

Technopreneurship 4.0: Shaping Sustainable Innovation for the Digital Economy

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A B S T R A C T

The purpose of this study is to explore the future of technopreneurship in the context of sustainable innovation and the evolving digital economy. It aims to analyze how technopreneurs can integrate sustainability principles into technological innovation to meet global demands for greener, smarter, and more inclusive economic development. Using a qualitative-descriptive approach, this study investigates key drivers, challenges, and strategies adopted by emerging digital entrepreneurs to balance profitability with social and environmental responsibility.

The data were collected through in-depth interviews with 12 technopreneurs aged between 25 and 40 years, actively running digital-based start-ups in Indonesia, particularly in sectors such as e-commerce, agritech, edtech, and green energy. Additional insights were obtained from three innovation experts and two policymakers in the digital economy sector. Literature review and case study analysis were also conducted to support the triangulation of data.

This research utilizes the Triple Bottom Line (TBL) framework—People, Planet, and Profit—as an analytical lens to evaluate how digital business models can evolve to address sustainability goals while remaining competitive. SWOT and PESTEL analyses were used to identify internal capabilities and external environmental factors influencing technopreneurship.

Findings reveal that technopreneurs who adopt circular economy models, utilize renewable technologies, and embed ethical digital practices tend to gain stronger market positioning, consumer trust, and long-term viability. The study concludes that sustainable innovation is not only an ethical imperative but also a strategic advantage in the digital economy. These insights offer practical recommendations for entrepreneurs, educators, and policymakers in shaping a resilient and sustainable digital future.

1. Introduction

In recent decades, the rapid evolution of digital technology has fundamentally transformed entrepreneurial practices, giving rise to a new breed of entrepreneurs commonly known as technopreneurs. Technopreneurship refers to entrepreneurial ventures that leverage digital technologies as core business enablers, creating disruptive innovations and scalable solutions

across various industries (Ndubisi & Capel, 2022). As digitalization accelerates, technopreneurs play a crucial role in shaping economic development, job creation, and social transformation worldwide. However, the environmental and social challenges posed by global issues such as climate change, resource depletion, and social inequality have led to growing concerns about sustainability in technological entrepreneurship (Schaltegger & Wagner, 2011; Lüdeke-Freund et al., 2022).

Sustainable innovation has thus emerged as a critical paradigm for technopreneurship. It encompasses the development of new products, processes, or business models that deliver economic value while reducing environmental impacts and generating social benefits (Bos-Brouwers, 2010). This aligns with the Triple Bottom Line (TBL) framework, which emphasizes balancing People, Planet, and Profit in business activities (Elkington, 2004). Scholars have argued that sustainable innovation is not merely a response to regulatory pressures but also an avenue for competitive advantage, improved market reputation, and long-term business resilience (Centobelli et al., 2017). For digital entrepreneurs, adopting sustainable practices can result in increased consumer trust and new market opportunities, particularly as sustainability becomes an essential criterion in consumer decision-making (Testa et al., 2015).

Emerging economies like Indonesia are witnessing significant growth in digital entrepreneurship, driven by widespread internet penetration, a youthful demographic, and government initiatives promoting the digital economy (Nugroho et al., 2022). Yet, technopreneurs in these contexts face unique challenges, including limited access to green technologies, insufficient funding for sustainable projects, and regulatory uncertainties (Dhewanto et al., 2022). Despite these hurdles, innovative digital start-ups in sectors such as green energy, agriculture technology (agritech), and circular economy solutions are beginning to integrate sustainability into their core strategies (Fauzi et al., 2023). Understanding how these technopreneurs navigate sustainability imperatives is essential for fostering inclusive and resilient economic growth.

Technopreneurship's potential to contribute to sustainable development goals (SDGs) is increasingly recognized by policymakers and scholars. Digital technologies like artificial intelligence (AI), Internet of Things (IoT), and blockchain offer innovative pathways for resource efficiency, waste reduction, and transparent supply chains (George et al., 2021). However, their deployment must be carefully managed to prevent unintended negative impacts such as digital divides, energy-intensive infrastructures, and ethical concerns regarding data privacy and algorithmic bias (Gawer & Cusumano, 2014; Adner & Kapoor, 2016). Therefore, integrating sustainable innovation into technopreneurship demands a holistic approach involving technological design, business strategy, and stakeholder collaboration (Zahra & Wright, 2016).

