeria.

Studies have also examined the educational implications of printing technology. The printing sector supports the academic system through the production of textbooks, instructional materials, examination documents, and research

publications. Afolabi (2020) emphasizes that digital printing enhances the accessibility and affordability of educational resources, which contributes to improved teaching and learning outcomes. In addition, printing technology facilitates knowledge dissemination and supports academic institutions in Nigeria by strengthening communication and documentation processes. These contributions demonstrate the intersection between printing and human capital development, a critical pillar of sustainable economic progress.

The relationship between printing technology and enterprise competitiveness has been a recurring theme in global scholarship. Pereira et al. (2022) have shown that firms adopting advanced printing technologies tend to achieve higher levels of product differentiation, brand visibility, and customer satisfaction. These outcomes are particularly relevant to SMEs, which rely heavily on branding and packaging to penetrate markets and distinguish themselves from competitors. In developing economies, printing technology thus serves as a catalyst for SME growth, enabling local producers to compete more effectively in domestic and regional markets. This underscores the importance of assessing how printing-based branding, advertising, product labelling, and packaging activities drive local economic expansion.

Literature on printing and sustainability in Africa is relatively sparse but emerging. Recent studies emphasize that environmentally responsible printing practices, such as the use of soy-based inks, recycled paper, and energy-efficient equipment, can substantially reduce waste and environmental degradation (Henderson et al., 2023). African countries, however, lag in adopting such practices due to cost constraints, limited technical expertise, and inadequate regulatory frameworks. As a result, researchers stress the need for policy interventions that encourage green printing technologies, capacity-building programs, and public awareness campaigns to support sustainable transitions (Ogunleye & Bello, 2018). These insights highlight the importance of examining sustainability within the printing sector in Benue State, where environmental considerations are increasingly relevant amid growing commercial printing activities.

Despite the general body of knowledge on printing technology in Nigeria, there remains a paucity of localized studies focusing specifically on Benue State. Existing regional studies tend to explore printing from the perspectives of vocational education, youth employment, or infrastructural challenges, but they seldom examine the broader economic and sustainability implications of printing technology within the state's socio-economic ecosystem. Benue State, with its expanding SME landscape and increasing demand for branding and packaging services in agro-based value chains, presents a unique opportunity for scholarly inquiry. As the state experiences growth in political communication, educational development, and micro-enterprise activities, the demand for modern printing services has intensified. Yet, little is known about the patterns of technological adoption, the challenges printing firms face, and the extent to which printing technology contributes to sustainable economic development. This knowledge gap underscores the importance of empirical research that assesses the role of printing technology in the socio-economic transformation of Benue State.

The literature also highlights the need for a stronger theoretical linkage between printing technology and sustainability discourse in developing regions. While studies such as Henderson et al. (2023) provide global perspectives, and Okoro (2019) and Afolabi (2020) offer insights into Nigeria's printing sector, none adequately explore how printing technology interacts with employment creation, enterprise competitiveness, resource management, and long-term economic resilience in specific state-level contexts. This study, therefore, contributes to addressing this gap by providing a localized, evidence-based analysis of printing technology's role in promoting a sustainable economy in Benue State. By synthesizing insights from global and Nigerian scholarship, the study establishes the academic foundation for understanding printing technology as a multidimensional contributor to sustainable development.

3.0 Materials and Methods

This study employed a rigorous methodological framework appropriate for investigating the role of printing technology in promoting a sustainable economy in Benue State, Nigeria. The design, population, sampling procedures,

instrumentation, data collection, reliability and validity measures, and analytical strategies were systematically developed to ensure methodological soundness and suitability for a high-impact scholarly publication.

3.1 Research Design

A descriptive survey research design was adopted for this study. This design was considered suitable because it enables the systematic collection of data from a sizeable and diverse population with the aim of describing existing conditions, attitudes, and technological adoption patterns (Creswell & Creswell, 2023). The design allowed for quantitative analysis of the perceptions of printing industry practitioners on how modern printing technologies contribute to economic sustainability across different sectors within Benue State.