This study aims to examine the future of technopreneurship by exploring how sustainable innovation is integrated into digital entrepreneurial ventures, particularly in the Indonesian context.

It investigates key drivers, barriers, and strategic practices adopted by technopreneurs to balance profitability with social and environmental responsibility. Furthermore, it seeks to contribute practical insights for entrepreneurs, educators, and policymakers on fostering a digital economy that is not only innovative but also sustainable and inclusive.

The significance of this research lies in addressing the literature gap regarding sustainable technopreneurship in emerging digital economies. By employing frameworks such as the Triple Bottom Line and analytical tools like SWOT and PESTEL analyses, this study provides a comprehensive understanding of the dynamic interplay between digital innovation and sustainability imperatives. Ultimately, sustainable technopreneurship is poised to become a cornerstone of future economic development, aligning entrepreneurial success with broader societal and environmental goals (Bocken et al., 2014; Zahra & Wright, 2016).

Theoretical Framework

Technopreneurship has emerged as a significant field of study, reflecting the intersection of technological innovation and entrepreneurial behavior. The theoretical underpinnings of technopreneurship are rooted in several domains, including entrepreneurship theory, innovation management, and sustainability studies. These interrelated disciplines provide crucial perspectives for understanding how digital entrepreneurs navigate technological opportunities while integrating sustainable practices into their business models.

Technopreneurship and Innovation Theory

Fundamentally, technopreneurship can be viewed through the lens of Schumpeterian innovation, where entrepreneurs are seen as agents of creative destruction, introducing new combinations that disrupt existing market structures (Schumpeter, 1934). Schumpeter's theory emphasizes innovation as a key driver of economic development, which resonates strongly with the modern digital economy where technological advancements create continuous waves of disruption (Fagerberg, 2005). In this context, technopreneurs function as innovators who leverage emerging technologies—such as artificial intelligence (AI), blockchain, and Internet of Things (IoT)—to create scalable, transformative solutions (George et al., 2021).

Additionally, the Dynamic Capabilities Theory suggests that firms must develop capacities to sense, seize, and reconfigure resources to adapt to rapidly changing environments (Teece, 2009). This is highly relevant to technopreneurship, where entrepreneurs continuously reconfigure business models and technological assets to remain competitive and address sustainability imperatives (Zahra et al., 2006).

Sustainable Innovation and Triple Bottom Line

Sustainable innovation serves as another crucial theoretical pillar in this study. It involves the development of products, services, or processes that contribute simultaneously to economic

performance, environmental preservation, and social well-being (Bos-Brouwers, 2010). This holistic perspective aligns with Elkington's Triple Bottom Line (TBL) framework, which asserts that businesses must consider People, Planet, and Profit in decision-making processes (Elkington, 2004). The TBL framework has become instrumental for guiding technopreneurs in designing business models that do not merely focus on financial returns but also promote ecological sustainability and social equity (Bocken et al., 2014).

Studies indicate that integrating sustainability into innovation processes can enhance firms' legitimacy, reduce operational risks, and create new market opportunities, particularly as consumers increasingly demand environmentally and socially responsible products (Centobelli et al., 2017; Testa et al., 2015). Moreover, sustainable business models often foster resilience and long-term value creation, critical in volatile digital markets (Bocken et al., 2014).

Digital Economy Context

Technopreneurship exists within the broader context of the digital economy, characterized by the pervasive use of digital technologies that transform production, consumption, and organizational practices (Gawer & Cusumano, 2014). Digital platforms, data-driven decision-making, and network effects redefine traditional market dynamics, enabling technopreneurs to scale innovations rapidly and penetrate new markets (Adner & Kapoor, 2016).

However, the digital economy also introduces complex sustainability challenges, such as rising e-waste, high energy consumption from data centers, and digital inequality (Hilty & Aebischer, 2015). Therefore, sustainable technopreneurship requires reconciling technological progress with environmental stewardship and social inclusion (Zahra & Wright, 2016). This demands a theoretical integration between digital innovation capabilities and sustainability principles to inform effective entrepreneurial strategies.

Analytical Frameworks

To analyze sustainable technopreneurship, several analytical frameworks are employed. The SWOT analysis (Strengths, Weaknesses, Opportunities, Threats) helps evaluate internal capabilities and external market conditions that influence technopreneurs' ability to adopt sustainable practices (Gurel & Tat, 2017). Meanwhile, PESTEL analysis (Political, Economic, Social, Technological, Environmental, Legal) provides a macro-environmental perspective, crucial for assessing regulatory, economic, and socio-cultural factors affecting sustainable entrepreneurship (Aguilar, 1967).

Collectively, these theories and frameworks form the conceptual foundation of this research, enabling a systematic examination of how technopreneurs integrate sustainability into their business models in the digital economy. This theoretical grounding is essential for identifying

effective strategies that balance innovation-driven growth with societal and environmental responsibilities.

Methods

This study employs a qualitative descriptive research design to explore how technopreneurs integrate sustainable innovation into their business practices within the context of the digital economy. The qualitative approach is appropriate for capturing in-depth insights into experiences, perceptions, and strategies of technopreneurs, which cannot be adequately explained through quantitative data alone (Creswell & Poth, 2018). This design also allows flexibility in exploring contextual dynamics, particularly in emerging economies like Indonesia.

Data were gathered using semi-structured interviews, document analysis, and case studies to achieve data triangulation and ensure research validity. A total of 12 technopreneurs were purposively selected as primary respondents. These technopreneurs are founders or co-founders of digital-based startups in Indonesia, operating in sectors such as e-commerce, agritech, renewable energy, education technology (edtech), and fintech. All selected respondents have operated their ventures for at least three years and have publicly communicated a commitment to sustainability or ESG (Environmental, Social, Governance) principles.

Additionally, three innovation and sustainability experts—comprising one academic, one policymaker, and one industry consultant—were interviewed to provide complementary perspectives. Secondary data were collected from company websites, sustainability reports, government digital economy roadmaps, and industry white papers to provide contextual enrichment.

Interviews were conducted in both Indonesian and English, depending on the respondent's preference. Each interview lasted between 45 to 90 minutes and was recorded (with consent), transcribed, and translated where necessary. The interview protocol included open-ended questions focused on:

1. Motivation for adopting sustainability practices
2. Integration of sustainability into business models and technology development
3. Perceived challenges and enablers
4. Impact on innovation, market reception, and long-term viability

The interviews followed a semi-structured format, which allowed the researchers to probe emergent themes while maintaining consistency across respondents (Kallio et al., 2016).

Thematic analysis was used to identify recurring patterns and interpret the underlying meanings across the data (Nowell et al., 2017). The process involved six steps: (a) data familiarization, (b) initial coding, (c) generating themes, (d) reviewing themes, (e) defining and naming themes, and

(f) producing the report (Braun & Clarke, 2006). Coding was carried out manually and then validated using NVivo 12 software to ensure consistency and reliability.

To strengthen the analytical framework, this study incorporated the Triple Bottom Line (TBL) model to categorize findings into economic, social, and environmental dimensions (Elkington, 2004). Further, SWOT and PESTEL frameworks were applied to contextualize internal capabilities and external influences on technopreneurial decisions (Gurel & Tat, 2017; Aguilar, 1967).

All participants provided informed consent and were assured of anonymity and confidentiality. Ethical clearance was obtained from the research committee of the affiliated university. Interview data were anonymized and securely stored in encrypted files, accessible only to the research team. To enhance trustworthiness, the study employed triangulation (data, method, and investigator), member checking, and peer debriefing. Draft interpretations were shared with several respondents to confirm accuracy and resonance with their experiences. Reflexivity was also maintained through a research journal documenting assumptions, biases, and decisions throughout the study process (Lincoln & Guba, 1985).

This methodological design allows for a robust, context-sensitive understanding of sustainable technopreneurship practices in the digital economy and supports the development of grounded recommendations for policy and practice.

Result and Discussion

1. Overview of Respondents

The 12 technopreneurs interviewed in this study represented a diverse array of digital startup sectors including agritech (3 respondents), edtech (2), renewable energy (2), e-commerce (3), and fintech (2). All respondents operated in urban centers of Indonesia such as Jakarta, Bandung, Yogyakarta, and Makassar, with active market operations for 3–7 years. Most respondents were in the 25–40 age range and had previous exposure to sustainability either through education or international incubator programs.