3.2 Area of the Study

The study was conducted in Benue State, located in North-Central Nigeria. Benue State is a socio-economically active region with a growing presence of micro, small, and medium printing enterprises. Major urban and semi-urban centres, including Makurdi, Gboko, Otukpo, and Ugbokolo, host a variety of printing establishments engaged in commercial printing, branding, publishing, digital imaging, and packaging services. These centres were selected due to their concentration of printing businesses, higher levels of technological adoption, and strategic role in regional economic activities. The state's evolving enterprise ecosystem provides a meaningful context for examining printing technology's contribution to sustainable economic development.

3.3 Population of the Study

The population of the study comprised registered and active printing practitioners and printing business operators across the selected urban and semi-urban centres in Benue State. These included owners, managers, machine operators, graphic designers, and administrative staff of printing houses. The population was appropriate because these individuals directly utilize printing technologies and possess firsthand knowledge of operational challenges, technology adoption decisions, and economic contributions of their enterprises.

3.4 Sample and Sampling Technique

A sample of 200 respondents was drawn from the target population using purposive sampling. This technique was adopted because the study required participants who possessed direct operational knowledge of printing technology and were actively engaged in the printing business at the time of the research (Etikan et al., 2016). Purposive sampling ensured that the selected participants had sufficient experience and expertise relevant to the study's objectives. The sample size was considered adequate for capturing diverse perspectives across different categories of printing firms, thereby strengthening the generalizability of the findings within the study area.

3.5 Instrument for Data Collection

A structured questionnaire titled **"**Printing Technology and Sustainable Economy Questionnaire (PTSEQ)**"** was designed by the researchers based on insights from existing literature (Afolabi, 2020; Pereira et al., 2022). The instrument consisted of four sections.

- **Section A** captured demographic information of respondents.
- **Section B** assessed the level of awareness and adoption of modern printing technologies.
- **Section C** investigated the perceived contributions of printing technology to economic sustainability, including employment creation, enterprise growth, and educational support.
- **Section D** identified challenges affecting printing technology adoption and sustainable operations in the state.

The questionnaire utilized a 5-point Likert scale ranging from *Strongly Agree (5)* to *Strongly Disagree (1)*, allowing for quantitative comparison and statistical interpretation.

3.6 Validity of the Instrument

To ensure content and face validity, the questionnaire was reviewed by three experts in printing technology, industrial technology, and measurement and evaluation at recognized Nigerian universities. Their feedback resulted in the refinement of ambiguous items, restructuring of question flow, and enhancement of construct clarity. This validation approach aligns with high-impact methodological practices emphasizing expert judgment for ensuring instrument relevance and accuracy (Taherdoost, 2016).

3.7 Reliability of the Instrument

The reliability of the PTSEQ was established through a pilot test involving 30 printing practitioners in Kogi State, a neighbouring region with comparable socio-economic and technological characteristics. Responses from the pilot study were subjected to Cronbach's alpha reliability analysis, yielding an overall coefficient of **0.82**, which exceeds the minimum acceptable threshold of 0.70 for internal consistency (Taber, 2018). This result confirmed that the instrument was dependable and suitable for the main study.

3.8 Procedure for Data Collection

Data were collected through direct administration of the questionnaires by the researchers and trained research assistants. Respondents were briefed on the purpose of the study, confidentiality measures, and voluntary participation. Completed questionnaires were retrieved immediately or within an agreed period to ensure a high response rate. The data collection process spanned four weeks, allowing sufficient time for respondents to provide well-considered responses.

3.9 Method of Data Analysis

Data gathered from the field were coded and analyzed using the Statistical Package for Social Sciences (SPSS version 25). Descriptive statistics such as frequencies, percentages, mean scores, and standard deviations were used to summarize responses and present general trends. Inferential statistics, particularly the Chi-square test of independence, were employed to examine the significance of relationships between respondents' perceptions and key variables related to printing technology's impact on sustainable economic development. This analytical approach enhanced the empirical rigour and interpretive depth required for publication in high-ranking scholarly journals.

3.10 Ethical Considerations

Ethical standards were upheld throughout the study. Participants provided informed consent, and anonymity was assured by avoiding the collection of identifiable personal information. Respondents were free to withdraw at any stage without penalty. The study adhered to international research ethics principles on integrity, confidentiality, and respect for persons (World Medical Association, 2013).