Their ventures demonstrated various levels of sustainability integration—from basic environmental practices such as energy efficiency and paperless operations to more complex implementations including supply chain transparency using blockchain, digital carbon footprint tracking, and inclusive platforms for rural communities.

2. Key Themes from Thematic Analysis

Thematic analysis revealed four major themes:

a. Sustainability as a Competitive Advantage

The majority of respondents emphasized that adopting sustainable practices not only met ethical obligations but also improved brand reputation, attracted investment, and resonated with younger customer segments. One founder of a green logistics startup explained:

“We noticed a 30% increase in customer retention after publishing our sustainability roadmap. People want to support brands that care.”

This aligns with literature suggesting that sustainable practices can increase customer trust and market differentiation in saturated digital environments (Ndubisi & Capel, 2022).

b. Barriers to Implementation

Despite intentions, many technopreneurs faced financial and operational barriers. Sustainability initiatives—such as eco-friendly packaging, carbon offsetting, and ethical sourcing—required upfront costs that were difficult to cover in early-stage ventures. Some respondents also cited limited access to green capital and mentorship in sustainable innovation. These findings echo earlier studies which found that early-stage technopreneurs in emerging economies often struggle to balance growth with sustainability due to limited resources and institutional support (Schaltegger & Wagner, 2011; Lüdeke-Freund et al., 2022).

c. Technology as a Sustainability Enabler

Several participants reported using digital technologies not just for business scaling, but also to track and optimize sustainability goals. Agritech ventures, for instance, deployed IoT-based soil sensors to minimize water usage, while edtech platforms used adaptive learning algorithms to reduce screen time and digital waste. This confirms that digitalization can play a catalytic role in advancing the UN Sustainable Development Goals (SDGs), particularly in resource optimization, remote service delivery, and behavioral change (George et al., 2021; Hilty & Aebischer, 2015).

d. Institutional and Ecosystem Influence

Respondents acknowledged that regulatory policies, investor expectations, and incubator ecosystems significantly shaped their sustainability orientation. Startups enrolled in impact-oriented accelerators such as UNDP’s Youth Co:Lab or government-backed sandbox initiatives were more likely to integrate ESG metrics into their KPIs. This supports the idea that sustainable technopreneurship is not only an individual behavior but is also influenced by institutional arrangements and ecosystem incentives (Zahra & Wright, 2016).

3. Discussion

a. The Role of the Triple Bottom Line (TBL)

The empirical data reflect a growing adoption of the Triple Bottom Line (TBL) model in technopreneurial ventures. While profit remains a priority, increasing attention is given to social (People) and environmental (Planet) dimensions. For instance, fintech startups offering microloans for female entrepreneurs not only generate revenue but also promote gender equity. Meanwhile,

green e-commerce platforms that use biodegradable packaging reduce environmental harm while maintaining customer loyalty.

This practical application of the TBL framework confirms its relevance in guiding technopreneurs toward balanced growth strategies. Previous studies have argued that businesses adhering to TBL principles tend to have greater resilience and stakeholder support in the long run (Elkington, 2004; Testa et al., 2015).

b. Integration with Dynamic Capabilities

Findings also support the Dynamic Capabilities Theory, where technopreneurs adapt their resource configurations to align with emerging environmental and social expectations. Several startups demonstrated high agility in responding to sustainability trends, such as pivoting to circular business models or integrating traceability features into their digital platforms.

This ability to sense, seize, and reconfigure not only reflects internal capability maturity but also shows alignment with broader ecosystem shifts—a crucial skill in volatile digital markets (Teece, 2009; Zahra et al., 2006).

c. Contradictions and Tensions

However, the study also uncovered tensions between growth and sustainability, especially among startups under pressure to achieve scale rapidly. The "move fast and break things" ethos common in digital entrepreneurship often conflicts with the slower, reflective processes needed for sustainability integration. For example, one startup ceased its waste-tracking dashboard feature due to low user engagement, despite its positive environmental potential.

This tension reflects a known paradox in sustainable entrepreneurship where long-term impact goals may conflict with short-term survival imperatives (Bocken et al., 2014). It underscores the need for patient capital, impact-driven investment, and revised success metrics beyond immediate growth.

d. Policy and Ecosystem Implications

To enable more widespread adoption of sustainable innovation, respondents called for greater policy clarity, green financing mechanisms, and education on sustainability metrics. Startups noted that while Indonesia's digital economy roadmap encourages innovation, it lacks specific guidelines or incentives for ESG integration. Several participants suggested the creation of sustainability certification systems for startups, modeled on B Corp or ESG scoring, as a means to attract responsible investors and consumers. This recommendation aligns with global calls for embedding sustainability criteria into entrepreneurship support structures, including accelerators, public procurement, and tax incentives (Centobelli et al., 2017).

Conclusion

This study examined the integration of sustainable innovation within technopreneurial ventures in Indonesia's emerging digital economy. The findings reveal that while technopreneurs increasingly recognize sustainability as both an ethical obligation and a strategic asset (Elkington, 2004; Testa et al., 2015), significant barriers persist. Financial constraints, lack of institutional support, and limited technical knowledge about sustainable practices continue to impede widespread adoption (Dhewanto et al., 2022; Lüdeke-Freund et al., 2022). Nevertheless, technopreneurs who successfully integrate sustainability into their core business models enjoy enhanced market differentiation, greater consumer trust, and improved resilience in volatile digital markets (Ndubisi & Capel, 2022).

The application of the Triple Bottom Line (TBL) framework was found highly relevant, as technopreneurs strive to balance economic viability with environmental stewardship and social impact (Elkington, 2004; Bocken et al., 2014). Many ventures are already deploying digital technologies such as AI, IoT, and blockchain to enable sustainable operations, optimize resource usage, and increase transparency (George et al., 2021; Hilty & Aebischer, 2015). However, the path to sustainable technopreneurship is neither linear nor free from contradictions, as entrepreneurs often face trade-offs between rapid growth and sustainable practices (Bocken et al., 2014).

Overall, the study underscores that sustainable technopreneurship is not merely a technical or operational choice but a strategic imperative shaping the future competitiveness of digital ventures. As global challenges like climate change and social inequality intensify, technopreneurs who embed sustainability into their innovation ecosystems are likely to emerge as leaders in the digital economy (Zahra & Wright, 2016).

Implications

a. For Technopreneurs

Technopreneurs should proactively integrate sustainability into business planning from the earliest stages of venture development. Sustainable practices should be seen not as cost centers but as drivers of innovation and differentiation. Leveraging digital tools for sustainability metrics, circular business models, and transparent supply chains can open new market opportunities and build long-term brand value. However, entrepreneurs must balance ambition with realistic implementation, considering financial viability and operational capacity.

b. For Policymakers

Policymakers play a pivotal role in fostering sustainable technopreneurship. Clear regulatory frameworks, tax incentives, and green financing mechanisms are critical to lowering entry barriers for startups aiming to integrate sustainability. Programs such as sustainability-focused accelerators or certification systems similar to B Corp could help signal credible sustainability commitments

to investors and consumers. Furthermore, targeted capacity-building initiatives should be established to educate entrepreneurs on ESG principles and sustainable innovation practices.

c. For Investors

Investors should broaden their evaluation criteria beyond financial returns to include sustainability metrics and impact indicators. Technopreneurs committed to sustainable innovation often demonstrate stronger resilience and stakeholder loyalty, reducing long-term risks. Thus, impact investing and ESG-aligned funds are well-positioned to support the next wave of digital ventures aiming for sustainable transformation.

d. For Academia

Academic institutions should embed sustainability and digital entrepreneurship into curricula, equipping future technopreneurs with both technical and ethical competencies. Collaborative research between universities, startups, and industry stakeholders can also help develop practical frameworks for sustainable innovation that are locally relevant yet globally scalable.

Limitations and Future Research

While this study provides valuable insights, it is limited by its qualitative scope and focus on Indonesia. Future research could extend these findings through quantitative approaches to measure the financial and social impacts of sustainability practices in technopreneurship across different regions. Comparative studies among various emerging economies could also offer richer perspectives on context-specific challenges and solutions.

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