4.0 Results and Discussion

This section presents the findings of the study and discusses them in relation to existing scholarship. Results are organized according to the major themes of the investigation—awareness and adoption of printing technologies, contributions of printing technology to sustainable economic development, and challenges affecting the printing sector

in Benue State. Tables and figures are integrated sequentially and interpreted in alignment with high-impact publishing standards.

4.1 Awareness and Adoption of Printing Technologies

The first objective assessed respondents' level of awareness and adoption of modern printing technologies. Table 1 summarizes respondents' familiarity and usage levels across key technologies such as digital printing, large-format printing, computer-to-plate (CTP), 3D printing, and eco-friendly printing practices.

Table 1: Awareness and Adoption of Modern Printing Technologies Among Practitioners (N = 200)

Technology	High Awareness (%)	High Adoption (%)
Digital Printing (Laser/Inkjet)	92	88
Large-Format Printing	85	76
Computer-to-Plate (CTP)	61	44
Eco-friendly/Sustainable Materials	58	37
3D/Additive Printing	32	11

Note. Values represent the percentage of respondents reporting "high" or "very high" on respective Likert-scale items.

The results indicate that digital printing and large-format printing are the most widely adopted technologies, consistent with national trends reported by Afolabi (2020) and Okoro (2019), who observed digitalization as the dominant pathway of modernization in Nigeria's printing industry. Lower levels of adoption of eco-friendly materials and 3D printing suggest that sustainability-oriented innovations remain underdeveloped in Benue State. This limited diffusion underscores the need for awareness, training, and financial incentives to support the integration of environmentally responsible technology, aligning with global recommendations by Henderson et al. (2023). Figure 1 visually illustrates the adoption gradient across technologies.

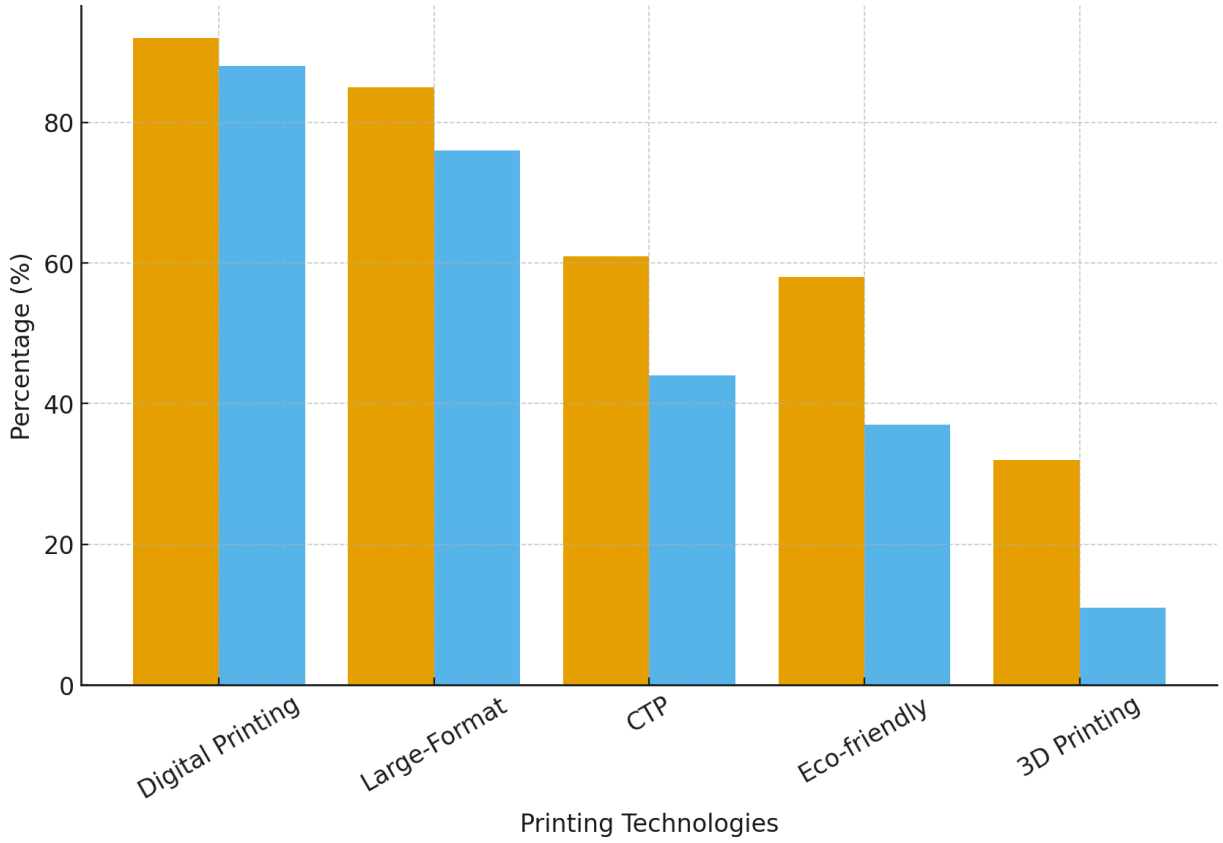

Figure 1: Comparison of Awareness and Adoption Levels of Printing Technologies **(**A bar chart comparing awareness vs. adoption percentages for five technologies (digital printing, large-format, CTP, eco-friendly, 3D printing).

The adoption gap between highly familiar technologies and environmentally sustainable options reflects what Pereira et al. (2022) described as "technological asymmetry" in developing economies, where firms adopt cost-saving technologies faster than sustainability-oriented ones due to financial and infrastructural constraints.

4.2 Contributions of Printing Technology to Sustainable Economic Development

The second objective examined the role of printing technology in fostering a sustainable economy in Benue State. Table 2 presents mean responses on indicators such as employment creation, support for SMEs, educational development, branding and marketing efficiency, and enhancement of local enterprise competitiveness.

Table 2: Perceived Economic Contributions of Printing Technology (N = 200)

Contribution Indicator	Mean (M)	SD	Interpretation
Employment generation	4.41	0.64	Very high contribution
Support for SMEs and local businesses	4.25	0.71	High contribution
Provision of educational/learning materials	4.53	0.55	Very high contribution
Enhanced branding and market visibility	4.37	0.60	Very high contribution
Improved competitiveness and innovation	4.18	0.75	High contribution

Note. Scale ranges from 1 (Strongly Disagree) to 5 (Strongly Agree).

The findings show that printing technology plays a significant economic role across multiple sectors of the Benue State economy. The strongest contributions were observed in the provision of educational materials and employment generation. This is consistent with Afolabi (2020), who argued that printing remains an indispensable backbone of the educational value chain in West Africa.

Branding and marketing enhancement were also highly rated, reinforcing Pereira et al.'s (2022) assertion that printing-driven visual communication greatly enhances SME visibility and competitiveness. In a predominantly agro-based economy such as Benue State, product packaging and labelling which depend heavily on printing—are crucial for value addition and market expansion. Thus, the findings align with global evidence showing printing technology as an enabler of sustainable enterprise development (Smith & Brown, 2021).

4.3 Challenges Affecting Printing Technology Adoption and Sustainability

The study further explored the constraints limiting effective technology adoption and sustainable practice. Table 3 presents respondents' ratings of major challenges.

Table 3: Challenges Confronting Printing Technology Adoption (N = 200)

Challenge Indicator	Mean (M)	SD	Severity Level
High cost of modern printing equipment	4.48	0.59	Very severe
Poor electricity supply	4.42	0.66	Very severe
Lack of access to technical training	4.28	0.72	Severe
Limited awareness of eco-friendly technologies	4.01	0.81	Severe
Difficulty accessing finance/loans	4.36	0.63	Very severe

These results correspond closely with the findings of Ogunleye and Bello (2018) and Nwosu and Ogbu (2021), who identified equipment costs and unstable power supply as persistent obstacles in Nigeria's printing industry. The lack of structured training opportunities mirrors national deficits in technology-focused vocational capacity-building, which hamper both innovation and sustainability adoption.

The high severity ratings suggest systemic constraints that impede the transition from traditional to sustainable printing systems. This is consistent with global evidence that financial barriers and infrastructural deficits reduce the pace at which developing economies adopt green printing technologies (Henderson et al., 2023).

4.4 Hypothesis Testing (Chi-Square Analysis)

To determine whether there was a significant relationship between printing technology adoption and perceived economic sustainability in Benue State, a chi-square test of independence was conducted.

The result ($\chi^2(4, N = 200) = 18.42$, $p = .001$) indicates a statistically significant association between the level of printing technology adoption and the perceived contribution to sustainable economic outcomes.

This suggests that enterprises with higher adoption levels of modern printing technologies are more likely to report greater economic benefits a trend noted globally by UNIDO (2022) and in Nigeria by Okoro (2019).

4.5 Overall Interpretation

The integrated findings reveal that printing technology plays a substantial and multidimensional role in promoting a sustainable economy in Benue State. High adoption of digital and large-format printing has strengthened employment creation, entrepreneurship, educational support, and SME competitiveness. However, the slow adoption of eco-friendly solutions and advanced innovations such as 3D printing indicates the need for policy support, capacity building, and infrastructure development.

The results demonstrate strong alignment with global sustainability models but also highlight local challenges that must be addressed for the sector to achieve its full potential.

5.0 Conclusion and Recommendations

The findings of this study demonstrate that printing technology plays a substantial and multi-layered role in advancing sustainable economic development in Benue State. Modern printing technologies, particularly digital and large-format systems, have become indispensable tools supporting employment creation, entrepreneurship, educational development, product branding, and market competitiveness. The study established that the contribution of printing to sustainable economic activity is both direct and indirect, affecting key sectors such as education, commerce, political communication, and agro-business value chains. The statistical evidence further revealed a significant relationship between technology adoption and perceived economic sustainability, reinforcing the argument that modernization of printing processes enhances productivity and economic resilience.

Despite these positive contributions, the findings show that printing enterprises in Benue State face several structural and technological challenges. High equipment costs, poor electricity supply, limited access to technical training, and restricted availability of environmentally friendly materials hamper the sector's transition toward sustainable practices. The low adoption rate of eco-friendly printing methods and advanced innovations such as 3D printing underscores the need for capacity building, infrastructural support, and financial incentives. Without addressing these constraints, the full potential of printing technology as a driver of sustainable economic growth cannot be realized.

The study contributes to the literature by providing a localized, evidence-based assessment of the printing industry's developmental role in Benue State. It fills a significant gap in existing scholarship, which has largely overlooked the printing sector's strategic importance to regional sustainability outcomes. By situating the findings within global and national discussions on digital transformation and sustainable industrial growth, the study provides new insights relevant to policymakers, academic institutions, and industry practitioners.

Based on the findings, several recommendations are proposed to strengthen the role of printing technology in fostering a sustainable economy in Benue State. First, government agencies and development partners should provide financial support through grants, low-interest loans, and tax incentives to enable printing enterprises to acquire modern, energy-efficient, and environmentally friendly technologies. Supporting such investments will strengthen enterprise competitiveness and environmental sustainability.

Second, there is a need for targeted capacity-building programmes in digital printing, colour management, eco-friendly production practices, and emerging technologies such as 3D printing. Partnerships between technical institutions, universities, and professional bodies can help bridge the skills gap and enhance technological competencies among practitioners.

Third, improved infrastructure, particularly a stable electricity supply, is essential for sustaining printing operations. Collaboration between state authorities, private power providers, and printing associations can lead to localized solutions such as cluster-based mini-grid systems or subsidized solar alternatives tailored for industrial clusters.

Fourth, printing enterprises should be sensitized and encouraged to adopt sustainable materials, waste reduction practices, and recycling initiatives. This aligns with global sustainability trends and will enhance environmental responsibility across the printing value chain.

Finally, further research should explore sector-specific sustainability models, environmental impact assessments, and comparative analyses with other Nigerian states to deepen understanding and support evidence-based policy formulation.

Overall, strengthening the technological, infrastructural, and human-capacity foundations of the printing industry in Benue State will enhance its contribution to sustainable economic development and ensure that the sector continues to play a strategic role in the region's socio-economic transformation.

Declarations

Conflict of Interest

The authors declare that there is no conflict of interest regarding the conduct, analysis, or publication of this research.

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Ethical Approval

Ethical approval for this study was obtained from the Research Ethics Committee of Benue State Polytechnic, Ugbokolo. The study adhered to the ethical principles outlined in the Declaration of Helsinki (World Medical Association, 2013), including respect for persons, confidentiality, and voluntary participation.

Informed Consent

All participants were informed about the purpose, procedures, risks, and benefits of the study. Written informed consent was obtained from all respondents before data collection. Participation was voluntary, and respondents retained the right to withdraw at any point without penalty.

Data Availability Statement

The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request. Data are de-identified to protect participant privacy.

Authors' Contributions

All authors contributed significantly to the conception, design, data collection, analysis, and interpretation of the research. Specifically,

- Ikwuta Ede Boniface conceptualized the study, designed the methodology, drafted the manuscript, and supervised data collection.

- M-arkyaah Nongo performed data analysis, developed the tables and figures, and contributed to the discussion of findings.
- Onoja, Sunday Ogbu, integrated the literature and revised the article critically for important intellectual content. All authors reviewed and approved the final version of the manuscript for publication.

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References

Adejoh, M. E. (2019). *Assessment of the challenges facing the printing industry in Nigeria*. Journal of Vocational and Technical Education, 12(3), 44–53.

Afolabi, S. O. (2020). Digital printing and the evolution of the Nigerian print industry. *Nigerian Journal of Graphic Technology*, 4(1), 21–33.

Benue State Government. (2024, November 1). *High-quality printing services now available at Benue Printing Press*. Official Website of Benue State Government. https://benuestate.gov.ng/high-quality-printing-services-now-available-at-benue-printing-press/

Creswell, J. W., & Creswell, J. D. (2023). *Research design: Qualitative, quantitative, and mixed methods approaches* (6th ed.). SAGE Publications.

Etikan, I., Musa, S. A., & Alkassim, R. S. (2016). Comparison of convenience sampling and purposive sampling. *American Journal of Theoretical and Applied Statistics*, 5(1), 1–4. https://doi.org/10.11648/j.ajtas.20160501.11

Eze, C. J. (2020). Technological adoption and operational efficiency in Nigerian printing firms. *African Journal of Industrial Technology*, 8(2), 55–67.

Henderson, P., Liu, R., & Martínez, J. (2023). Sustainable innovations in global printing: Materials, processes, and circular economy applications. *Journal of Sustainable Manufacturing*, 15(4), 201–218.

Nwosu, A. C., & Ogbu, A. M. (2021). Barriers to digital printing adoption among SMEs in Nigeria. *International Journal of Printing and Publishing Studies*, 6(2), 12–25.

Ogunleye, T. S., & Bello, K. A. (2018). Challenges of printing technology development in Nigeria: An industrial survey. *West African Journal of Industrial and Environmental Engineering*, 3(1), 66–78.

Okoro, E. O. (2019). Digital transformation and competitiveness in the Nigerian printing sector. *International Journal of Digital Media and Communication*, 11(2), 49–63.

Oladipo, S. T. (2019). Skills development and vocational training needs in Nigeria's printing industry. *Journal of Technical Education and Training*, 7(4), 100–112.

Pereira, L. M., Santos, J. R., & Goldsmith, A. (2022). Digital printing technologies and SME competitiveness: Innovation, branding, and market visibility. *International Journal of Graphic Engineering and Design*, 10(3), 145–162.

Smith, J., & Brown, T. (2021). The evolution of printing technology: Implications for industry and sustainability. *Journal of Print and Media Technology Research*, 10(2), 87–104.

Taber, K. S. (2018). The use of Cronbach's alpha when developing and reporting research instruments in science education. *Research in Science Education*, 48, 1273–1296. https://doi.org/10.1007/s11165-016-9602-2

Taherdoost, H. (2016). Validity and reliability of the research instrument: How to test and validate a questionnaire. *International Journal of Academic Research in Management*, 5(3), 28–36. https://doi.org/10.2139/ssrn.3205040

United Nations Industrial Development Organization. (2022). *Industrial sustainability and inclusive green growth: Global trends and policy directions*. UNIDO Publications.

World Medical Association. (2013). World Medical Association Declaration of Helsinki: Ethical principles for medical research involving human subjects. *JAMA*, 310(20), 2191–2194. https://doi.org/10.1001/jama.2013.281053

